1. INTRODUCTION

There are a large number of objects around us which we can see and feel. **Anything that occupies space and has mass is called matter.** Ancient Indian and Greek philosopher's believed that the wide variety of object around us are made from combination of five basic elements: Earth, Fire, Water, Air and Sky. The Indian philosopher Kanad (600 BC) was of the view that matter was composed of very small, indivisible particle called "parmanus". Ancient Greek philosopher also believed that all matter was composed of tiny building blocks which were hard and indivisible. The Greek philosopher Domocritus named these building blocks as atoms, meaning indivisible. All these people had their philosophical views about matter, these views were never put to experimental test.

It was John Dalton who firstly developed a theory on the structure of matter, latter on which was known as **Dalton's atomic theory.**

DALTON'S ATOMIC THEORY:

- Matter is made up of very small indivisible particle called atoms.
- All the atoms of an element are identical in all respect i.e. mass, shape, size, etc. and atoms of different elements are different in nature.
- Atoms cannot be created or destroyed by any chemical process.

Classification of matter

- On the basis of physical behaviour
  - Solids
  - Liquids
  - Gases
- On the basis of chemical behaviour
  - Pure substances
    - Element
    - Compound
  - Mixtures

2. LAWS OF CHEMICAL COMBINATIONS

The combination of elements to form compounds is governed by the following five basic laws.

LAW OF CONSERVATION OF MASS:

It states that matter can neither be created nor destroyed.

This law was put forth by Antoine Lavoisier in 1789. He performed careful experimental studies for combustion reactions for reaching to the above conclusion. This law formed the basis for several later developments in chemistry.

Lavoisier stated that **"during any physical or chemical change the total mass of the products produced is equal to the total mass of the reactants reacted"**. He showed that when mercuric oxide was heated the total mass of mercury and oxygen produced was equal to the total mass of mercuric oxide.

Ex. 1: When 20 g of $NaHCO_3$ is heated, 12.62 g of Na_2CO_3 and 5.24g of CO_2 is produced. How many grams of H_2O is produced?

Solution: Total mass of $NaHCO_3$ heated = 20 gms ;
Total mass Na_2CO_3 produced = 12.62 gms
Total mass of CO_2 produced = 5.24 gms
$\therefore$ Mass of H_2O produced = 20–12.62 –5.24 = 2.14 gms

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LAW OF DEFINITE PROPORTIONS:

This law was given by, a French chemist, Joseph Proust. **He stated that a given compound always contains exactly the same proportion of elements by weight.**

Irrespective of the source, a given compound always contains same elements in the same proportion. The validity of this law has been confirmed by various experiments. It is sometimes also referred to as **Law of definite composition.**

This law implies that irrespective of how a compound is prepared or from where the compound originates, it is always made up of the same elements combined in the same proportion by the weight.
For example, if water is taken from difference sources, such as rivers, oceans, wells etc. they all contain hydrogen and oxygen, combined in the same proportion by weight in it.

Ex. 2: **When 50 g of ammonia is heated it gives 41.18 g of Nitrogen. When 10 g of Nitrogen is combined with required amount of hydrogen it produces 12.14g ammonia. Show that the given data follows the law of constant compositions.**

Solution: If 50g of Ammonia gives 41.18g of Nitrogen, then the percentage of Nitrogen in ammonia is $\frac{41.18}{50} \times 100 = 82.36\%$.

If 10g of Nitrogen gives 12.14 g of Ammonia then percentage of Nitrogen in ammonia is $\frac{10}{12.14} \times 100 = 82.37\%$.

LAW OF MULTIPLE PROPORTIONS:

This law was proposed by Dalton in 1803. According to this law, **if two elements can combine to form more than one compound, the masses of one element that combine with a fixed mass of the other element, are in the ratio of small whole numbers.**

For example, carbon and oxygen combine to form CO and CO_2. In CO, 12 parts by mass of carbon combines with 16 parts by mass of oxygen while in CO_2 12 parts by mass of carbon combines with 32 parts by mass of oxygen. Therefore the ratio of the masses of oxygen that combines with a fixed mass of carbon is 16:32 that is 1:2.

Ex. 3: **Sodium and oxygen combine to form two compounds of which one is Na_2O. The percentage of sodium in the other compound is 59%. Find the formula of this compound.**

Solution: Percentage of sodium in Na_2O is $\frac{2 \times 23}{62} \times 100 = 74.2\%$ and percentage of oxygen is 25.8%.

Percentage of sodium in other compound is 59% while that of oxygen is 41%. This means that in the first compound (Na_2O) if we take 100 gm then 25.8 gm of oxygen will be present therefore the mass of sodium combining with 1g of oxygen would be $\frac{74.2}{25.8} = 2.87$ g. Similarly in the second compound the mass of sodium combining with one gm of oxygen is $\frac{59}{41} = 1.44$g. The ratio of masses of sodium combining with the fixed mass of oxygen is 2.87: 1.44 = 2:1. Therefore formula of the other compound is Na_2O_2.

LAW OF RECIPROCAL PROPORTIONS:

This law which was proposed by Ritcher (1792) states that **"when two elements combine separately with fixed mass of third element then the ratio of their masses in which they do so is either the same or some whole number multiple of the ratio in which they combine with each other".**

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FOR EXAMPLE:

Carbon, Sulphur and Oxygen form CO_2, SO_2 and CS_2. In CO_2 12 parts by mass of carbon combine with 32 parts by mass of oxygen while in SO_2 32 parts by mass of Sulphur combine with 32 parts by mass of oxygen. Ratio of masses of carbon and sulphur which combine with fixed mass of oxygen is 12:32 or 3:8.In CS_2 12 parts by mass of carbon combines with 64 parts by mass of sulphur therefore the ratio of mass of carbon to sulphur in carbon disulphide is 12:64 i.e. 3:16.

Therefore, the ratio is $\frac{3}{8} : \frac{3}{16}$ or 2:1

GAY - LUSSAC LAW OF COMBINING VOLUMES:

This law which was proposed by Gay – Lussac states that, **the volumes of gaseous reactants reacted and the volumes of gaseous products formed, all measured at the same temperature and pressure bear a simple ratio.**

FOR EXAMPLE:

The reaction involved in Haber's Process (Nitrogen and hydrogen gases react to form ammonia)

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

1 vol 3 vol 2 vol

It is observed that the ratio of the volumes of N_2 and H_2 reacted and volume of NH_3 produced is equal to **1:3:2** which is a simple ratio.

- **This law is applicable only for gaseous reactions and should not be used for non–gaseous reactants and products.**

3. ATOMIC MASS & MOLECULAR MASS

Analysis of water shows that it contains 88.89% oxygen and 11.11% of hydrogen by mass. Thus the ratio of masses of hydrogen and oxygen in water is 11.11: 88.89 or 1:8. Moreover the ratio of number of hydrogen and oxygen atoms in water molecule can be shown to be 2 : 1.

Therefore oxygen is 16 times heavier than hydrogen. Therefore relative atomic mass of oxygen is 16 units if we take mass of hydrogen atom as 1 unit. In 1961 International Union of Pure and Applied Chemists (IUPAC) selected the most stable isotope of carbon, C–12 as the standard for comparison of atomic masses of elements. The mass of C–12 atom is taken as 12 atomic mass unit.

The scale in which the relative atomic masses of different elements are expressed is called atomic mass unit or amu.

Atomic mass Unit (amu) = $\frac{1}{12}$ the mass of a C - 12 atom = 1.660539×10^{-24} gm

$$\text{Atomic mass of an element} = \frac{\text{Mass of one atom of the element}}{\frac{1}{12} \times \text{Mass of one atom of } {}^{12}_{6}C}$$

One amu is also called one Dalton (Da). Nowadays amu has been replaced by 'u' which is known as unified mass.

MOLECULAR MASS:

Molecular Mass is the sum of atomic masses of the elements present in a molecule. It is obtained by multiplying the atomic mass of each element by the number of its atoms and adding them together. For example, molecular mass of methane which contains one carbon atom and four hydrogen atoms can be obtained as follows:

Molecular mass of methane, CH_4 = (12.011) + 4 (1.008) = 16.043

Similarly, molecular mass of H_2O = 2 × atomic mass of hydrogen + 1 × atomic mass of oxygen
= 2 (1.008) + 16.00 = 18.016

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4. MOLE CONCEPT

One mole is an amount of substance containing Avogadro's number of particles. Avogadro's number is equal to 602,214,199,000,000,000,000,000 or more simply, $6.02214199 \times 10^{23}$.

A mole (symbol mol) is defined as the amount of substance that contains as many atoms, molecules, ions, electrons or any other elementary entities as there are carbon atoms in exactly 12 gm of ^{12}C. The number of atoms in 12 gm of ^{12}C is called Avogadro's number (N_A).

$$N_A = 6.022 \times 10^{23}$$

From mass spectrometer we found that there are 6.022×10^{23} atoms present in 12 gm of C – 12 isotope. The number of entities in 1 mol is so important that it is given a separate name and symbol known as Avogadro constant denoted by N_A. i.e. on the whole we can say that 1 mole is the collection of 6.022×10^{23} entities. Here entities may represent atoms, ions, molecules or even pens, chairs , paper etc also include in this but as this number (N_A) is very large therefore it is used only for very small things.

❖ HOW BIG IS A MOLE?

One mole of marbles would cover the entire Earth (oceans included) for a depth of three miles. One mole of $100 bills stacked one on top of another would reach from the Sun to Pluto and back 7.5 million times. It would take light 9500 years to travel from the bottom to the top of a stack of 1 mole of $1 bills.

GRAM ATOMIC MASS:

- The atomic mass of an element expressed in grams is called gram atomic mass of that element.
- It is also defined as mass of 6.022×10^{23} atoms.
- It is also defined as the mass of one mole atoms.
- It is also defined as the mass of 1 gram atom of the element.

For example for oxygen atom:

Atomic mass of 'O' atom = mass of one 'O' atom = 16 amu

Gram atomic mass = mass of 6.022×10^{23} 'O' atoms

= 16 amu x 6.022×10^{23}

= $16 \times 1.66 \times 10^{-24} \times 6.022 \times 10^{23} \simeq 16$ gm/mole

$\because 1.66 \times 10^{-24} \times 6.022 \times 10^{23} = 1$

Ex. 4: How many atoms of oxygen are there in 16 g oxygen.

Sol. $x \times 1.66 \times 10^{-24} \times 16 = 16g$ $\qquad x = \dfrac{1}{1.66 \times 10^{-24}} = N_A$

GRAM MOLECULAR MASS :

- The molecular mass of a substance expressed in gram is called the gram-molecular mass of the substance.
- It is also defined as mass of 6.022×10^{23} molecules.
- It is also defined as the mass of 1 mole molecules.
- It is also defined as the mass of 1 gram molecule.

For examples for 'O_2' molecules :

Molecular mass of 'O_2' molecule = mass of one 'O_2' molecule

= 2 × mass of one 'O' atom

= 2 × 16 amu

= 32 amu

Gram molecular mass = mass of 6.022×10^{23} 'O_2' molecules

= 32 amu × 6.022×10^{23}

= $32 \times 1.66 \times 10^{-24}$ gm × 6.022×10^{23}

= 32 gm/mole

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Ex. 5: The molecular mass of H_2SO_4 is 98 amu. Calculate the number of moles of each element in 294 g of H_2SO_4.

Sol. Gram molecular mass of H_2SO_4 = 98 gm

Moles of H_2SO_4 = $\frac{294}{98} = 3\,moles$

H_2SO_4	H	S	O
one molecule	2 atoms	one atom	4 atoms
1 x N_A	2 x N_A atoms	1 x N_A atoms	4 x N_A atoms
∴ one mole	2 mole	one mole	4 mole
∴ 3 mole	6 mole	3 mole	12 mole

AVOGADRO'S HYPOTHESIS:

Equal volume of the gases have equal number of molecules (not atoms) at same temperature and pressure condition.

N.T.P. (Normal Temperature and Pressure)
Temperature = 0°C or 273 K
Pressure = 1 atm = 760 mm of Hg
Volume of one mole of any gas at NTP is found to be experimently equal to 22.4 litres which is known as molar volume at NTP.

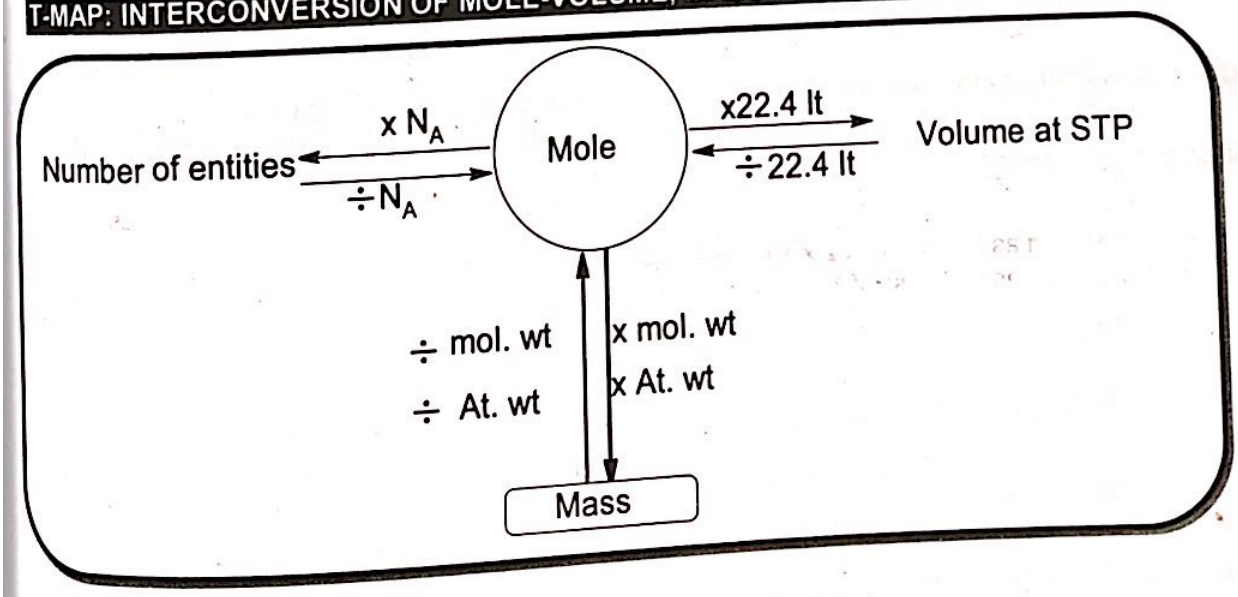
S.T.P. (Standard Temperature and Pressure)
Temperature = 0°C or 273 K
Pressure = 1 bar = 0.987 atm
Volume of one mole of any gas at STP is found to be experimently equal to 22.7 litres which is known as molar volume at STP.

Ex. 6: Calculate the volume in litre of 20 g hydrogen gas at STP.

Sol. No. of moles of hydrogen gas = $\frac{\text{Given mass}}{\text{Molecular mass}} = \frac{20gm}{2gm} = 10\,mol$

Volume of hydrogen gas at STP = 10 x 22.7 lt = 227 lt.

T-MAP: INTERCONVERSION OF MOLE-VOLUME, MASS AND NUMBER OF PARTICLES



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FORMULA SHEET FOR MOLE CALCULATIONS:

S. No.	Items	Formula
1.	Molecules	$\frac{\text{Wt. in gm}}{\text{Molecular mass}}$
2.	Atom	$\frac{\text{Wt. in gm}}{\text{Atomic mass}}$
3.	Gases	$\frac{\text{Volume at STP}}{\text{Standard molar Volume at STP}}$
4.	Any Particle	$\frac{\text{Number of particles}}{\text{Avogardro number}}$
5.	Moles of A in A_xB_y	x
6.	For Gases at any P(in atm), V(in litres) & T(in K)	$n = \frac{PV}{RT}$ where R = 0.0821 lit-atm/mol K

IMPORTANT NOTES:

1. **STP and NTP conditions :** STP means that temperature is 0°C or 273K and pressure is one bar. NTP means that temperature is 0°C or 273K and pressure is one atm.
2. **1 gm - atom** is same as 1 mole of an atom & hence will have wt equal to atomic wt expressed in gms.
3. **1 gm – molecule** is same as 1 mole of the molecule & hence will have wt equal to molecular wt expressed in gms.
4. **1 gm – Ion** is same as 1 mole of an ion & hence will have wt equal to ionic wt

❖ Remember 1 gm of atom & 1gm– atom are two different phrases. Former is mentioning wt (equal to 1gm) & latter is mentioning moles.

e.g. (1) " x g atom of nitrogen " = x moles of N atom = $(x \times N_A)$ number of N atoms

(2) "x g molecule of nitrogen" = x moles of N_2 molecules = $(x \times N_A)$ molecules of N_2 = $(2x \times N_A)$ number of N atom

Ex. 7: How many g atom and no. of atoms are there in (a) 60 g carbon (b) 224.4 g Cu? Given : At. Weight of C and Cu are 12 and 63.6 respectively. Avogadro's no. = 6.02 x 10^{23}.

Solution : $\because$ g atom $= \frac{wt}{at.wt}$ and No. of atoms $= \frac{wt. \times Av.No.}{at.wt}$

(a) $\therefore$ **For 60 g C :** g atom $= \frac{60}{12} = 5$

No. of atoms $= \frac{60 \times 6.02 \times 10^{23}}{12} = 30.1 \times 10^{23}$

(b) For 224.4 g Cu : g atom $= \frac{224.4}{63.6} = 3.53$

No. of atoms $= \frac{224.4 \times 6.02 \times 10^{23}}{63.6} = 21.24 \times 10^{23}$

Ex. 8: Find the number of g atoms and weight of an element having 2 x 10^{23} atoms. At. Weight of element is 32.

Solution $\because$ N_A atoms have 1 g atom

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2×10^{23} atoms have $=\frac{2\times10^{23}}{6.022\times10^{23}}=0.33g\ atom$

$\because$ N_A atoms of elements weigh 32 g

$\therefore$ 2×10^{23} **atoms of element weigh** $=\frac{2\times10^{23}\times32}{6.022\times10^{23}}=10.628g$

Ex. 9: **How many mole and molecules of O_2 are there in 64g O_2? What is the mass of one molecule of O_2?**

Solution: $\because$ moles of O_2 in 32 g O_2 = 1

$\therefore$ In 64 g O_2 moles $=\frac{64\times1}{32}=2\,mole$

$\because$ 32 g O_2 contains 6.022×10^{23} molecules

$\therefore$ 64 g O_2 contains $=\frac{6.022\times10^{23}\times64}{32}=12.044\times10^{23}$ molecules

$\therefore$ N_A molecules of O_2 weigh 32 gm

$\therefore$ 1 molecule of O_2 weighs $=\frac{32}{6.022\times10^{23}}=5.3138\times10^{-23}\,gm.$

Ex. 10: **From 200 mg of CO_2, 10^{21} molecules are removed. How many g and mole of CO_2 are left?**

Solution : $\because$ 6.022×10^{23} molecules of CO_2 = 44 g

$\therefore$ 10^{21} molecules of CO_2 $=\frac{44\times10^{21}}{6.022\times10^{23}}g$

$= 7.31 \times 10^{-2}$

= 73. 1 mg

$\therefore$ CO_2 left = 200 – 73.1 = 126.9 mg

Also Mole of CO_2 left $=\frac{wt.}{M.wt}=\frac{126.9\times10^{-3}}{44}=2.88\times10^{-3}$

5. AVERAGE WEIGHT

AVERAGE ATOMIC WEIGHT:

For elements, which have atoms with different relative masses (isotopes) the atomic mass is taken as weighted mean of the atomic masses.

Average atomic weight = $\sum$ % of Isotope X Atomic Wt. of Isotope

For example, chlorine contains two isotopes of atomic masses 35 amu and 37 amu. The relative abundance of these two is in the ratio of 3:1. Thus the atomic mass of chlorine is the average of different relative masses. Therefore atomic mass of chlorine is equal to $\frac{35\times3+37\times1}{4}$ = 35.5 amu.

Ex. 11: Calculate average atomic wt. of silicon if relative abundance is 92.23% Si^{28}, 4.77%Si^{29}, 3% Si^{30}

Solution : Av at wt $=\frac{92.23\times28+4.77\times29+3\times30}{100}$ = 28.1 amu

Ex. 12: Calculate % abundance of Ag^{109} if it is known that silver exist in only two isotopes Ag^{107}& Ag^{109} having average atomic weight = 108.5

Solution : let the % abundance of Ag^{109} be x

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$$\therefore 108.5 = \frac{x \times 109 + (100 - x) \times 107}{100}$$

$$\Rightarrow 10850 - 10700 = 2x \qquad \Rightarrow x = 75\%$$

Shortcut to calculate % abundance when an element X is having only two isotopes X^A & X^B & average atomic wt is X_{avg}

$$\Rightarrow \% \, of \, X^A = \frac{\left| X_{avg} - wt \, of \, X^B \right|}{\left| wt \, of \, X^A - wt \, of \, X^b \right|} \times 100$$

% obtained above is mole %.

AVERAGE MOLECULAR WEIGHT:

For homogenous mixture of several substances having number of moles, n_i & molecular mass $M_{(i)}$ for i^{th} species, the average molecular weight is given as

$$\text{Average Molecular wt.} = \frac{n_1 \times M_1 + n_2 \times M_2 + ...}{n_1 + n_2 + ...}$$

$$= \frac{Total \, weight}{Total \, no.of \, moles.} \qquad = \frac{\sum n_i M_i}{\sum n_i}$$

Ex. 13: Dry air has a molar composition as 20% O_2 & 80% N_2. Calculate average molecular wt. of dry air.

Solution :.Average Molecular wt $= \frac{20 \times 32 + 80 \times 28}{100} = 28.8$

MINIMUM MOLECULAR WEIGHT:

It is the molecular weight of a compound shown by presence of minimum number of atoms
[i.e. for monomer = 1 , Dimer = 2 , Trimer = 3 , Tetramer = 4]

e.g. Insulin contains 3.4% of Sulphur, Find its Minimum Molecular Weight.
100g insulin contains 3.4g S (sulphur). Assuming it to be monomer [as nothing specified] one sulphur atom $\approx$32 amu (atomic mass) ,We can write , 3.4 g S is contained by 100g insulin

32g S is contained by $\left(\frac{100}{3.4} \times 32\right)$ = Minimum Molecular Weight

6. DETERMINATION OF MOLECULAR & EMPERICAL FORMULAE

The molecular formula of a compound may be defined as the formula which gives the actual number of atoms of various elements present in the molecule of the compound. For example, the molecular formula of the compound glucose can be represented as $C_6H_{12}O_6$. A molecule of glucose contains six atoms of carbon, twelve atoms of hydrogen and six atoms of oxygen.
In order to find out molecular formula of a compound, the first step is to determine its empirical formula from the percentage composition.

$$\text{Mass \% of an element} = \frac{\text{Mass of that element}}{\text{Molar mass}} \times 100$$

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EMPIRICAL FORMULA:

The empirical formula of a compound may be defined as the formula which gives the simplest whole number ratio of atoms of the various elements present in the molecule of the compound. The empirical formula of the compound glucose ($C_6H_{12}O_6$) is CH_2O which shows that C,H and O are present in the simplest ratio of 1:2:1

Empirical formula mass of substance is equal to the sum of atomic masses of all the atoms in the empirical formula of the substance. Molecular formula is a whole number multiple of empirical formula.

Thus Molecular formula = (Empirical formula) × n where n = 1,2,3...

$$n = \frac{\text{Molecular Formula}}{\text{Empirical Formula}} = \frac{\text{Molecular Mass}}{\text{Empirical Mass}}$$

STEPS FOR WRITING THE EMPIRICAL FORMULA:

The percentage of the elements in the compound is determined by suitable methods and from the data collected, the empirical formula is determined by the following steps:

- Divide the percentage of each element by its atomic mass. This will give the relative number of moles of various elements present in the compound.
- Divide the quotients obtained in the above step by the smallest of them so as to get a simple ratio of moles of various elements.
- Multiply the figures, so obtained by a suitable integer if necessary in order to obtain a whole number ratio.
- Finally write down the symbols of the various elements side by side and put the above number as the subscripts to the lower right hand corner of each symbol. This will represent the empirical formula of the compound.

STEPS FOR WRITING THE MOLECULAR FORMULA:

- Calculate the empirical formula as described above.
- Find out the empirical formula mass by adding the atomic masses of all the atoms present in the empirical formula of the compound.
- Divide the molecular mass (determined experimentally by some suitable method) by the empirical formula mass and find out the value of n.

DENSITY:

Density is of two types,

- **Absolute Density**
- **Relative Density**

For liquid and solids:

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

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

For Gases :

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

Where P is pressure of gas, M = mol. Wt. of gas , R is the gas constant , T is the temperature.

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VAPOUR DENSITY:

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

$$\text{Vapour density} = \frac{d_{gas}}{d_{H_2}} = \frac{\frac{PMgas}{RT}}{\frac{PM_{H_2}}{RT}} \quad \Rightarrow \quad \text{V. D.} = \frac{M_{gas}}{M_{H_2}} = \frac{M_{gas}}{2}$$

$M_{gas} = 2$ (V.D.)

Relative density can be calculated w.r.t. to other gases also.

Ex. 14 : What is the V.D. of SO_2 with respect to CH_4

Solution: V.D. = $\frac{(MW)_{SO_2}}{(MW)_{CH_4}}$ **V.D. =** $\frac{64}{16} = 4$

Ex. 15 : 11.2 litre of the particular gas at N.T.P. weighs 16 gram. What is the V. D. of gas.

Solution: wt.of 11.2 litre = 16 gram.

moles = $\frac{11.2}{22.4} = \frac{16}{M}$ $M = 32\,gm/mole$ **V.D.=** $\frac{32}{2} = 16$

Ex. 16: A substance, on analysis, gave the following percentage composition: Na = 43. 4%, C = 11.3%, O = 45.3%. Calculate its empirical formula. {Na = 23, C = 12, O = 16]

Solution:

Element	SYMBOL	% age	Atomic Mass	Relative number of moles	Simple ratio of moles	Simplest whole no. ratio
Sodium	Na	43.4	23	$\frac{43.4}{23} = 1.88$	$\frac{1.88}{0.94} = 2$	2
Carbon	C	11.3	12	$\frac{11.3}{12} = 0.94$	$\frac{0.94}{0.94} = 1$	1
Oxygen	O	45.3	16	$\frac{45.3}{16} = 2.83$	$\frac{2.83}{0.94} = 3$	3

Therefore, the empirical formula is Na_2CO_3.

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Ex. 17: A compound has the following composition: Mg = 9.76%, S = 13.01%, O = 26.01%, H_2O = 51.22%. What is its empirical formula? [Mg = 24, S = 32, O = 16, H = 1]

Solution:

Element	Symbol	% age	Atomic Mass	Relative number of moles	Simple ratio of moles	Simplest Whole no. ratio
Magnesium	Mg	9.76	24	$\frac{9.76}{24} = 0.406$	$\frac{0.406}{0.406} = 1$	1
Sulphur	S	13.01	32	$\frac{13.01}{32} = 0.406$	$\frac{0.406}{0.406} = 1$	1
Oxygen	O	26.01	16	$\frac{26.01}{16} = 1.625$	$\frac{1.625}{0.406} = 4$	4
Water	H_2O	51.22	18	$\frac{51.22}{18} = 2.846$	$\frac{2.846}{0.406} = 7$	7

Hence, the empirical formula is $MgSO_4 . 7H_2O$.

Ex. 18: What is the simplest formula of the compound which has the following percentage composition. Carbon 80%, Hydrogen 20%. If the molecular mass is 30, calculate its molecular formula.

Solution:

Element	% age	At. Mass	Relative number of moles	Simple ratio of moles	Simples whole no. ratio
C	80	12	$\frac{80}{12} = 6.66$	$\frac{6.66}{6.66} = 1$	1
H	20	1	$\frac{20}{1} = 20$	$\frac{20}{6.66} = 3$	3

∴ Empirical formula is CH_3

∴ Empirical mass = 12 × 1 + 1 × 3 = 15 $\quad n = \frac{\text{Molecular mass}}{\text{Emprical formula mass}} = \frac{30}{15} = 2$

Molecular formula = Empirical formula × 2 = $CH_3 \times 2 = C_2H_6$

Ex. 19: A compound on analysis gave the following percentage composition: C = 54.54%, H = 9.09%, O = 36.36%. The vapour density of the compound was found to be 44. Find out the molecular formula of the compound.

Solution: Calculation of empirical formula.

Element	% age	At. Mass	Relative number of moles	Simple ratio of mole	Simplest whole no. ratio
C	54.54	12	$\frac{54.54}{12} = 4.53$	$\frac{4.53}{2.27} = 2$	2
H	9.09	1	$\frac{9.09}{1} = 9.09$	$\frac{9.09}{2.27} = 4$	4
O	36.36	16	$\frac{36.36}{16} = 2.27$	$\frac{2.27}{2.27} = 1$	1

∴ Empirical formula is C_2H_4O. Calculation of molecular formula:

Empirical formula mass = 12 ×2+1×4+16×1 = 44

Molecular mass = 2 × Vapour density = 2× 44 = 88

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{88}{44} = 2$$

Molecular formula = Empirical formula × n = $C_2H_4O \times 2 = C_4H_8O_2$.

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Ex. 20: **An organic compound on analysis gave the following data: C = 57.82%, H = 3.6%, and the rest is oxygen. Its vapour density is 83. Find its empirical and molecular formula.**

Solution: Calculation of empirical formula:

Element	% age	At. Mass	Relative number of moles	Simple ratio of moles	Simplest whole no. ratio
C	57.82	12	$\frac{57.82}{12} = 4.80$	$\frac{4.8}{2.4} = 2$	4
H	3.60	1	$\frac{3.60}{1} = 3.60$	$\frac{3.6}{2.3} = 1.5$	3
O	38.58	16	$\frac{38.58}{16} = 2.40$	$\frac{2.4}{2.4} = 1$	2

$\therefore$ Empirical formula is $C_4H_3O_2$. Empirical formula mass = 12×4+ 1×3 + 2 × 16 = 83

Molecular mass = 2 × V.D. = 2 × 83 = 166

$$n = \frac{\text{Molecular mass}}{\text{Emprical formula mass}} = \frac{166}{83} = 2$$

Molecular formula = Empirical formula × n $= C_4H_3O_2 \times 2 = C_8H_6O_4$

Ex. 21: **2.746 gm of a compound gave on analysis 1.94 gm of silver, 0.268 gm of sulphur and 0.538 gm of oxygen. Find the empirical formula of the compound. (At masses : Ag = 108, S = 32, O = 16)**

Solution: To calculate percentage composition.

Percentage composition of the compound is calculated as under:

$$\text{Silver} = \frac{1.94}{2.746} \times 100 = 70.65\%$$

$$\text{Sulphur} = \frac{0.268}{2.746} \times 100 = 9.75\ \% \qquad \text{Oxygen} = \frac{0.538}{2.746} \times 100 = 19.6\%$$

To calculate empirical formula:

Element	% age	At. Mass	Relative number of moles	Simplest ratio of moles	Simplest whole no. ratio
Ag	70.65	108	$\frac{70.65}{108} = 0.654$	$\frac{0.654}{0.305} = 2$	2
S	9.75	32	$\frac{9.75}{32} = 0.305$	$\frac{0.305}{0.305} = 1$	1
O	19.6	16	$\frac{19.6}{16} = 1.22$	$\frac{1.22}{0.305} = 4$	4

$\therefore$ Empirical formula is Ag_2SO_4

7. STOICHIOMETRY

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. Before understanding how to calculate the amounts of reactants required or those produced in a chemical reaction, let us study what information is available from the balanced chemical equation of a given reaction. Let us consider the combustion of methane. A balanced equation for this reaction is as given below:

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2\,H_2O(g)$$

The above balance reaction gives the following information:

- For every 1 mole of CH_4, 2 mole of O_2 will be required to produce 1 mole of CO_2 and 2 moles of H_2O. this signifies **Mole – Mole relation**

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- For every 16 gms of CH_4, 64 gms of O_2 will be required to produce 44gms of CO_2 and 36 gms of H_2O this signifies **Mass – Mass relation**
- Ratio of moles of $CO_2 : H_2O$ at any time = 1 : 2
- There will be no change in total mass of all reactants and products at any time for any chemical reaction.
- For the above reaction only, there will be no change in total number of moles of all reactants and products.

In order to solve the problems based on chemical calculations the following steps, in general, are quite helpful.

- Write the balanced chemical equation.
- Write the atomic mass/molecular mass/moles/molar volumes of the species involved in calculations.
- Calculate the result by applying unitary method.

7.1 INTERPRETATION OF BALANCED CHEMICAL EQUATIONS

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

1. Mass – mass analysis
2. Mass – volume analysis
3. Volume – volume analysis

MASS – MASS ANALYSIS:

Consider the reaction, $2KClO_3 \rightarrow 2KCl + 3O_2$

According to stoichiometry of the reaction

Mass – mass ratio: 2 x 122.5 : 2 x 74.5 : 3 x 32

Or $$\frac{Mass\ of\ KClO_3}{Mass\ of\ KCl} = \frac{2\times122.5}{2\times74.5}$$

$$\frac{Mass\ of\ KClO_3}{Mass\ of\ O_2} = \frac{2\times122.5}{3\times32}$$

Ex. 22 : 367.5 gram $KClO_3$ (M = 122.5) is heated. How many gram KCl and oxygen is produced.

Solution: Balanced chemical equation for heating of $KClO_3$ is

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

Mass – mass ratio: 2 x 122.5 gm 2 x 74.5 gm : 3 x 32 gm

$$\frac{Mass\ of\ KClO_3}{Mass\ of\ KCl} = \frac{2\times122.5}{2\times74.5} \Rightarrow \frac{367.5}{W} = \frac{122.5}{74.5}$$

W_{KCl} = 3 x 74.5 = 223.5 gm

$$\frac{Mass\ of\ KClO_3}{Mass\ of\ O_2} = \frac{2\times122.5}{3\times32} \Rightarrow \frac{367.5}{W} = \frac{2\times122.5}{3\times32}$$

W_{oxygen} = 144 gm

Ex. 23: **How many grams of oxygen (O_2) are required to completely react with 0.200 g of hydrogen (H_2) to yield water (H_2O)? Also calculate the amount of water formed. (At. Mass H = 1; O = 16).**

Solution: The balanced equation for the reaction is

$2H_2$	+	O_2	$\longrightarrow$	$2H_2O$
2 mol		1 mol		2 mol
4 g		32 g		36 g

Now, 4g of H_2 require oxygen = 32 g

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0.200 g of H_2 require oxygen = $\frac{32}{4} \times 0.200 = 1.6$ g

Again, 4g of H_2 produce H_2O = 36 g

0.200 g of H_2 produce H_2O = $\frac{36}{4} \times 0.200 = 1.8$ g.

MASS – VOLUME ANALYSIS :

Now again consider decomposition of $KClO_3$

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

Mass Volume ratio, 2 x 122.5 gm : 2 x 74.5 gm : 3 x 22.4 lt at N.T.P.

we can use two relation for volume of oxygen.

$$\frac{Mass\ of\ KClO_3}{volume\ of\ O_2\ at\ NTP} = \frac{2 \times 122.5}{3 \times 22.4 lt} \quad ...(i)$$

And $$\frac{Mass\ of\ KCl}{volume\ of\ O_2\ at\ NTP} = \frac{2 \times 74.5}{3 \times 22.4 lt} \quad ...(ii)$$

Ex. 24: Calculate the volume of O_2 and volume of air needed for combustion of 1 kg carbon at NTP.(Assume air contains 20% oxygen)

Solution: $C + O_2 \longrightarrow CO_2$

$\because$ 12 g C requires O_2 = 22.4 litre of O_2 = 1 mole of O_2 = 32 g of O_2

$\therefore$ 1000 g C requires $O_2 = \frac{22.4 \times 1000}{12}$ litre

= 1866.67 litre O_2

$\therefore$ $V_{air} = 5 \times V_{O_2} = 5 \times 1866.67 = 9333.35$ litre

Ex. 25: What volume of oxygen at N.T.P. can be produced by 6.125 g of potassium chlorate according to the reaction $2KClO_3 \longrightarrow 2KCl + 3O_2$.

Solution: The given chemical equation is :

$2KClO_3$ $\longrightarrow$	$2KCl$ +	$3O_2$
2 mol	2 mol	3 mol
2 × 122.5 g		3 × 22.4L at N.T.P

Now 245 g of $KClO_3$ produce oxygen at N.T.P. = 3 × 22.4 L

6.125 g of $KClO_3$ produce oxygen = $\frac{3 \times 22.4}{245} \times 6.125 = 1.68$ L at N.T.P.

VOLUME – VOLUME RELATIONSHIP:

It relates the volume of gaseous species (reactants or product) with the volume of another gaseous species (reactant or product) involved in a chemical reaction.

Ex. 26: What volume of oxygen gas at NTP is necessary for complete combustion of 20 litre of propane measured at 0°C and 760 mm pressure.

Solution: The balanced equation is

$$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$$

$1vol \quad 5vol$

$1litre \quad 5litre$

1 litre of propane requires = 5 litre of oxygen

20 litre of propane will require = 5 x 20 = 100 litre of oxygen at 760 mm pressure and 0°C.

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Ex. 27: The percentage by volume of C_3H_8 in a mixture of C_3H_8, CH_4 and CO is 36.5. Calculate the volume of CO_2 produced when 100 mL of the mixture is burnt in excess of O_2.

Solution: $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O(l)$

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O(l)$

$CO + \frac{1}{2}O_2 \longrightarrow CO_2$

Let a mL, b mL and c mL be volumes of C_3H_8, CH_4 and CO respectively in 100 mL given simple, then a + b + c = 100 and a = 36.5

Now CO_2 is formed as a result of combustion of mixture.

$$\therefore \text{Vol. of } CO_2 \text{ formed} = 3a + b + c \begin{pmatrix} \because \text{ 1 vol. } C_3H_8 \text{ gives 3 vol. } CO_2 \\ \text{1vol. } CH_4 \text{ gives 1 vol. } CO_2 \\ \text{1 vol. CO gives 1 vol. } CO_2 \end{pmatrix}$$

$$= 3 \times 36.5 + (100 - 36.5) = 173 \text{ mL}$$

7.2 LIMITING REAGENT

In many situations one of the reactants is present in excess therefore some of this reactant is left over on completion of the reaction. For example, consider the combustion of hydrogen.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

Suppose that 2 moles of H_2 and 2 moles of O_2 are available for reaction. It follows from the equation that only 1 mole of O_2 is required for complete combustion of 2 moles of H_2 ; 1 mole of O_2 will, therefore, be left over on completion of the reaction. The amount of the product obtained is determined by the amount of the reactant that is completely consumed in the reaction. This reactant is called the limiting reagent. Thus, limiting reagent may be defined as the reactant which is completely consumed during the reaction.

In the above example H_2 is the limiting reagent. The amount of H_2O formed will, therefore, be determined by the amount of H_2. Since 2 moles of H_2 are taken, it will form 2 moles of H_2O on combustion.

- The best method to identify limiting reagent is by dividing given moles of each reactant by their stoichiometric coefficient, the one with least ratio is limiting reagent. It is particularly useful when number of reactants are more than two.

Ex. 28: How much magnesium sulphide can be obtained from 2.00 g of magnesium and 2.00 g of sulphur by the reaction Mg + S $\longrightarrow$ MgS? Which is the limiting reagent? Calculate the amount of the reactants which remains unreacted.

Solution : First of all each of this masses are converted into moles:

$$2.00 \text{ g of Mg} = \frac{2.00}{24.3} = 0.0824 \text{ moles of Mg}$$

$$2.00 \text{ g of S} = \frac{2.00}{32.1} = 0.0624 \text{ moles of S}$$

From the equation, Mg + S $\longrightarrow$ MgS, it follows that one mole of Mg reacts with one mole of S. We are given more moles of Mg than of S. Therefore, Mg is in excess and some of it will remain unreacted when the reaction is over. S is the limiting reagent and will control the amount of product. From the equation we note that one mole of S gives one mole of MgS, so 0.0624 mole of S will react with 0.0624 mole of Mg to form 0.0624 mole of MgS.

Molar mass of MgS	=	56.4 g
∴ Mass of MgS formed	=	0.0624 × 56.4 g = 3.52 g of MgS
Moles of Mg left unreacted	=	0.0824 –0.0624 moles of Mg
	=	0.0200 moles of Mg

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Mass of Mg left unreacted = moles of Mg × molar mass of Mg
= 0.0200 × 24.3 g of Mg = 0.486 g of Mg

Ex. 29: 4 mole of $MgCO_3$ is reacted with 6 moles of HCl solution. Find the volume of CO_2 gas produced at NTP. The reaction is $MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$

Solution: From the reaction $MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$

Given moles	4 mole		6 mole
Given mole ratio	2	:	3
Stoichiometric Coefficient ratio	1	:	2

There should be one limiting reagent.
To find the limiting reagent, divide the given moles by stoichiometric coefficient.

$MgCO_3$	HCl
$\frac{4}{1} = 4$	$\frac{6}{2} = 3$

HCl is limiting reagent.

$\because \quad \frac{\text{moles of HCl}}{2} = \frac{\text{moles of } CO_2 \text{ produced}}{1}$

$\therefore$ moles of CO_2 produced = 3 moles

$\therefore$ volumes of CO_2 produced at N.T.P, = $3 \times 22.4 = 67.2L$

Ex. 30: What weight of AgCl will be precipitated when a solution containing 4.77 g NaCl is added to a solution of 5.77g of $AgNO_3$?

Solution:

	$AgNO_3$	+	NaCl	⟶	AgCl	+	$NaNO_3$
mmoles. mixed	$\frac{5.77}{170} \times 1000$ = 33.94		$\frac{4.77}{58.5} \times 1000$ = 81.54		0		0
mmoles. left	0		47.60		33.94		33.94

$\therefore$ mmoles of AgCl formed = 33.94

$\frac{w}{143.5} \times 1000 = 33.94 \qquad W_{AgCl} = 4.87\,g$

7.3 CALCULATION INVOLVING PERCENT YIELD

In general, when a reaction is carried out in the laboratory we do not obtain actually the theoretical amount of the product. The amount of the product that is actually obtained is called the actual yield. Knowing the actual yield and theoretical yield, the percentage yield can be calculated as

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

7.4 PRINCIPLE OF ATOM CONSERVATION (POAC)

In chemical reaction atoms are conserved, so moles of atoms shall also be conserved. This is known as principle of atomic conservation. This principle is helpful in solving problems of nearly all stoichiometric calculations e.g.

$$KClO_{3(s)} \longrightarrow KCl_{(s)} + O_{2(g)}$$

Applying POAC for K atoms
Moles of K atoms in $KClO_3$ = Moles of K atoms in KCl
Since one mole of $KClO_3$ contains 1 mol of K atom. Similarly 1 mol of KCl contains one mole of K atoms.

$\therefore 1 \times n_{KClO_3} = 1 \times n_{KCl} \Rightarrow 1 \times \frac{W_{KClO_3}}{M_{KClO_3}} = \frac{W_{KCl}}{M_{KCl}}$ (Mass-mass relationship)

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Applying POAC for 'O' atoms Moles of O atom in $KClO_3$ = Moles of O atom in O_2

$\therefore 3 \times n_{KClO_3} = 2 \times n_{O_2} \Rightarrow 3 \times \frac{W_{KClO_3}}{M_{KClO_3}} = 2 \times \frac{\text{Vol. of } O_2 \text{ at STP}}{\text{Standard Molar Volume}}$

(Mass volume relationship of reactant and product)

In this way applying POAC we can break the chemical equation into a number of arithmetic equations without balancing the chemical equation. Moreover number of reactions and their sequence from reactants to products are not required. It is important to note that POAC can be applied for the atoms which remain conserved in chemical reaction.

- Please note that the balanced reaction is essential in Mole method of solving .Only while using POAC (which would be applicable only in certain cases), balanced reaction is not required.
- You can use POAC for all atoms in the compound only if all the reactants and products are known.

Ex. 31: A sample of $KClO_3$ on decomposition yielded 448 mL of oxygen gas at NTP Calculate :
(i) weight of oxygen produced ,
(ii) weight of $KClO_3$ originally taken
(iii) weight of KCl produced
(K = 39 , Cl = 35.5 and O = 16)

Solution: (i) Mole of oxygen = $\frac{448}{22400} = 0.02$

Wt. of oxygen = 0.02 x 32 = 0.64gm

(ii) $KClO_3 \rightarrow KCl + O_2$

Applying POAC for O atoms,

Moles of O atoms in $KClO_3$ = moles of O atoms in O_2

3 (moles of $KClO_3$)= 2 (moles of O_2)

(1 mole of $KClO_3$ contains 3 moles of O and 1 mole of O_2 contains 2 moles of O)

$$3 \times \frac{wt. of\ KClO_3}{mol.\ wt.\ of\ KClO_3} = 2 \times \frac{vol.\ at\ NTP(litre)}{22.4}$$

$$3 \times \frac{wt. of\ KClO_3}{122.5} = 2 \times \frac{vol.\ at\ NTP\ (litre)}{22.4}$$

Wt. of $KClO_3$ = **1.634 g**

(iii) Again applying POAC for K atoms, Moles of K atoms in $KClO_3$ = 1 x moles of KCl

(1 mole of $KClO_3$ contains 1 mole of K and 1 mole of KCl contains 1 mole of K)

$$1 \times \frac{wt.\ of\ KClO_3}{mol.\ wt.\ of\ KClO_3} = 1 \times \frac{wt. of\ KCl}{mol.\ wt.\ of\ KCl}$$

Wt. of KCl = 0.9937 g.

Ex. 32: 27.6 g of 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.

Solution: $K_2CO_3 \xrightarrow[steps]{Several} K_2Zn_3[Fe(CN)_6]_2$

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 x mole of K_2CO_3 = 12 x moles of $K_2Zn_3[Fe(CN)_6]_2$

$$\left(\because 1\ mole\ of\ K_2CO_3\ contains\ 1\ mole\ C\ \&\ 1\ mole\ of\ K_2Zn_3[Fe(CN)_6]_2\ contains\ 12\ mole\ of\ C\right)$$

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

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

[mol. wt. of $K_2CO_3 = 138$ and mol. wt. of $K_2Zn_3[Fe(CN)_6]_2 = 698$]

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Ex. 33: In a gravimetric determination of P, an aqueous solution of dihydrogen phosphate ion $H_2PO_4^-$ 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, $Mg_2P_2O_7$ which is weighed. A solution of $H_2PO_4^-$ yielded 1.054 g of $Mg_2P_2O_7$. What weight of NaH_2PO_4 was present originally?

Solution: $NaH_2PO_4 + Mg^{2+} + NH_4^+ \rightarrow Mg(NH_4)PO_4.6H_2O \xrightarrow{heated} Mg_2P_2O_7$

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

$1 \times$ moles of $NaH_2PO_4 = 2 \times$ moles of $Mg_2P_2O_7$

($\because$ 1 mole of NaH_2PO_4 contains 1 mole of P and 1 mole of $Mg_2P_2O_7$ contains 2 moles of P)

$$\frac{\text{wt. of } NaH_2PO_4}{\text{mol. wt. of } NaH_2PO_4} = 2 \times \frac{\text{wt. of } Mg_2P_2O_7}{\text{mol. wt. of } Mg_2P_2O_7}$$

$$\frac{\text{wt. of } NaH_2PO_4}{120} = 2 \times \frac{1.054}{222}$$

Wt. of NaH_2PO_4 = 1.14 g.

Ex. 34: What weight of CO is required to form $Re_2(CO)_{10}$ from 2.50 g of Re_2O_7 according to the unbalanced reaction:

$Re_2O_7 + CO \rightarrow Re_2(CO)_{10} + CO_2$

(Re = 186.2, C = 12 and O = 16)

Solution: Suppose the relative moles of each reactant and product are as follows (just for convenience)

$$\underset{a\,moles}{Re_2O_7} + \underset{b\,moles}{CO} \rightarrow \underset{c\,moles}{Re_2(CO)_{10}} + \underset{d\,moles}{CO_2}$$

Applying POAC for Re atoms,

Moles of Re in Re_2O_7 = moles of Re in $Re_2(CO)_{10}$

$2 \times$ moles of $Re_2O_7 = 2 \times$ moles of $Re_2(CO)_{10}$

2a = 2c or a = c ... (i)

Applying POAC for C atoms,

Moles of C atoms in CO = moles of C in $Re_2(CO)_{10}$ + moles of C in CO_2

$1 \times$ moles of CO $= 10 \times$ moles of $Re_2(CO)_{10} + 1 \times$ moles of CO_2

Or b = 10c + d .... (ii)

Applying POAC for O atoms,

Moles of O in Re_2O_7 + moles of O in CO

= moles of O in $Re_2(CO)_{10}$ + moles of O in CO_2

$7 \times$ moles of $Re_2O_7 + 1 \times$ moles of CO $= 10 \times$ moles of $Re_2(CO)_{10} + 2 \times$ moles of CO_2

or 7a + b = 10 c + 2d .... (iii)

From the eqns. (i), (ii), (iii), we get, 17a = b

i.e., $17 \times$ moles of Re_2O_7 = moles of CO

$$17 \times \frac{2.50}{484.4} = \frac{\text{wt. of CO in g}}{28} \cdot \left[\begin{array}{c}\text{mol. wt. of } Re_2O_7 = 484.4 \\ \text{mol. wt. of CO} = 28\end{array}\right]$$

Wt. of CO = 2.46 g.

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Ex. 35: **1.84 g of a mixture of $CaCO_3$ and $MgCO_3$ was heated to a constant weight. The constant weight of the residue was found to be 0.96 g. Calculate the percentage composition of the mixture. (Ca = 40, Mg = 24, C = 12, O = 16)**

Solution : **On heating $CaCO_3$ and $MgCO_3$, one of the products, CO_2, escapes out.**

We have,

$$\underset{x\,g}{CaCO_3} + \underset{(1.84-x)g}{MgCO_3} \rightarrow \underset{y\,g}{CaO} + \underset{(0.96-y)g}{MgO} + CO_2 \uparrow$$

Applying POAC for Ca atoms,

Moles of Ca atoms in $CaCO_3$ = moles of Ca atoms in CaO

$1 \times$ moles of $CaCO_3 = 1 \times$ moles of CaO

$$\frac{x}{100} = \frac{y}{56} \qquad \begin{bmatrix} CaCO_3 = 100 \\ CaO = 56 \end{bmatrix} \qquad \text{... (i)}$$

Again applying POAC for Mg atoms,

Moles of Mg in $MgCO_3$ = moles of Mg in MgO

$1 \times$ moles of $MgCO_3 = 1 \times$ moles of MgO

$$\frac{1.84-x}{84} = \frac{0.96-y}{40} \begin{bmatrix} MgCO_3 = 84 \\ MgO = 40 \end{bmatrix} \qquad \text{.... (ii)}$$

From eqns. (i) and (ii), we get x = 1 g, y = 0.84 g

$$\%\text{ of } CaCO_3 = \frac{1}{1.84} \times 100 = 54.34\,\%$$

$$\%\text{ of } MgCO_3 = 45.66\,\%$$

Ex. 36: **What mass of zinc is required to produce hydrogen by reaction with HCl which is enough to produce 4 mol of ammonia according to the reactions.**

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$
$$3H_2 + N_2 \longrightarrow 2NH_3$$

Solution: The given equations are

$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

$3H_2 + N_2 \longrightarrow 2NH_3$

From the equations it is clear that

2 mol of NH_3 require = 3 mol of H_2 ; 3 mol of H_2 require = 3 mol of Zn

Thus, 2 mol of NH_3 require = 3 mol of Zn = 3×65 g of Zn

$$\therefore \text{ 4 mol of } NH_3 \text{ require } = \frac{3 \times 65}{2} \times 4 = 390 \text{ g of Zn.}$$

8. CONCENTRATION TERMS

Many chemical reactions occur in the solution state and hence stoichiometric problems may sometimes involve different concentration terms of solutions to give an idea of amount of solute and solvent present in the solution. There are various ways to represent concentration of the solution as mentioned below.

- In a solution the designation of solute and solvent is often a matter of convenience, however many a times the one present in smaller quantity is termed as solute. Also, a solution may have more than one solute but solvent cannot be more than one.
- All the concentration terms given below are applicable only when there is a homogenous solution or when solute completely dissolves in the solvent.

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The following concentrations terms are used to expressed the concentration of a solution. These are

1. Molarity (M)
2. Molality (m)
3. Mole fraction (X)
4. % calculation
5. Normality (N) (will be discussed in volumetric analysis)
6. ppm

Please remember that all these concentration terms are related to one another. By knowing one concentration term you can also find the other concentration terms. Let us discuss all of them one by one.

8.1 MOLARITY (M)

The number of moles of a solute dissolved in 1 L (1000 ml) of the solution is known as the molarity of the solution.

$$\text{Molarity of solution} = \frac{\text{number of moles}}{\text{volume of solution in litre}}$$

Let a solution is prepared by dissolving w gm of solute of mol. wt. M in V ml water.

$\therefore$ Number of moles of solute dissolved = $\frac{w}{M}$

$\therefore$ V ml water have $\frac{w}{M}$ mole of solute

$\therefore$ 1000 ml water have $\frac{w \times 1000}{M \times V_{\text{in ml}}}$

$$\therefore \text{Molarity (M)} = \frac{w \times 1000}{(\text{Mol. wt of solute}) \times V_{\text{in ml}}}$$

Some other relations may also useful.

$$\text{Number of millimoles} = \frac{\text{mass of solute}}{(\text{Mol. wt. of solute})} \times 1000 = (\text{Molarity of solution} \times V_{\text{in ml}})$$

$$\text{Molarity} = \frac{\text{Number of millimole of solute}}{\text{Total volume of solution in ml}}$$

❖ If a particular solution having volume V_1 and molarity = M_1 is diluted to V_2 mL then

$M_1V_1 = M_2V_2$ $\quad$ M_2 : Resultant molarity

❖ If a solution having volume V_1 and molarity M_1 is mixed with another solution of same solute having volume V_2 mL & molarity M_2

M_R = Resultant molarity $= \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$

❖ Molarity is a unit that depends upon temperature. It varies inversely with temperature. Mathematically : Molarity decreases as temperature increases.

$$\text{Molarity} \propto \frac{1}{\text{temperature}} \propto \frac{1}{\text{volume}}$$

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Ex. 37: **149 gm of potassium chloride (KCl) is dissolved in 10 L of an aqueous solution. Determine the molarity of the solution (K = 39, Cl = 35.5)**

Solution: Molecular mass of KCl = 39 + 35.5 = 74.5 gm

$\therefore$ Moles of KCl = $\frac{149gm}{74.5gm} = 2$ $\therefore$ Molarity of the solution = $\frac{2}{10} = 0.2M$

Ex. 38: **What volume of a 3.0 M HCl solution be mixed with 500 mL of a 7 M HCl solution to prepare a HCl solution whose molarity will be 4.0?**

Solution: Let V mL of 3.0 M HCl solution is taken, then $3\,V + 500 \times 7 = 4 \times (500 + V) \Rightarrow V = 1500$ mL

Ex. 39: **Determine molarity of a solution obtained by mixing 50 mL of a 0.26 M H_2SO_4 solution with another 150 mL 0.48 M H_4SO_4 solution.**

Solution: It is a case of mixing of two solutions of different molarities. Applying the mixing formula:

$$\Rightarrow \quad M_3 = \frac{M_1V_1 + M_2V_2}{V_3} = \frac{50 \times 0.26 + 150 \times 0.48}{50 + 150} = 0.425 \text{ M}$$

Ex. 40: **What volume of a 5.00 M H_2SO_4 solution should be added to a 150 mL 1.0 M H_2SO_4 solution to obtain a solution of sulphuric acid of molarity 2.5?**

Solution: It is again a case of mixing of two solutions. Let us assume that V mL of the stock solution of H_2SO_4 is added.

$\Rightarrow \quad 5V + 150 \times 1.0 = 2.5 \times (150 + V)$

$\Rightarrow \quad 2.5\,V = 225$

$\therefore \quad V = \frac{225}{2.5} = 90\,mL$

Ex. 41: **A 150 mL 0.25 M NaCl solution, 250 mL 0.45 M $CaCl_2$ solution and a 100 mL 0.60 M $AlCl_3$ solution are mixed together and diluted to a final volume of 750 mL by adding enough water. Determine molarity of chloride ion (Cl^-) in solution assuming that all three salts are completely soluble as well as completely dissociated.**

Solution: First we need to calculate total mmoles of Cl^- from the three salt solutions:

mmoles of Cl^- ion from NaCl = 37.5

mmoles of Cl^- ion from $CaCl_2$ $= 2 \times$ mmoles of $CaCl_2$

$= 2 \times 112.5 = 225$

mmoles of Cl^- ion from $AlCl_3$ $= 3 \times$ mmoles of $AlCl_3$

$= 3 \times 60 = 180$

$\Rightarrow$ Total mmoles of Cl^- in final solution

= 37.5 + 225 + 180 = 442.5

$\Rightarrow$ Molarity of $Cl^- = \frac{\text{mmoles of } Cl^-}{\text{mL of solution}} = \frac{442.5}{750} = 0.59$ M

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8.2 MOLALITY (m)

The molality is the number of moles of solute present in one Kg of solvent

$$m = \frac{w_{solute} \times 1000}{\text{Molecular Mass of solute} \times w_{solvent}\,(gm)}$$

❖ Molality is independent of temperature changes.

Ex. 42 : 255 gm of an aqueous solution contains 5 gm of urea. What is the concentration of the solution in terms of molality. (Mol. wt. of urea = 60)

Solution: Mass of urea = 5 gm

Molecular mass of urea = 60

Number of moles of urea = $\frac{5}{60} = 0.083$

Mass of solvent = (255 – 5) = 250 gm

$\therefore$ Molality of the solution = $\frac{\text{Number of moles of solute}}{\text{Mass of solvent in gram}} \times 1000$

$= \frac{0.083}{250} \times 1000 = 0.333$

Ex. 43: The molarity and molality of a solution are M and m respectively. If the molecular weight of the solute is M', calculate the density of the solution in terms of M, m and M'.

Solution: Let weight of solute be w g and weight of solvent is W g and volume of solution is V mL.

$\therefore$ $M = \frac{w \times 1000}{M' \times V}$ ... (1)

$m = \frac{w \times 1000}{M' \times W}$ ... (2)

$D = \frac{w + W}{V}$ ... (3)

By Eq. (1) $w = \frac{MM'V}{1000}$ ... (4)

By Eq. (2) $W = \frac{w \times 1000}{M' \times m} = \frac{MM'V \times 1000}{1000 \times M' \times m}$ by Eq. (4)

$W = \frac{MV}{m}$ ... (5)

$\therefore$ By Eq. (3) $D = \frac{\frac{MV}{m} + \frac{MM'V}{1000}}{V}$ $D = M\left[\frac{1}{m} + \frac{M'}{1000}\right]$

MOLARITY(M) AND MOLALITY(m) FOR PURE SUBSTANCES:

1. **Water :**

Let the sample of water has 1000 ml

Mass of water = 1000 gm [density of water = 1gm/mL.]

Moles of water $= \frac{1000}{18} mol$

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$\therefore Molarity = \frac{\left(\frac{1000}{18}\right)}{1} = 55.55M$ & molality = $\frac{\left(\frac{1000}{18}\right) mol}{1\ kg} = 55.55\ m$

2. **Pure ethanol :**

d gm/ml (density of ethanol)

(C_2H_5OH) let volume of ethanol taken be 1000 ml.

$\therefore wt\ of$ ethanol in 1000 ml = $1000 \times d\ gm$

Mol of ethanol $= \frac{1000d}{46}$ $\therefore$ Molarity $= \frac{1000d}{46}$

& molality of ethanol = $\frac{\left(\frac{1000d}{46}\right) mol}{\left(\frac{1000d}{1000}\right) kg} = \frac{1000}{46}$

- **Parts per million (ppm)** → Amount of solute (in g) with 10^6 g solvent
- **Parts per billion (ppb)** → Amount of solute (in g) with 10^9 g solvent

8.3 MOLE FRACTION (X)

The ratio of number of moles of the solute or solvent present in the solution and the total number of moles present in the solution is known as the mole fraction of substance concerned.

Let number of moles of solute in solution = n

Number of moles of solvent in solution = N

$\therefore$ Mole fraction of solute $(X_1) = \frac{n}{n+N}$

$\therefore$ Mole fraction of solvent $(X_2) = \frac{N}{n+N}$

Also $X_1 + X_2 = 1$

- Mole fraction is a pure number. It will remain independent of temperature changes.

8.4 PERCENTAGE CONCENTRATION

The concentration of a solution may also be expressed in terms of percentage in the following way.

1. **% WEIGHT BY WEIGHT (W/W):**

It is given as mass of solute present in per 100 gm of solution.

$$\% \text{ w/w} = \frac{\text{mass of solute in gm}}{\text{mass of solution in gm}} \times 100$$

2. **% WEIGHT BY VOLUME (W/V) :**

It is given as mass of solute present in per 100 ml of solution

$$\% \text{ w/v} = \frac{\text{mass of solute in gm}}{\text{volume of solution in ml}} \times 100$$

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3. % VOLUME BY VOLUME (V/V) :

It is given as volume of solute present in per 100 ml solution.

$$\% \text{ V/V} = \frac{\text{Volume of solute in ml}}{\text{Volume of solution in ml}} \times 100$$

Ex. 44: 0.5 g of a substance is dissolved in 25 g of a solvent. Calculate the percentage amount of the substance in the solution.

Solution: Mass of substance = 0.5 g Mass of solvent = 25 g

$\therefore$ Percentage of the substance (w/w) $= \frac{0.5}{0.5+25} \times 100 = 1.96$

Ex. 45: $20cm^3$ of an alcohol is dissolved in $80cm^3$ of water. Calculate the percentage of alcohol in solution.

Solution: Volume of alcohol = $20cm^3$ Volume of water = $80cm^3$

$\therefore$ percentage of alcohol $= \frac{20}{20+80} \times 100 = 20\%$

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SOLVED OBJECTIVE PROBLEMS

Problem 1: **Assuming that petrol is octane (C_8H_{18}) and has density 0.8 g/ml, 1.425 litre of petrol on complete combustion will consume**
(A) 50 mole of O_2 (B) 125 mole of O_2 (C) 100 mole of O_2 (D) 200 mole of O_2

Solution: Mass of octane $= 1.425 \times 10^3 \times 0.8$ g

Moles of octane $= \frac{1425 \times 0.8}{114} = 10$ moles

$C_8H_{18} + \frac{25}{2}O_2 \longrightarrow 8CO_2 + 9H_2O$

From the equation it can be seen

For 1 mole octane oxygen required $= \frac{25}{2}$ moles

$\therefore$ for 10 mole octane oxygen required $= \frac{25}{2} \times 10 = 125$ moles $\therefore$ **(B)**

Problem 2: **Weight of 1 atom of an element is 6.644×10^{-23} g. What is number of atoms of element in 40 kg of it.**
(A) 10^3 g atom (B) 10^2 g atom (C) 10^4 g atom (D) 10 g atom

Solution: Weight of Avogadro number (N_A) of atoms of the element

$= 6.644 \times 10^{-23} \times 6.022 \times 10^{23} = 40$ g

40 g = weight of 1g atom $\therefore$ 40×10^3 g = weight of 10^3 g atom $\therefore$ **(A)**

Problem 3: **8 g of O_2 has the same number of molecules as in**
(A) 7 g of CO (B) 14 g of CO (C) 28 g of CO (D) 11 g of CO_2

Solution: 8 g $O_2 = \frac{8}{32}$ i.e., $\frac{1}{4}$ moles of O_2 ($\because$ mol.wt. of $O_2 = 32$)

Now, 7 g of CO $= \frac{7}{28}$ mole of CO ($\because$ Mol.wt.of CO = 28) $= \frac{1}{4}$

28 g of CO $= \frac{28}{28} = 1$ mole of CO $\therefore$ 14 g of CO $= \frac{14}{28} = \frac{1}{2}$ mole of CO

11 g of $CO_2 = \frac{11}{44} = \frac{1}{4}$ mole CO_2 ($\therefore$ mol.wt.of $CO_2 = 44$)

Same number of moles means same number of molecules . $\therefore$ **(A) and (D)**

Problem 4: **A compound contains 3.2% of oxygen. The minimum mol wt. of the compound is**
(A) 300 (B) 440 (C) 350 (D) 500

Solution: The compound must contain at least one oxygen atom
So, a minimum of 1 g atom of oxygen will be present in 1 g molecule i.e., 1 mole of the compound.
If M is the mol. wt. of the compound then since 16 is the atomic mass of oxygen so minimum of 16 g of oxygen will be present in M g of the compound

Thus, % of oxygen $= \frac{16}{M} \times 100$ or $3.2 = \frac{16 \times 100}{M}$ or M = 500 $\therefore$ **(D)**

Problem 5: **Arrange the following in order of increasing mass**
(i) 3.0115×10^{23} molecules of white phosphorus (P_4) (ii) 10 moles of H_2 gas
(iii) 1 g molecule of anhydrous Na_2CO_3 (iv) 33.6 L of CO_2 gas at N.T.P.
(A) ii < i < iv < iii (B) iii < vi < i <ii (C) i < ii < iv < iii (D) i < iv < iii < ii

Solution: i) At. wt. of P = 31 and atomicity of P in white P is 4
Mol.wt. of white P = 31 × 4 = 124
$\therefore$ 6.023×10^{23} molecules of white P weigh 124 g

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$\therefore$ 3.0115×10^{23} molecules of white P weigh $\frac{124}{6.023} \times 3.015 = 62$ g

ii) Wt. of 1 mole of H_2 gas = 2 g
wt. of 10 moles of H_2 gas = 2 × 10 = 20 g

iii) 1 g molecule of anhydrous Na_2CO_3 = Mol wt. of Na_2CO_3 in g = 106 g

iv) At NTP 22.4 lit CO_2 weighs 44 g
$\therefore$ 33.6 lit CO_2 weighs $\frac{44}{22.4} \times 33.6$ g= 66 g

So, the correct choice ; ii < i < iv < iii $\therefore$ (A)

Problem 6: Arrange the following in order of decreasing mass
i. 1F atom ii. 1 N atom iii. 1 O atom iv. 1 H atom
(A) i > iii > iv >ii (B) iv > ii > iii >i (C) i > iii > ii > iv (D) iii >i > ii > iv

Solution: Mass of 1F atom $= \frac{19}{6.022 \times 10^{23}}$ (since At.wt. of F = 19)

Mass of 1N atom $= \frac{14}{6.022 \times 10^{23}}$

Mass of 1 H atom $= \frac{1}{6.022 \times 10^{23}}$

Mass of 1 O atom $= \frac{16}{6.022 \times 10^{23}}$ i > iii > ii > iv $\therefore$ (C)

Problem 7: The number of millimoles contained in 0.160 g of NaOH is :
(A) 0.04 (B) 0.4 (C) 4 (D) 40

Solution: Number of millimoles $= \frac{\text{wt in gm}}{\text{mol wt}} \times 1000 = \frac{0.16 \times 1000}{40} = 4$ $\therefore$ (C)

Problem 8: The number of moles present in 1m^3 of any gas at NTP is :
(A) 32. 4 (B) 54.6 (C) 44.6 (D) 28.2

Solution: 22.4 lit of any gas contains 1 mole or $\frac{22.4}{10^3}$ m^3 of any gas contains 1 mole

$\therefore$ 1 m^3 of any gas contains $\frac{10^3}{22.4}$ moles = 44.6 $\therefore$ (C)

Problem 9: The minimum quantity of H_2S needed to precipitate 63.5 gm of Cu^{2+} will be nearly.
(A) 63.5 gm (B) 31.75 gm (C) 34 gm (D) 32 gm

Solution: Since the ppt is of CuS, hence all the S atoms will be conserved

$\therefore \frac{w_{H_2S}}{34}$ = moles of Sulphur = moles of Copper = $\frac{63.5}{63.5}$

$\therefore w_{H_2S}$ = 34 gm $\therefore$ (C)

Problem 10: How many molecules are present in 12 L of liquid CCl_4? The density of the liquid is 1.59 g cm^{-3}
(A) 7.44 × 10^{26} (B) 0.744 × 10^{26} (C) 1.59 × 10^{26} (D) 15.9 × 10^{26}

Solution: 1 cc of CCl_4 contains 1.59 gms of it = $\frac{1.59}{154} = 0.0103$ moles

$\therefore$ 12 L of liquid CCl_4 will contain = 12 × 1000 × 0.0103 $\Rightarrow$ 0.744 × 10^{26} molecules of it
$\therefore$ (B)

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Problem 11: **13.4g of a sample of unstable hydrated salt: $Na_2SO_4 \cdot nH_2O$ was found to contain 6.3g of water. Determine the number of water of crystallisation.**

(A) 6 **(B) 5** **(C) 7** **(D) 8**

Solution:

$$\frac{\text{wt. of water}}{\text{wt. of sample}} = \frac{\text{wt. of water in the compound}}{\text{mol. wt. of the compound}}$$

$$\frac{6.3}{13.4} = \frac{n \times 18}{142 + 18n} \quad \Rightarrow n = 7$$

∴ **(C)**

Problem 12: **The mass of $BaCO_3$ produced when excess of CO_2 is bubbled through a solution of 0.205 mol $Ba(OH)_2$ is**

(A) 81 g **(B) 40.5 g** **(C) 20.25 g** **(D) 162 g**

Solution: $Ba(OH)_2 + CO_2 \rightarrow BaCO_3 + H_2O$

Mol. wt. of $BaCO_3 = 137 + 12 + 16 \times 3 = 197$

$$\text{No. of mole} = \frac{\text{wt. of substance}}{\text{mol wt.}}$$

∵ 1 mole of $Ba(OH)_2$ gives 1 mole of $BaCO_3$

∴ 0.205 mole of $Ba(OH)_2$ will give 0.205 mole of $BaCO_3$

∴ wt. of 0.205 mole of $BaCO_3$ will be $0.205 \times 197 = 40.385\,gm \approx 40.5\,gm$

∴ **(B)**

Problem 13: **What will be the volume of CO_2 at NTP obtained on heating 10 grams of (90% pure) limestone**

(a) 22.4 litre **(B) 2.016 litre** **(C) 2.24 litre** **(D) 20.16 litre**

Solution: $\underset{10\,gm}{CaCO_3} \rightarrow CaO + CO_2$

$$90\%\ \text{pure} = 9\ gm = \frac{9}{100}\ \text{mole}$$

Mole of $CaCO_3$ = moles of CO_2 = 0.09 mole

At NTP vol. $CO_2 = 0.09 \times 22.4 = 2.016\,L$ ∴ **(B)**

Problem 14: **The number of water molecules present in a drop of water (volume = 0.0018 ml) at room temperature is**

(A) 6.022×10^{19} **(B)** 1.084×10^{18} **(C)** 4.84×10^{17} **(D)** 5.023×10^{23}

Solution:

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

Weight of 0.0018ml = 0.0018 gm (since $d_{H_2O} = 1\,gm/ml$)

$$\text{No. of moles} = \frac{\text{weight}}{\text{Molecular weight}} = \frac{0.0018}{18} = 1 \times 10^{-4}$$

∴ No. of water molecules = $6.022 \times 10^{23} \times 1 \times 10^{-4} = 6.023 \times 10^{19}$ ∴ **A**

Problem 15: **From 160 g of $SO_2(g)$ sample, 1.2046×10^{24} molecules of SO_2 are removed then find out the volume of left over $SO_2(g)$ at NTP.**

(A) 11.2L (B) 22.4 L (C) 44.82 L (D) 61.2 L

Solution: To calculate no. of moles in 160 gm sample of SO_2.

$$n = \frac{W}{M} = \frac{160g}{64g/mole} = 2.5\text{mole}$$

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To calculate no. of moles of SO_2 removed.

$$n = \frac{\text{given no. of molecules}}{N_A} = \frac{1.2046 \times 10^{24}}{6.022 \times 10^{23}} = 2\text{mole}$$

no. of mole of SO_2 left = 2.5 – 2 = 0.5 mole

volume of SO_2 left at NTP. ∴(A)

$V = n \times 22.4\ L = 11.2\ L$

Problem16: 340 g NH_3 (M = 17) when decompose how many litres of nitrogen gas is produced at NTP.

(A) 224 Lt (B) 448 Lt (C) 226Lt (D) 322 Lt

Solution:

$$2NH_3 \longrightarrow N_2 + 3H_2$$

Mole – mole ratio: 2 mole : 1 mole 3 mole

Mass volume ratio: 2×17 g : 22.4 L at STP

$$\frac{\text{Volume of } N_2 \text{ at NTP}}{\text{mass of } NH_3} = \frac{22.4L}{2 \times 17}$$

$$\text{Vol. of } N_2 \text{ at. NTP} = \frac{22.4L}{2 \times 17} \times 340 = 224\ L.$$ ∴(A)

Problem17: 518 gm of an aqueous solution contain 18 gm of glucose (mol.wt. = 180). What is the molality of the solution.

(A) 0.2 (B) 0.4 (C) 0.6 (D) 0.8

Solution: Mass of solution = 518 g.

Mass of solute = 18 g

Mass of solvent = 518 – 18 = 500 g

Number of moles of glucose = $\frac{18}{180} = 0.1$

$$\therefore \quad \text{Molality of the solution} = \frac{\text{Number of moles of solute}}{\text{mass of solvent in gram}} \times 1000$$

$$= \frac{0.1}{500} \times 1000 = 0.2m$$ ∴ (A)

Problem18: 0.25 g of a substance is dissolved in 6.25 g of a solvent. Calculate the percentage amount of the substance in the solution.

(A) 3.85% (B) 6.85% (C) 48.5 % (D) 91.2 %

Solution: Mass of solute = 0.25 g

Mass of solvent = 6.25 g

Mass of solution = 0.25 +6.25 = 6.50 g.

Percentage amount of the solute = $\frac{0.25}{6.50} \times 100 = 3.85\%$ ∴(A)

Problem19: The vapour density of a mixture containing NO_2 and N_2O_4 is 38.3 at 27^0C. Calculate the mole of NO_2 in 100 mole mixture.

(A) 33.48 (B) 44.66 (C) 76.46 (D) 91.22

Solution: Mol. wt. of Mixture of NO_2 and $N_2O_4 = 38.3 \times 2 = 76.6$

Let a mole of NO_2 are present in mixture

wt of NO_2 + wt of N_2O_4 = Total wt of mixture

$$a \times 46 + (100 - a)92 = 100 \times 76.6$$

a = 33.48 mole ∴ (A)

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Problem20: **A compound contains 28% N and 72% of a metal by weight. Three atoms of metal combine with two atoms of N. Find the atomic weight of metal.**
(A) 24 (B) 26 (C) 32 (D) 48

Solution: Given that, $3M + 2N \longrightarrow M_3N_2$

Let a is at. wt, of metal

$\because$ (3a + 28)g M_3N_2 has metal = 3a gm

$\therefore$ 100 g M_3N_2 has metal = $\frac{3a \times 100}{(3a+28)}$ gm

$\because$ $\frac{3a \times 100}{(3a+28)} = 72$

$\therefore$ a = 24 $\therefore$ (A)

Problem21: **On heating 1.763 g of hydrated $BaCl_2$ to dryness, 1.505 g of anhydrous salt remained. What is the formula of hydrate?**
(A) $BaCl_2.2H_2O$ (B) $BaCl_2.3H_2O$
(C) $BaCl_2.4H_2O$ (D) $BaCl_2.5H_2O$

Solution: $\underset{\text{Mol.wt}(208+18n)}{BaCl_2 . nH_2O} \xrightarrow{\Delta} \underset{208}{BaCl_2} + nH_2O$

$\because$ (208 + 18n)g $BaCl_2 .nH_2O$ gives = 208 g $BaCl_2$

$\therefore$ 1.763 g $BaCl_2 . nH_2O = \frac{208 \times 1.763}{(208+18n)}$ g $BaCl_2 = 1.505$

$n = 1.98 \approx 2$

$\therefore$ formula is $BaCl_2.2H_2O$ $\therefore$ (A)

SOLVED SUBJECTIVE PROBLEMS

Problem 1: **0.05 gm of commercial sample of $KClO_3$ on decomposition liberated just sufficient oxygen for complete oxidation of 20 ml CO at 27°C and 750 mm pressure. Calculate % of $KClO_3$ in sample**

Solution: Applying PV = nRT for CO:

Moles of CO (n_{CO}) = $\frac{PV}{RT} = \frac{750 \times 20}{760 \times 0.0821 \times 300 \times 1000} = 8.01 \times 10^{-4}$

$CO + \frac{1}{2}O_2 \longrightarrow CO_2$, $\frac{n_{CO}}{n_{O_2}} = \frac{1}{1/2} = 2$

$\therefore$ moles of O_2 required $(n_{O_2}) = \frac{n_{CO}}{2} = \frac{8.01 \times 10^{-4}}{2}$

$2KClO_3 \longrightarrow 2KCl + 3O_2$

As 3 moles of O_2 are given by 2 mole of $KClO_3$

$\therefore$ $\frac{8.01 \times 10^{-4}}{2}$ mol of O_2 are given by = $\frac{2}{3} \times \frac{8.01 \times 10^{-4}}{2}$ mol of $KClO_3$

= 2.66×10^{-4} mol of $KClO_3$

$\therefore$ Weight of $KClO_3$ = $2.66 \times 10^{-4} \times 122.5$ gm = 3.26×10^{-2} gm

$\therefore$ % of $KClO_3$ in the mixture = $\frac{3.26 \times 10^{-2}}{0.05} \times 100 = 65\%$

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Problem 2: **Upon mixing 45.0 ml of 0.25 M lead nitrate solution with 25 mL of 0.10 M chromic sulphate solution precipitation of lead sulphate takes place. How many moles of lead sulphate are formed? Also calculate the concentrations of the species left behind in final solution. Assume that lead sulphate is completely insoluble.**

Solution:

	$3Pb(NO_3)_2$	+	$Cr_2(SO_4)_3$	$\longrightarrow$	$3PbSO_4\downarrow$	+	$2Cr(NO_3)_3$
mmoles.(initial)	45×0.25 = 11.25		25×0.1 = 2.5 (limiting reagent)		0		0
mmoles (final)	3.75		0		7.5		5

Hence, mmoles of $PbSO_4$ precipitated = 7.5

Final Volume of Solution = 70 ml

$$[Pb^{2+}] = \frac{3.75}{70} = 5.36 \times 10^{-2}\ M$$

$$[NO_3^-] = \frac{3.75\times2+5\times3}{70} = \frac{22.5}{70} = 0.32\ M \qquad [Cr^{3+}] = \frac{2.5\times2}{70} = \frac{5}{70} = 7.14 \times 10^{-2}\ M$$

Problem 3: **A mixture of propane and methane is contained in a vessel of unknown volume V at a temperature T and exerts a pressure of 320 mm Hg. The gas is burnt in excess O_2 and all the carbon is recovered as CO_2. The CO_2 is found to have a pressure of 448 mm Hg in a volume V, at the same temperature T. Calculate mole fraction of propane in mixture.**

Solution: Let the moles of propane (C_3H_8) = n_1 $\quad\therefore$ Moles of methane CH_4 = n_2

We know that PV = nRT $\quad\therefore 320 \times V = (n_1+n_2)\ RT$ ...(1)

after combustion

$$\underset{n_1}{C_3H_8} + 5O_2 \rightarrow \underset{3n_1}{3CO_2} + 4H_2O$$

$$\underset{n_2}{CH_4} + 2O_2 \rightarrow \underset{n_2}{CO_2} + 2H_2O$$

total moles of CO_2 formed = $(3n_1+n_2)$

Once again we have PV = nRT $\Rightarrow$ $448 \times V = (3n_1 + n_2)RT$ ....(2)

Dividing eqn (2) by (1) we have $\frac{448}{320} = \frac{(3n_1+n_2)}{(n_1+n_2)} \Rightarrow \frac{n_1}{n_2} = 0.25$

Mol fraction of C_3H_8 = $\frac{n_1}{n_1+n_2} = \frac{0.25n_2}{0.25n_2+n_2} = 0.2$

Problem 4: **An organic compound contains 69% Carbon and 4.8% hydrogen the remainder being oxygen. Calculate the masses of Carbon dioxide and Water formed by the complete combustion of 0.20 g of the substance.**

Solution.

$$\%C = \frac{12\times W_{CO_2}\times100}{44\times W_{substance}} \quad \therefore W_{CO_2} = \frac{\%C\times44\times W_{substance}}{12\times100}$$

$$= \frac{69\times44\times0.20}{12\times100} = 0.506\,g$$

$$\%H = \frac{2\times W_{H_2O}\times100}{18\times W_{substance}} \quad \therefore W_{H_2O} = \frac{\%H\times18\times W_{substacne}}{2\times100}$$

$$= \frac{4.8\times18\times0.2}{2\times100} = 0.0864\,g$$

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Problem 5: **K – 40 is a naturally occurring radioactive isotope having natural abundance 0.012% of potassium isotopes. How many K – 40 atoms do you ingest by drinking one cup of whole milk containing 370 mg of K ?**

Solution: Amount of K – 40 in 370 mg K $= \frac{370 \times 0.012}{100}$ mg

$= 0.0444$ mg

$\because$ 40 g K – 40 has atoms of K – 40 = 6.022×10^{23}

$\therefore$ 0.0444×10^{-3} g K – 40 has atoms = $\frac{6.022 \times 10^{23} \times 0.0444 \times 10^{-3}}{40}$

$= 6.69 \times 10^{17}$ atoms

Problem 6: **P and Q are two elements which forms P_2Q_3 and PQ_2. If 0.15 mole of P_2Q_3 weights 15.9 g and 0.15 mole of PQ_2 weights 9.3 g. what are atomic weights of P and Q?**

Solution: Let atomic Wt. of P and Q are a and b respectively.

$\therefore$ Mol. wt. of $P_2Q_3 = 2a + 3b$ and Mol. wt. of $PQ_2 = a + 2b$

now given that 0.15 mole of P_2Q_3 weight 15.9 g

$$(2a + 3b) = \frac{15.9}{0.15} \qquad \left(\because \frac{\text{wt.}}{\text{mol.wt.}} = \text{mole}\right)$$

Similarly $(a + 2b) = \frac{9.3}{0.15}$

Solving these two equations

b = 18 a = 26

Problem 7: **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 100 g of $KClO_4$.

Solution: Taking the given reactions

$$4KClO_3 \longrightarrow 3KClO_4 + KCl$$

$$12KClO \longrightarrow 8KCl + 4KClO_3$$

$$12Cl_2 + 24KOH \longrightarrow 12KClO + 12H_2O + 12KCl$$

Adding $12Cl_2 + 24KOH \longrightarrow 3KClO_4 + 21KCl + 12H_2O$

Mol. wt. of $KClO_4 = 138.5$

$\because$ 3×138.5 g$KClO_4$ is formed by = 12×71 gCl_2

$\therefore$ 100 g $KClO_4$ will be formed = $\frac{12 \times 71 \times 100}{3 \times 138.5}$

= 205.05 g

Problem8: **A hydrocarbon contains 10.5 g of carbon per g of H. One litre vapours of hydrocarbon at 127^0C and 1 atm pressure weights 2.8g. find molecular formula of hydrocarbon.**

Solution: Given,

C	:	H
10.5		1

$\therefore$ Total = 11.5

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Now from $PV = \frac{w}{M}RT$ for vapours of compound

$$1 \times 1 = \frac{2.8}{M} \times 0.0821 \times 400$$

$\therefore$ Mol.wt. of compound = 92

$\because$ 11.5 g has 1 g H

$\therefore$ 92 g has $\frac{92 \times 1}{11.5} = 8\,g\,H = 8g$ atom of H

And thus, 92 g has 84 g carbon = 7g atom carbon

$\therefore$ Molecular formula = C_7H_8

Problem 9: **The reaction, $2C + O_2 \longrightarrow 2CO$ is carried out by taking 24 g of carbon and 96 g of O_2, find out:**

(a) Which reactant is left in excess?

(b) How much of it is left?

(c) How many mole of CO are formed?

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

Solution:

	$2C$	$+ \; O_2$	$\longrightarrow$	$2CO$	
Mole before reaction	$\frac{24}{12}$ = 2	$\frac{96}{32}$ = 3		0	$\because$ Mole ratio of
Mole after reaction	0	2		2	$C:O_2:CO::2:1:2$

(a) $\therefore$ O_2 is left in excess.

(b) 2 mole of O_2 or 64 g O_2 is left.

(c) 2 mole of CO or 56 g CO is formed.

(d) To use O_2 completely total 6 mole of carbon or 72 g carbon is needed.

Problem10: **A polystyrene, having formula $Br_3C_6H_3(C_8H_8)_n$ was prepared by heating styrene with tribromobenzoyl peroxide in the absence of air. If it was found to contain 10.46% bromine by weight, find the value of n.**

Solution: Let the weight of polystyrene prepared be 100 g.

$\therefore$ No. of mole of Br in 100 g of polystyrene = $\frac{10.46}{80}$ = 0.1308 mole

From the formula of polystyrene, we have,

No. of moles of Br = 3 × mole of $Br_3C_6H_3(C_8H_8)_n$

$$0.1308 = 3 \times \frac{wt.}{mol.wt.} = \frac{3 \times 100}{315 + 104n}$$

Solving we get n = 19

Problem11: **A sample of gaseous hydrocarbon occupying 1.12 litre at NTP, when completely burnt in air produced 2.2 g CO_2 and 1.8 g H_2O. Calculate the weight of hydrocarbon taken and the volume of O_2 at NTP required for its combustion.**

Solution: Formula of hydrocarbon be C_aH_b

$$\therefore \quad C_aH_b + \left(a + \frac{b}{4}\right)O_2 \longrightarrow aCO_2 + \frac{b}{2}H_2O(l)$$

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$\because$ 22.4 litre C_aH_b gives 44a g CO_2

$\therefore$ 1.12 litre C_aH_b gives = $\frac{44a \times 1.12}{22.4} g CO_2$

$\therefore$ $\frac{44a \times 1.12}{22.4} = 2.2$

$\therefore$ a = 1

$\because$ 22.4 litre or 1 mole C_aH_b gives $\frac{b}{2} \times 18 g H_2O$

$\therefore$ 1.12 litre C_aH_b gives $\frac{b}{2} \times \frac{18 \times 1.12}{22.4} g\ H_2O$

$\therefore$ $\frac{b \times 18 \times 1.12}{2 \times 22.4} = 1.8$ $\Rightarrow b = 4$

$\therefore$ Hydrocarbon is CH_4

$\therefore$ Wt. of 1.12 litre CH_4 at NTP = $\frac{16 \times 1.12}{22.4} = 0.8g$

Also moles of O_2 used in combustion for 22.4 litre CH_4

$= a + \frac{b}{4}$

= 1 + 1 = 2 mole

$\because$ 22.4 litre CH_4 requires 2 mole O_2 or 2×22.4 litre O_2

$\therefore$ 1.12 litre CH_4 requires = $\frac{2 \times 22.4 \times 1.12}{22.4}$

= 2.24 litre O_2

Problem12: The density of 3M solution of $Na_2S_2O_3$ is $1.25 g mL^{-1}$. Calculate,

(a) the % by weight of $Na_2S_2O_3$

(b) mole fraction of $Na_2S_2O_3$

(c) the molalities of Na^+ and $S_2O_3^{2-}$ ions.

Solution: Given $Na_2S_2O_3$ has molarity = 3 mole $litre^{-1}$

$\therefore$ Mole of $Na_2S_2O_3 = 3$

$\therefore$ Wt. of $Na_2S_2O_3 = 3 \times 158 = 474 g$

And V of solution = 1 litre = 1000 mL

$\therefore$ Wt. of solution = $1000 \times 1.25 = 1250 g$

$\therefore$ Wt. of water = 1250 – 474 = 776 g

(a) % by wt. of $Na_2S_2O_3$ = $\frac{\text{wt. of } Na_2S_2O_3}{\text{wt. of } Na_2S_2O_3 + \text{wt. of } H_2O} = \frac{474}{1250} \times 100 = 37.92$

(b) Mole fraction of $Na_2S_2O_3$ = $\frac{\text{Mole of } Na_2S_2O_3}{\text{Mole of } Na_2S_2O_3 + \text{Mole of } H_2O}$

$= \frac{3}{3 + 776/18} = 0.065$

(c) Molality of Na^+ = $\frac{\text{Mole of } Na^+}{\text{wt. of water in g}} \times 1000 = \frac{6 \times 1000}{776} = 7.732$

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Molality of $S_2O_3^{2-} = \frac{3\times1000}{776} = 3.865$

Problem 13: Calculate molality of 1 litre solution of 93% H_2SO_4 (w/v). The density of solution is 1.84 g mL^{-1}.

Solution: Given H_2SO_4 is 93% (w/v).

∴ Wt. of $H_2SO_4 = 93$ g

Volume of solution = 100 mL

∴ Wt. of solution = $100\times1.84 = 184$g

∴ Wt. of water = 184 – 93 = 91 g

∴ $\text{Molality} = \frac{\text{Mole}}{\text{Wt. of water in kg}} = \frac{93}{98\times\frac{91}{1000}} = 10.42$

Problem14: A solution of density $1.6 g\,mL^{-1}$ is 67% by weight. What will be the % by weight of the solution of same acid if it is diluted to density $1.2 gmL^{-1}$?

Solution: Consider 100 mL of solution 67% by weight

∴ Wt. of solution = $100\times1.6 = 160$g

Wt. of solute = $\frac{67\times160}{100} = 107.2$ g

Now suppose X g of H_2O added in it $(d_{H_2O} = 1 gm/ml)$

Wt. of new solution = (160 + X) g

Also volume of new solution = (100 + X) mL

∴ Wt. of new solution = $(100+X)\times1.2g = (120+1.2X)g$

∴ 160 +X = (120 + 1.2X) g X = 200 mL or 200g

∴ % by weight of new solution = $\frac{107.2}{(160+200)}\times100 = 29.78\%$

Problem15: 10 mL of a solution of KCl containing NaCl gave on evaporation 0.93 g of the mixed salt which gave 1.865 g of AgCl by the reaction with $AgNO_3$. Calculate the quantity of NaCl in 10 mL of solution.

Solution: $\underset{ag}{NaCl} \xrightarrow{AgNo_3} AgCl$

$\underset{bg}{KCl} \xrightarrow{AgNo_3} AgCl$

∴ a + b = 0.93 ... (1)

∵ 58.5 g NaCl gives = 143.5 g AgCl

∴ a g NaCl gives = $\frac{143.5\times a}{58.5}$ g AgCl

Similarly,

∵ 74.5 g KCl gives = 143.5 g AgCl

∴ b g KCl gives = $\frac{143.5\times b}{74.5}$

∴ $\frac{143.5a}{58.5} + \frac{143.5\times b}{74.5} = 1.865$ ... (2)

Solving Eqs. (1) and (2),

a = 0.14 g , b = 0.79 g

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Problem16: **A sample of metal chloride weighing 0.22 g required 0.51 g of $AgNO_3$ to recipitate the chloride completely. The specific heat of the metal is 0.057. find out the molecular formula of the chloride, if the symbol of the metal is 'M'.**
(Ag = 108, N = 14, O = 16, Cl = 35.5)

Solution: Let the valency of the metal M be x

$$MCl_x + AgNO_3 \rightarrow AgCl$$

As it is clear from the question that both Ag and Cl atoms are conserved, applying POAC for Ag atoms, we get

Moles of Ag atoms in $AgNO_3$ = moles of Ag atoms in AgCl

$1 \times$ moles of $AgNO_3 = 1 \times$ moles of AgCl

$$\frac{0.51}{170} = \text{moles of AgCl} \quad ...(1)$$

Again applying POAC for Cl atoms, we get

Moles of Cl atoms in MCl_x = moles of AgCl

$x \times$ moles of $MCl_x = 1 \times$ moles of AgCl

$$x \times \frac{0.22}{\text{mol. wt. of } MCl_x} = \text{moles of AgCl}$$

Now, at. Wt. of $M = \frac{6.4}{0.057} = 112.3$ (Dulong and Petit;s law)

$\therefore$ molecular weight of MCl_x = (112.3 + 35.5x)

$$\therefore \quad x \times \frac{0.22}{(112.3+35.5x)} = \text{moles of AgCl} \quad ...(2)$$

From equations (1) and (2), $x \approx 3$

Since valency is a whole number

$\therefore$ x = 3 and the formula of the metal chloride is MCl_3.

Problem17: **Calculate the resultant molarity of following:**
(a) 200 ml 1 M HCl + 300 ml water
(b) 1500 ml 1 M HCl + 18.25 g HCl
(c) 200 ml 1M HCl + 100 ml 0.5 M HCl.

Solution: (a) $M_R = \frac{M_1V_1}{V_R} = \frac{1 \times 200}{500} = 0.4M$

(b) Milimoles of HCl = $\frac{18.25}{36.5} \times 1000 = 500$

Milimoles of HCl present in solution = $1500 \times 1 = 1500$

Total milimoles = 1500 + 500 = 2000.

$\because$ MV = 2000 $\quad M = \frac{2000}{V} = \frac{2000}{1500} = \frac{4}{3}M$

(c) $M_R = \frac{M_1V_1 + M_2V_2}{V_1 + V_2} = \frac{1 \times 200 + 0.5 \times 100}{300} = \frac{5}{6}M$

Problem18: **A mixture of FeO and Fe_3O_4 when heated in air to constant weight, gains 5% in its weight. Find out composition of mixture.**

Solution: $2\,FeO + \frac{1}{2}O_2 \longrightarrow Fe_2O_3$; $\quad 2\,Fe_3O_4 + \frac{1}{2}O_2 \longrightarrow 3Fe_2O_3$

Let weight of FeO = a g and weight of $Fe_3O_4 = b$ g

$\therefore$ a + b = 100 ... (1)

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Now, $2 \times 72g$ FeO gives $Fe_2O_3 = 160g$

$\therefore$ a g FeO gives $Fe_2O_3 = \frac{160 \times a}{144}$ g

Also, 2×232 g of Fe_3O_4 gives $Fe_2O_3 = 160 \times 3g$

$\therefore$ b g Fe_3O_4 gives $Fe_2O_3 = \frac{160 \times 3 \times b}{464}$ g

$\therefore$ $\frac{160a}{144} + \frac{160 \times 3 \times b}{464} = 105$ ... (2)

Solving eqs. (1) and (2),

a = 20.25 g $\therefore$ FeO = 20.25 %

b = 79.75 g and $Fe_3O_4 = 79.75\%$

Problem 19: A sample of chalk contains impurity in form of clay which loses 14.5% of its weight of water on prolong heating. 5 g of chalk on heating shows a loss in weight (due to evolution of CO_2 and water) by 1.507 g. Calculate % of chalk in the sample.

Solution: Chalk has Clay + $CaCO_3$ (Chalk)

a g b g

$\therefore$ a + b = 5 ... (1)

On heating (1) Clay loses water (2) $CaCO_3$ loses CO_2

Now, Weight loss of water by a g clay = $\frac{14.5 \times a}{100}$

Weight loss of CO_2 by b g $CaCO_3$ = $\frac{44 \times b}{100}$

$\therefore$ $\frac{14.5 \times a}{100} + \frac{44 \times b}{100} = 1.507$ ... (2)

Solving eqs. (1) and (2), a = 2.349 g b = 2.651 g

$\therefore$ % of chalk, i.e., $CaCO_3 = \frac{2.651}{5} \times 100 = 53\%$

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FOUNDATION BUILDER (OBJECTIVE PROBLEM)

LAWS OF CHEMICAL COMBINATIONS

1. Potassium combines with two isotopes of chlorine (^{35}Cl and ^{37}Cl) respectively to form two samples of KCl. Their formation follows the law of:
(A) constant proportions (B) multiple proportions
(C) reciprocal proportions (D) none of these

2. H_2S contains 5.88% hydrogen, H_2O contains 11.11% hydrogen while SO_2 contains 50% sulphur. These figures illustrate the law of:
(A) conservation of mass (B) constant proportions
(C) multiple proportions (D) reciprocal proportions

3. Irrespective of the source, pure sample of water always yields 88.89% mass of oxygen and 11.11% mass of hydrogen. This is explained by the law of:
(A) conservation of mass (B) constant composition
(C) multiple proportion (D) constant volume

MOLE CONCEPT

4. The best standard of atomic mass is:
(A) carbon-12 (B) oxygen-16 (C) hydrogen-1.008 (D) chlorine-35.5

5. The chemical formula of a particular compound represents:
(A) the size of its molecule
(B) the shape of its molecule
(C) the total number of atoms in a molecule
(D) the number of different types of atoms in a molecule

6. Two containers P and Q of equal volume (1 litre each) contain O_2 and SO_2 respectively at 300 K and 1 atmosphere. Then
(A) Number of molecules in P is less than that in Q
(B) Number of molecules in Q is less than that in P
(C) Number of molecules in P and Q are same
(D) Either (A) or (B)

7. 7.5 grams of a gas occupy 5.6 litres of volume at STP. The gas is
(A) NO (B) N_2O (C) CO (D) CO_2

8. The weight of a molecule of the compound $C_{60}H_{122}$ is
(A) 1.4×10^{-21} g (B) 1.09×10^{-21} g (C) 5.025×10^{23} g (D) 16.023×10^{23} g

9. 1.0 mole of CO_2 contains:
(A) 6.02×10^{23} atoms of C (B) 6.02×10^{23} atoms of O
(C) 18.1×10^{23} molecules of CO_2 (D) 3 g-atoms of CO_2

10. The number of atoms in 1.4 g nitrogen gas is:
(A) 6.02×10^{22}. (B) 3.01×10^{22} (C) 1.20×10^{23} (D) 6.02×10^{23}

11. Which of the following has the smallest number of molecules?
(A) 22.4×10^3 ml of CO_2 gas (B) 22 g of CO_2 gas
(C) 11.2 litre of CO_2 gas (D) 0.1 mole of CO_2 gas

12. The number of grams of H_2SO_4 present in 0.25 mole of H_2SO_4 is
(A) 0.245 (B) 2.45 (C) 24.5 (D) 49.0

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13. At NTP 1.0 g of hydrogen gas has volume in litre:
(A) 1.12 (B) 22.4 (C) 2.24 (D) 11.2

14. 19.7 kg of gold was recovered from a smuggler. The atoms of gold recovered are: (Au = 197)
(A) 10 (B) 6.02×10^{23} (C) 6.02×10^{24} (D) 6.02×10^{25}

15. The molecular mass of CO_2 is 44 amu and Avogadro's number is 6.02×10^{23}. Therefore, the mass of one molecule of CO_2 is:
(A) 7.31×10^{-23} (B) 3.65×10^{-23} (C) 1.01×10^{-23} (D) 2.01×10^{-23}

16. The number of moles of H_2 in 0.224 litre of hydrogen gas at NTP is:
(A) 1 (B) 0.1 (C) 0.01 (D) 0.001

17. Choose the wrong statement:-
(A) 1 Mole means 6.02×10^{23} particles
(B) Molar mass is mass of one molecule
(C) Molar mass is mass of one mole of a substance
(D) Molar mass is molecular mass expressed in grams

18. 3 mol of ammonia contains:
(A) 18 gm of hydrogen (B) 42 gm of nitrogen
(C) both (D) None

19. Total no. of protons in 36 ml of water at 4°C (where ρ of water = 1 g/ml) is
(A) 20 (B) 16 (C) 20 N_A (D) 16N_A

20. In which of the following pairs both members have same no. of atoms
(A) 1 gm O_2, 1 gm O_3 (B) 1 gm N_2, 2 gm N
(C) Both (D) None

21. The molecular wt. of green vitriol is M_0. The wt. of 10^{-3} N_A molecules of it is
(A) M_0 gm (B) M_0 mg (C) 10^3 M_0 gm (D) 10^{-3} M_0 mg

22. Which of the following has the highest mass
(A) 1g atom of C (B) ½ mole of CH_4 (C) 10ml of H_2O (D) 3.011×10^{23} atom of oxygen.

23. Which one of the following samples contains the largest number of atoms.
(A) 2.5 mole CH_4 (B) 10 mole He (C) 4 mole SO_2 (D) 1.8 mole S_8

24. The no. of atoms in 52 a.m.u. of He is
(A) 13×10^{23} (B) 1.3×10^{23} (C) 13 (D) 103

25. The no. of electrons in 2 gm ion of nitrate ion (NO_3^-) is
(A) 64 (B) 64N_A (C) 32 (D) 32N_A

26. The mass of carbon present in 0.5 moles of $K_4[Fe(CN)_6]$ is
(A) 1.8 g (B) 18 g (C) 3.6 g (D) 36 g

27. The largest no. of molecules is in
(A) 28 g of CO_2 (B) 46 g of C_2H_5OH (C) 36 g of H_2O (D) 54 g of N_2O_5

28. How many electrons are present in 180 gm. of water
(A) 1 N_A (B) 10 N_A (C) 18 N_A (D) 100 N_A

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29. How many molecules of H_2O are contained in 2.48 g of $Na_2S_2O_3.5H_2O$ (at.wt. of Na=23,S=32)
(A) 3×10^{20} (B) 3×10^{21} (C) 3×10^{22} (D) 3×10^{23}

30. The no. of silver atoms present in a 90% pure silver wire weighing 10 g. is (at.wt. of Ag=108)
(A) 8×10^{22} (B) 0.62×10^{23} (C) 5×10^{22} (D) 6.2×10^{29}

31. The number of molecules of water in 333 g of $Al_2(SO_4)_3.18H_2O$ is
(A) $18\times6.02\times10^{23}$ (B) $9\times6.02\times10^{23}$ (C) 18 (D) 36

32. The number of water molecules present in a drop of water weighing 0.018 g is
(A) 6.02×10^{26} (B) 6.02×10^{23} (C) 6.02×10^{20} (D) 6.02×10^{19}

33. If N_A is Avogadro's number, then the number of valence electrons in 4.2 g of nitride ion (N^{3-}) is (Given One atom of N has 5 valence electrons)
(A) 2.4 N_A (B) 4.2 N_A (C) 1.6 N_A (D) 3.2 N_A

34. A person adds 3.42 of sucrose ($C_{12}H_{22}O_{11}$) in his cup of tea to sweeten it. How many atoms of carbon does he add?
(A) 132.44×10^{21} atoms (B) 66.22×10^{21} atoms
(C) 0.1 atoms (D) 72.27×10^{21} atoms

35. The total number of protons in 8.4 g of $MgCO_3$ is ($N_A = 6.02\times10^{23}$) :
(A) 2.52×10^{22} (B) 2.52×10^{24} (C) 3.01×10^{24} (D) 3.01×10^{22}

36. 4.4 g of CO_2 and 2.24 litre of H_2 at NTP are mixed in a container. The total number of molecules present in the container will be
(A) 6.022×10^{23} (B) 1.2044×10^{23} (C) 2 mole (D) 6.023×10^{24}

37. Which sample contains the largest number of atoms:
(A) 1 mg of C_4H_{10} (B) 1 mg of N_2 (C) 1 mg of Na (D) 1 mL of water

38. The atomic weight of a triatomic gas is a. The correct formula for the number of moles of gas in its w gram is:
(A) $\frac{3w}{a}$ (B) $\frac{w}{3a}$ (C) 3wa (D) $\frac{a}{3w}$

39. Number of atoms in 558.5 g Fe (at.wt 55.85) is:
(A) Twice that in 60 g carbon (B) 6.023×10^{22}
(C) Half in 8g He (D) $558.5\times6.023\times10^{23}$

40. How many moles of magnesium phosphate, $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms?
(A) 0.02 (B) 3.125×10^{-2} (C) 1.25×10^{-2} (D) 2.5×10^{-2}

EMPIRICAL AND MOLECULAR FORMULA

41. The simplest formula of a compound containing 50% by mass of element X (at. wt. 10) and 50% by mass of element Y (at. wt. 20) is ;
(A) XY (B) X_2Y (C) XY_2 (D) X_2Y_3

42. The hydrated salt $Na_2SO_4\cdot10H_2O$ undergoes X% loss in weight on heating and becomes anhydrous. The value of X will be

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(A) 10 (B) 45 (C) 56 (D) 70

43. An oxide of iodine (I =127) contains 25.4 g of iodine and 8 g of oxygen. Its formula could be
(A) I_2O_3 (B) I_2O (C) I_2O_5 (D) I_2O_7

44. The chloride of a metal contains 71% chlorine by weight and the vapour density of it is 50. The atomic weight of the metal will be
(A) 29 (B) 58 (C) 35.5 (D) 71

STOICHIOMETRY

45. What quantity of limestone ($CaCO_3$) on heating will give 56 Kg of CaO?
(A) 1000 Kg (B) 44 Kg (C) 56 Kg (D) 100 Kg

46. 2 mol of H_2S and 11.2 L SO_2 at N.T.P. reacts to form x mol of sulphur; x is
$SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$
(A) 1.5 (B) 3 (C) 11.2 (D) 6

47. How many grams of phosphoric acid (H_3PO_4) would be needed to neutralise 100 g of magnesium hydroxide ($Mg(OH)_2$).
(A) 66.7 g (B) 252 (C) 112.6 g (D) 168 g

48. If two mole of methanol (CH_3OH) completely burns to carbon dioxide and water, the weight of water formed is about
(A) 22 g (B) 18 g (C) 36 g (D) 72 g

49. In an experiment, it is found that 2.0769 g of Pure X produces 3.6769 g of pure X_2O_5. The number of moles of X is
(A) 0.04 (B) 0.06 (C) 0.40 (D) 0.02

50. 2.7 g of Ag_2CO_3 on being heated strongly yields a residue weighing
(A) 2.11 g (B) 2.48 g (C) 2.32 g (D) 2.64 g

51. If 1 mole of ethanol (C_2H_5OH) completely burns to CO_2 and H_2O, the weight of CO_2 formed is about.
(A) 22 g (B) 45 g (C) 66 g (D) 88 g

52. The percent loss in weight after heating a pure sample of $KClO_3$ (molecular weight = 122.5) will be
(A) 12.25 (B) 24.50 (C) 39.18 (D) 49.0

53. Calculate the weight of iron which will be converted into its oxide by the action of 18g of steam on it. $\left(2Fe + 3H_2O \longrightarrow Fe_2O_3 + 3H_2\right)$.
(A) 37.3 gm (B) 3.73 gm (C) 56 gm (D) 5.6 gm

54. A 10.0 g sample of a mixture of calcium chloride and sodium chloride is treated with Na_2CO_3 to precipitate the calcium as calcium carbonate. This $CaCO_3$ is heated to convert all the calcium to CaO and the final mass of CaO is 1.62 gms. The % by mass of $CaCl_2$ in the original mixture is :
(A) 15.2% (B) 32.1% (C) 21.8% (D) 11.07%

55. If 0.5 mol of $BaCl_2$ is mixed with 0.2 mol of Na_3PO_4, the maximum number of mol of $Ba_3(PO_4)_2$ that can be formed is
(A) 0.7 (B) 0.5 (C) 0.2 (D) 0.1

56. 0.5 mole of H_2SO_4 is mixed with 0.2 mole of $Ca(OH)_2$. The maximum number of mole of $CaSO_4$ formed is
(A) 0.2 (B) 0.5 (C) 0.4 (D) 1.5

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57. For the reaction A + 2B $\longrightarrow$ C + 3D, 5 moles of A and 8 moles of B will produce
(A) 5 moles of C (B) 4 moles of C (C) 8 moles of C (D) None of these

58. 2.4 kg of carbon is made to react with 1.35 kg of aluminium to form Al_4C_3. The maximum amount in kg of aluminium carbide formed is
(A) 5.4 (B) 3.75 (C) 1.05 (D) 1.8

59. Consider the reaction 2A $\longrightarrow$ 2B, B $\longrightarrow$ 2C, 3C $\longrightarrow$ 4D. The no. of moles of D formed starting 4 moles of A, are
(A) 8 (B) 16 (C) 4 (D) 10.67

60. Vapour density of air is (considering air as 80% N_2 and 20% O_2)
(A) 0.001293 (B) 1.293 (C) 14.4 (D) 28.9

61. The density of chlorine relative to air as mentioned in above problem is
(A) 2.44 (B) 3 (C) 71 (D) 4

62. A gaseous oxide contains 30.4% of nitrogen, one molecule of which contains one nitrogen atom. The density of the oxide relative to oxygen gas is
(A) 0.9 (B) 1.44 (C) 1.50 (D) 3.0

CONCENTRATION TERMS

63. An aqueous solution of urea containing 18 g urea in 1500 cc of solution has a density of 1.052 g/cc. If the mol.wt. of urea is 60, then the molality of solution is
(A) 0.2 (B) 0.192 (C) 0.064 (D) 1.2

64. Molarity of 1g H_2SO_4 solution in 1 lit. water is nearly
(A) 0.1 (B) 0.20 (C) 0.05 (D) 0.01

65. 20 ml of 0.2 M $Al_2(SO_4)_3$ is mixed with 20 ml of 0.6 M $BaCl_2$. Concentration of Al^{3+} ion in the solution will be
(A) 0.2 M (B) 10.3 M (C) 0.1 M (D) 0.25 M

66. 50 ml of 0.01 M $FeSO_4$ will react with what volume of 0.01 M $KMnO_4$ solution in acid medium? (1 mole $KMnO_4$ requires 5 mole of $FeSO_4$ for complete reaction)
(A) 50 ml (B) 25 ml (C) 100 ml (D) 10 ml

67. The number of H^+ ions present in 100 ml of 0.001M H_2SO_4 solution will be
(A) 120.4×10^{19} (B) 1.20×10^{20} (C) 6.023×10^{20} (D) 6.023×10^{21}

68. 3.0 molal NaOH solution has a density of 1.11 g/ml. The molarity of the solution is
(A) 2.97 (B) 3.05 (C) 3.64 (D) 3.050

69. 250 ml of a sodium carbonate solution contains 2.65 grams of Na_2CO_3. If 10 ml of this solution is diluted to one litre, what is the concentration of the resultant solution? (mol wt. of Na_2CO_3 = 106)
(A) 0.1 M (B) 0.001M (C) 0.01 M (D) 10^{-4} M

70. The mole fraction of NaCl in a solution containing 1 mole of NaCl in 1000g of water is:
(A) 0.0177 (B) 0.001 (C) 0.5 (D) 1.5

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GET EQUIPPED TO JEE MAIN

1. One mole of potassium chlorate is thermally decomposed and excess of aluminium is burnt in the gaseous product. How many mole of aluminium oxide are formed:
(A) 1 (B) 1.5 (C) 2 (D) 3

2. The density of a 3.60M sulphuric acid solution that is 29% H_2SO_4 (molar mass $98\,g\,mol^{-1}$) by mass will be:
(A) 1.22 (B) 1.45 (C) 1.64 (D) 1.88

3. 10 moles N_2 and 15 moles of H_2 were allowed to react over a suitable catalyst. 10 moles of NH_3 were formed. The remaining moles of N_2 and H_2 respectively are:
(A) 5 moles, 0 mole (B) 0 moles, 5 mole
(C) 9 moles, 12 mole (D) 0 moles, 0 mole

4. Reaction is: $Fe_2(SO_4)_3 + BaCl_2 \rightarrow BaSO_4 + FeCl_3$
How many moles of $BaCl_2$ is needed to produce $1/2$ mole of $FeCl_3$?
(A) $\frac{5}{2}$ moles (B) $\frac{1}{2}$ mole (C) $\frac{3}{4}$ mole (D) 2 moles

5. How many gms of copper $(at.wt = 64)$ would be displaced from the copper sulphate solution by adding 27 gm of aluminium $(at.wt = 27)$
(A) 32 (B) 64 (C) 96 (D) 160

6. 5 moles of CH_4 is burned with 8 moles of O_2 than calculate mole of CO_2 formed and remaining moles of excess reagent
(A) 4,1 (B) 1,4 (C) 0,5 (D) 5,0

7. 2.5 moles of a hydrocarbon $C_{10}H_x$ requires 32.5 moles of O_2 for complete combustion. Calculate value of x?
(A) 24 (B) 32 (C) 12 (D) 22

8. Calcium carbonate reacts with aqueous HCl to give $CaCl_2$ according to the reaction, $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$. The mass of $CaCO_3$ required to react completely with 25mL of 0.75M HCl is
(A) 0.1 g (B) 0.84 g (C) 8.4 g (D) 0.94 g

9. 25.0 ml of HCl solution gave, on reaction with excess $AgNO_3$ solution 2.125g of AgCl. The molarity of HCl solution is
(A) 0.25 (B) 0.6 (C) 1.0 (D) 0.75

10. Element X reacts with oxygen to produce a pure sample of X_2O_3. In an experiment it is found that 1.00g of X produces 1.16g of X_2O_3. Calculate the atomic weight of X.
Given: atomic weight of oxygen, $16.0\,g\,mol^{-1}$.
(A) 67 (B) 100.2 (C) 125 (D) 150

11. If half mole of oxygen gas 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) 54 g (D) 18 g

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12. 8 g of sulphur is burnt to form SO_2 which is oxidised by Cl_2 water. The solution is treated with $BaCl_2$ solution. The amount of $BaSO_4$ precipitated is
(A) 1 mole (B) 0.5 mole (C) 0.24 mole (D) 0.25 mole

13. A mixture of KBr and NaBr weighing 0.560 gm was treated with aqueous Ag^+ and all the bromide ion was recovered as 0.970 gm of pure AgBr. The weight of KBr in the sample is
(A) 0.25 gm (B) 0.212 (C) 0.36 (D) 0.285

14. Maximum no. of hydrogen atoms are in:
(A) 16g of CH_4
(B) 31.2g of C_6H_4
(C) 34.2g of $C_{12}H_{22}O_{11}$
(D) 36g of $C_6H_{12}O_6$

15. A sample contains 200 atoms of hydrogen, 0.05 gm atom of nitrogen, 10^{-20} gm atom of oxygen. What is the approximate no. of total atoms
(A) 200 (B) 6223 (C) 3×10^{22} (D) none of these

16. The element A at wt.=75 and B at wt. =32 combine to form a compound X. If 3 mol of B combine with 2 mol of A to give 1 mol of X, the weight of 5 mol of X is
(A) 246 gm (B) 1230 amu (C) 1.23 kg (D) None of these

17. Which of the following has greatest no. of oxygen atoms
(A) 10 mole water
(B) 200gm of $C_{12}H_{22}O_{11}$
(C) 144 gm O_3
(D) 2.5 mole H_2SO_3

18. Which of the following substances contains the greatest mass of chlorine
(A) 5 gm Cl_2
(B) 60 gm $NaClO_3$
(C) 0.10 mole of KCl
(D) 0.5 mole of Cl_2

19. Which of the following samples contains the smallest no. of atoms?
(A) 1 g of CO_2 (g) (B) 1 g of C_8H_{18} (l) (C) 1 g of C_2H_6 (g) (D) 1 g of LiF (s)

20. The wt. of NO having the same no. of oxygen atom present in 9.2 gm of NO_2 is
(A) 9.2 gm (B) 6 gm (C) 12 gm (D) 24 gm

21. The no. of moles of carbon dioxide which contain 8g of oxygen is
(A) 0.50 mole (B) 0.20 mole (C) 0.40 moles (D) 0.25 moles

22. Which of the following weighs the least
(A) 0.2 g atom of N (at. wt. N=14)
(B) 3×10^{23} atoms of C (at. wt. C = 12)
(C) 1 mole atoms of S (at. wt. S=32)
(D) 7 g silver (at. wt. Ag=108)

23. Which one of the following statements is not correct?
(A) One gm atom of silver equals 108 gms
(B) One mole of CO_2 and NH_3 at NTP occupies same volume
(C) One mole Ag weighs more than one mole of Zn .
(D) One gm molecule of CO_2 is 44 times heavier than one molecule of CO_2

24. A mixture contains n moles of H_2 and 2n moles of CH_4.The ratio of no. of C:H atoms in the mixture is:
(A) 1/5 (B) 2/3 (C) 4/5 (D) 1/3

25. The charge on 1 gram ion of Al^{3+} is (e represents magnitude of charge on 1 electron)
(A) 1/27 N_Ae coulomb
(B) 1/3 N_Ae coulomb
(C) 1/9 N_Ae coulomb
(D) 3 N_Ae coulomb

26. Cortisone is a molecular substance containing 21 atoms of carbon per molecule. The weight percentage of carbon in cortisone is 69.98%. What is the molecular weight of cortisone?
(A) 176.5 (B) 252.2 (C) 287.6 (D) 360.1

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27. A partially dried clay mineral contains 8% water. The original sample contained 12% water and 45% silica. % of Silica in the partially dried sample is nearly
(A) 50% (B) 49% (C) 55% (D) 47%

28. A compound contains 28% nitrogen and 72% metal by mass 3 atoms of the metal combine with 2 atoms of nitrogen. The atomic mass of metal is
(A) 36 (B) 20 (C) 24 (D) 36

29. An organic compound on analysis was found to contain 0.014% of nitrogen. If its molecule contains two N atoms, then the molecular mass of the compound
(A) 200 (B) 2000 (C) 20,000 (D) 200000

30. An element, X, have three isotopes X^{20}, X^{21} and X^{22}. The percentage abundance of X^{20} is 90% and its average atomic mass of the element is 20.11. The percentage abundance of X^{21} should be
(A) 9% (B) 8% (C) 10% (D) 0%

31. The O^{18}/O^{16} ratio in some meteorites is greater than that used to calculate the average atomic mass of oxygen on earth. The average mass of an atom of oxygen in these meteorites is ..... that of a terrestrial oxygen atom.
(A) equal to (B) greater than (C) less than (D) None of these

32. 6.023×10^{23} molecules of $Ca(OH)_2$ react with 3.01×10^{22} molecules of HCl, number of moles of $CaCl_2$ obtained are
(A) 0.05 (B) 0.10 (C) 0.025 (D) 3.01

33. A copper sulphate solution contains 1.595% of $CuSO_4$ by weight. Its density is 1.2 g / ml, Its molarity will be
(A) 0.12 (B) 0.06 (C) 1.20 (D) 1.595

34. Which of the following samples contains 2.0×10^{23} atoms?
(A) 8.0 g O_2 (B) 3.0 g Be (C) 8.0 g C (D) 19.0 g F_2

35. Simplest formulae of a compound containing 20% of element X (atomic weight 10) and 80% of element Y (atomic weight 20) is
(A) XY (B) X_2Y (C) XY_2 (D) X_2Y_3

36. At room temperature and pressure two flask of equal volumes are filled with H_2 and SO_2 respectively. Particles which are equal in number in two flasks are
(A) Atoms (B) Electrons (C) Molecules (D) Neutrons

37. Chlorophyll contains 2.68% of magnesium by mass. Calculate the number of magnesium atoms in 3.00 gms of chlorophyll.
(A) 2.01×10^{21} atoms (B) 6.023×10^{23} atoms
(C) 1.7×10^{20} atoms (D) 2.8×10^{22} atoms

38. What is the total number of atoms present in 25.0 mg of camphor $C_{10}H_{16}O$?
(A) 9.89×10^{19} (B) 6.02×10^{20} (C) 9.89×10^{20} (D) 2.67×10^{21}

39. The number of electron in the telluride ion. $_{52}Te^{2-}$ is
(A) 50 (B) 52 (C) 53 (D) 54

40. An ore contains 1.34% of the mineral argentite, Ag_2S, by weight. How many grams of this ore would have to be processed in order to obtain 1.00 g of pure solid silver, Ag?
(A) 74.6 g (B) 85.7 g (C) 134.0 g (D) 171.4 g

41. Hydrogen evolved at NTP on complete reaction of 27 gm of Al with excess of aq NaOH would be (Chemical reaction: $2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$)
(A) 22.4 lit (B) 44.8 lit (C) 67.2 lit (D) 33.6 lit

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FOUNDATION BUILDERS (SUBJECTIVE)

MOLE CONCEPT

1. The atomic wt. of two elements A and B are 20 & 40 resp. If X g of A contains Y atoms, how many atoms are present in 2X g of B.
2. Calculate the total number of electrons present in 1.6g of CH_4.
3. Calculate the total number of electrons present in 18 ml of water
4. Calculate the number of electrons, protons and neutrons in 1 mole of O^{2-} ions
5. Mass of one atom of 'X' is 6.642×10^{-23} g. What is its atomic mass?
6. Mass of one atom of an element A is 3.9854×10^{-23} g. How many atoms are contained in 1 g of the element of A?
7. From 200mg of CO_2, 10^{21} molecules are removed. How many moles of CO_2 are left?
8. Find the charge in coulomb on 1 g ion of N^{3-}
9. Calculate the ratio of no. of oxygen atoms present in 3.2 mg of SO_2 to the no. of S atoms present in 5 millimoles of $Na_2S_2O_3.5H_2O$
10. Calculate the total no. of oxygen and nitrogen atoms present in a mixture containing 8.2 gm of calcium 10 millimoles of sodium nitrate and $N_A/6$ molecules of NO_2.
11. How many year it would take to spend Avogadro number of rupees at the rate of 10 Lack rupees per second?
12. One atom of an element X weighs 6.644×10^{-23} g. Calculate the number of gram atoms in 40 kg of it.
13. A dot at the end of this sentence has a mass of about 1microgram.Assuming that the black stuff is carbon; calculate the approximate number of atoms of carbon needed to make such a dot.
14. How many iron atoms are present in a stainless steel ball–bearing having a radius 0.1 inch? The stainless steel contains 85.6% Fe by weight and has a density of 7.75g/cc.
15. A sample of potato starch was ground in a ball mill to give a starch like molecule of lower molecular weight. The product analyzed 0.086% phosphorus. If each molecule is assumed to contain one atom of phosphorus, what is the molecular weight of material?
16. Calculate volume of 3.4 g NH_3 at STP.
17. Oxygen is present in a 1 litre flask at a pressure of 760 mm of Hg. Calculate the number of oxygen molecules in the flask at 0°C.
18. 600 ml of a mixture of O_3 and O_2 weighs 1 g at NTP. Calculate the volume of ozone in the mixture.

EMPERICAL AND MOLECULAR FORMULA

19. Potassium manganate is a dark green crystalline substance whose composition is 40.2% K, 26.8% Mn and rest P. What is empirical formula?
20. A drug marijuana owes its activity to tetrahydrocannabinol, which contains 70% as many carbon atoms as hydrogen atoms and 15 times as many hydrogen atoms as oxygen atoms. The number of mole in a gram of tetrahydrocannabinol is 0.00318. Determine the molecular formula.

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21. A given sample of Xenon fluoride contains molecules of a single type XeF_n where n is a whole number. If 9.03×10^{20} molecules has a mass of 0.311 g then find the value of n.

22. A poisonous compound cadaverine has $58.77\%C, 13.81\%H$, and $27.42\%N$. Its molar mass is $102\,g/mol$. Determine its molecular formula.

23. What is the empirical formula of a compound $0.2801\,gm$ of which gave on complete combustion $0.9482\,gm$ of carbon dioxide and $0.1939\,gm$ of water.

DENSITY AND VAPOUR DENSITY

24. An alloy has Fe, Co and Mo equal to 71%, 12% and 17% respectively. How many cobalt atoms are there in a cylinder of radius 2.5 cm and a length of 10 cm? The density of alloy is 8.20 g/mL. Atomic weight of cobalt =58.9.

25. The vapour density (hydrogen = 1) of a mixture consisting of NO_2 and N_2O_4 is 38.3 at 26.7°C. Calculate the number of moles of NO_2 in 100 g of the mixture.

26. An aqueous solution of ethanol has density 1.025 g/mL and it is 8.0 M. Determine molality m of this solution.

PERCENTAGE COMPOSITION AND GRAVIMETRIC ANALYSIS

27. Determine the percentage composition 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 = 0.124 g.

28. LSD is a complex compound whose mass is made up of 74.27% carbon, 7.79% hydrogen, 12.99% nitrogen and 4.95% oxygen. What percent of the atoms in LSD are carbon atoms?

29. In a process for producing acetic acid, oxygen gas is bubbled into acetaldehyde, CH_3CHO, under pressure at 60°C in presence of suitable catalyst.
$2CH_3CHO(l) + O_2(g) \longrightarrow 2CH_3COOH(l)$
In a laboratory test of this reaction, 20 g CH_3CHO and 10 g O_2 were put into a reaction vessel.
(A) How many gram of acetic acid can be produced by these amounts of reactants?
(B) How many gram of the excess reactant remain after the reaction is complete?
(C) If actual yield is 23.8 g, calculate percentage yield.

30.

Reaction	Yield of reaction
(i) $2A + B \longrightarrow 3C + D$	20%
(ii) $2C + E \longrightarrow 4F$	40%
(iii) $7H + 3F \longrightarrow 8G$	50%

where B, E and H given in excess
Starting with 10 moles of A. Moles of G formed are

31. A 5.0 g sample of a natural gas consisting of CH_4, C_2H_4 was burnt in excess of oxygen yielding $14.5\,g\,CO_2$ and some H_2O as product. What is weight percentage of CH_4 and C_2H_4 in mixture.

STOICHIOMETRY

32. 27.6 g of 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 moles of the product.

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33. Find the mass of $Cu(NO_3)_2.3H_2O$ produced by dissolving 10g of copper in nitric acid and then evaporating the solution.

34. What weight of AgCl will be precipitated when solution containing 4.77 g of NaCl is added to a solution of 5.77 g of $AgNO_3$? (Na = 23, Cl = 35.5, Ag = 108, N = 14, O =16)

35. 1.84 g of a mixture of $CaCO_3$ and $MgCO_3$ was heated to a constant weight. The constant weight of the residue was found to be 0.96g.Calculate % composition of the mixture.

36. Potassium chlorate ($KClO_4$) is made in the following sequence of reactions:

$$Cl_2(g) + KOH(\text{cold \& diluted}) \longrightarrow KCl + KClO + H_2O$$

$$KClO \longrightarrow KCl + KClO_3$$

$$KClO_3 \longrightarrow KClO_4 + KCl$$

What mass of Cl_2 is needed to produce 1.385 kg of $KClO_4$?

37. For the above set of reactions what will be amount of KCl produced when 142 g of Cl_2 is taken?

38. 1 gm sample of $KClO_3$ was heated under such conditions that a part of it decomposed according to the equation

(i) $2KClO_3 \longrightarrow 2KCl + 3O_2$ and the remaining underwent change according to the equation

(ii) $4KClO_3 \rightarrow 3KClO_4 + KCl$

If the amount of O_2 evolved was 146.8 ml at NTP, calculate percentage by weight of $KClO_4$ in the residue.

39. Based on the following information, determine value of x and y:

$$(CH_3)_x AlCl_y \longrightarrow xCH_4(g) + yCl^- + Al^{3+} \xrightarrow{AgNO_3} AgCl(s)$$

0.643 g 0.222 g 0.996g

40. How much quantity of zinc will have to be reacted with excess of dilute HCl solution to produce sufficient hydrogen gas for completely reacting with the oxygen obtained by decomposing 6.125 g of $KClO_3$?

41.

	A	+	2B	$\longrightarrow$	7C
(t=0)	4/3 moles		1 mol		

(A) What is Limiting reagent?
(B) Which is in excess?
(C) Formed moles of C?

42. By the reaction of carbon and oxygen, a mixture of CO and CO_2 is obtained. What is the composition of the mixture obtained in moles when 20 grams of O_2 reacts with 12 grams of carbon ?

CONCENTRATION TERMS

43. What is the strength in g/litre of a solution of H_2SO_4, 12 cc of which neutralizes 15 cc of M/10 NaOH?

44. 100 ml solution of KOH contains 10 milli-moles of KOH. Calculate its strength in molarity and gram/litre.

45. Calculate the number of sulphate ions in 100 ml of 0.001 M H_2SO_4 solution.

46. What weight of $CuSO_4.5H_2O$ must be taken to make 0.5 lt. of 0.01 M Cu^{2+} ions.

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47. To 50 ml of 0.5 M H_2SO_4, 75 ml of 0.25 M H_2SO_4 is added. What is the concentration of the final solution?

48. 3 g of a salt of molecular weight 30 is dissolved in 250 g of water. Calculate the molality of the solution.

49. Mole fraction of I_2 in C_6H_6 is 0.2. Calculate molality of I_2 in C_6H_6.

50. The density of a 10% by mass KCl solution in water is 1.06 g/ml. Calculate molarity of KCl solution.

51. 105 ml of pure water (4°C) is saturated with NH_3 gas producing a solution of density 0.9 g/ml. If this solution contains 30% of NH_3 by wt. Calculate the volume of the solution.

52. An aqueous solution of ethanol has density 1.025 g/mL and it is 8.0 M. Determine molality of this solution.

MISCELLANEOUS PROBLEMS

53. If 5 moles each of SO_2 and O_2 at STP reacts and form SO_3 then calculate number of moles of SO_3 gas produced at STP,

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

54. Calculate the no. of moles of Fe_2O_3 produced at STP when 600gm of FeS_2 reacts with 800 gm of O_2.

$$4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$$

55. Calculate the weight of NH_3 required to neutralize 146 gm of HCl

$$NH_3 + HCl \longrightarrow NH_4Cl$$

56. 6.00 gm of H_2 reacts with 29.00 gm of O_2 to yield H_2O

(i) which is limiting reagent

(ii) Calculate the maximum amount of H_2O that can be formed

(iii) Calculate the amount of reactants which remains unreacted

$$2H_2 + O_2 \longrightarrow 2H_2O$$

57. What mass of $NaCl$ would contain the same total number of ions as 245 g of $MgCl_2$?

58. A mixture of pure $AgCl$ and pure $AgBr$ is found to contain 60.94% Ag by mass. What are mass percentages of Cl and Br in the mixture $(Ag = 108, Cl = 35.5, Br = 80)$

59. How much gas (in litres) will be produced at $0^\circ C$ and $760\,mm$ of pressure when $10\,g$ of oxalic acid ($H_2C_2O_4$) was heated with concentrated sulphuric acid?

60. 0.607 g of a silver salt (Ag_3A type) of a tribasic organic acid (H_3A type) was quantitatively reduced to $0.370\,g$ of pure silver. Calculate the molecular weight of the acid. $(Ag = 108)$.

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GET EQUIPPED TO JEE ADVANCED

ONLY ONE OPTION IS CORRECT

1. N_2 and H_2 are mixed in 14:3 mass ratio. After certain time ammonia was found to be 40% by mol. The mole fraction of N_2 at that time in the mixture of N_2, H_2 and NH_3 is
(A) 0.15 (B) 0.3 (C) 0.45 (D) none of these

2. Two flasks of equal volumes are evacuated, then one is filled with gas A and other with gas B at the same temperature and pressure. The weight of B was found to be 0.80 gm while the weight of gas A is found to be 1.40 gm. What is the weight of one molecule of B in compared to one molecule of A
(A) 1.40 times as heavy as A (B) 0.40 times as heavy as A
(C) 0.57 times as heavy as A (D) 0.80 times as heavy as A

3. On reduction with hydrogen, 3.6 g of an oxide of metal left 3.2 g of the metal. If the atomic weight of the metal is 64, the simplest formula of the oxide would be
(A) M_2O_3 (B) M_2O (C) MO (D) MO_2

4. A certain compound has the molecular formula X_4O_6. if 10 g of X_4O_6 has 5.72 g of X, atomic mass of X is :
(A) 32 amu (B) 37 amu (C) 42amu (D) 98 amu

5. If 224 ml of a triatomic gas has a mass of 1 g at 273 K and 1 atm pressure, then the mass of one atom is
(A) 55.3×10^{-23} g (B) 0.553×10^{-23} g (C) 5.53×10^{-23} g (D) 553×10^{-23} g

6. The weight of 350mL of a diatomic gas at 0^0C and 2 atm pressure is 1g. The wt of one atom is
(A)16 N_A (B) 32 N_A (C) $\frac{16}{N_A}$ (D) $\frac{32}{N_A}$

7. 25.4 g of iodine and 14.2g of chlorine are made to react completely to yield a mixture of ICl and ICl_3. Calcualte the ratio of moles of ICl and ICl_3.
(A) 1:1 (B) 1:2 (C) 1:3 (D) 2:3

8. A mixture contains $FeSO_4$ and $Fe_2(SO_4)_3$. If both $FeSO_4$ and $Fe_2(SO_4)_3$ provide equal number of sulphate ions then, the ratio of Fe^{2+} and Fe^{3+} ions in mixture is
(A) 1 : 2 (B) 2 :3 (C) 2 : 1 (D) 3 : 2

9. In what volume ratio a 0.36 M HNO_3 solution should be mixed with another 0.15 M HNO_3 solution to obtain a 0.24 M HNO_3 solution?
(A) 4 : 3 (B) 2 : 3 (C) 4 : 9 (D) 3 : 4

10. One atom of an element weighs 3.98×10^{-23}g. Its atomic mass is
(A) 18 (B) 29.9 (C) 24 (D) 108

11. Weight ratio of Fe:C in $Fe_2[Fe(CN)_6]$ is:
(A) 3/7 (B) 7/5 (C) 7/3 (D) 5/7

12. Which of the following has the highest mass:
(A) 12g of C atom (B)13 g of H atom (C)9 moles of NH_3 (D)80g molecule of H_2SO_4

13. Ratio of carbon to hydrogen atom is maximum in:
(A) 16 g CH_4 (B) 31.2 g C_6H_4 (C) 34.2 g $C_{12}H_{22}O_{11}$ (D)36 g $C_6H_{12}O_6$

14. How many grams are contained in 1 g atom of Nitrogen
(A) 14 g (B) 7 g (C) 1 g (D) Data Insufficient

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15. The volume of 3M HCl required to completely react with 1.431g of sodium carbonate
(A) 10 ml (B) 9 ml (C) 8 ml (D) 4.5 ml

16. In which of the following pairs do 1 g of each have an equal number of molecules?
(A) N_2O and CO (B) N_2 and C_3O_2 (C) N_2 and CO (D) NO_2 and CO_2

17. How many spherical colloidal oil particles $20\overset{0}{A}$ in radius can be made from a spherical oil drop whose radius is 2 microns?
(A) 10^9 (B) 10^6 (C) 10^4 (D) 10^2

18. A 10 g sample of $KClO_3$, gave on complete decomposition, 2.24 L of oxygen at NTP. What is the percentage purity of the sample of potassium chlorate?
(A) 61.2 (B) 81.6 (C) 96.6 (D) 24.6

19. A 0.65 M $BaCl_2$ solution is prepared by dissolving pure solid $BaCl_2.2H_2O$ in water. Determine the mass of hydrated salt dissolved per milliliter of solution and mass of anhydrous $BaCl_2$ present per milliliter of solution. Molar masses are : Ba = 137, Cl = 35.5.
(A) 0.158 g, 0.135 g (B) 0.226 g, 0.135 g (C) 0.248 g, 0.163 g (D) 1.1 g, 2.2 g

20. What volume of a 1.36 M HCl solution should be added to a 200 mL 2.4 M HCl solution and finally diluted to 500 mL so that molarity of final HCl solution becomes 1.24 M.
(A) 29.2 mL (B) 102.94 mL (C) 46.34 mL (D) 9.4 Ml

21. Potassium salt of benzoic acid (C_6H_5COOK) can be made by the action of potassium permanganate on toluene as follows:

$$C_6H_5CH_3 + KMnO_4 \longrightarrow C_6H_5COOK + MnO_2 + KOH + H_2O$$

If the yield of potassium benzonate can't realistically be expected to be more than 71%, what is the minimum number of grams of toluene needed to achieve this yield while producing 11.5 g of C_6H_5COOK?
(A) 6.23 (B) 9.3 (C) 4.23 (D) 5.63

22. A mixture of $CuSO_4.5H_2O$ and $MgSO_4.7H_2O$ is heated until all the water is driven-off. If 5.0 gm of a mixture gives 3g of anhydrous salts, what is the percentage by mass of $CuSO_4.5H_2O$ in the original mixture?
(A) 44% (B) 64% (C) 74% (D) 94%

23. Aspirin $C_9H_8O_4$, is prepared by heating salicylic acid, $C_7H_6O_3$ with acetic anhydride, $C_4H_6O_3$. The other product is acetic acid, $C_2H_4O_2$, $C_7H_6O_3 + C_4H_6O_3 \longrightarrow C_9H_8O_4 + C_2H_4O_2$
when 2.00 g of salicylic acid is heated with 4.00 g of acetic anhydride? If the actual yield of aspirin is 2.1 g, what is the percentage yield?
(A) 80.7% (B) 40.7% (C) 25.2 % (D) 43.9%

24. An element X forms an iodide XI_3 and a chloride XCl_3. The iodide is quantitatively converted to the chloride when it is heated in a stream of chlorine

$$2XI_3 + 3Cl_2 \longrightarrow 2XCl_3 + 3I_2$$

If 0.5000 g of XI_3 is treated, 0.2360 g of XCl_3 is obtained. Calculate the atomic weight of the element X.
(A) 246 (B) 139 (C) 180 (D) 196

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25. A solution of palmitic acid in benzene contains 4.24 g of acid per litre. When this solution is dropped on a surface, benzene gets evaporated and palmitic acid forms a unimolecular film on the surface. If we wish to cover an area of $500cm^2$ with unimolecular film, what volume of solution should be used? The area covered by one palmitic acid molecule may be taken as $0.21nm^2$.
Mol. Wt. of palmitic acid = 256.
(A) 4.38×10^{-5} (B) 2.4×10^{-5} (C) 4×10^{-41} (D) 5.6×10^{5}

26. 6.0 g of a sample containing $CuCl_2$ and $CuBr_2$ is dissolved in 100 mL water. A 10 mL portion of this solution on treatment with $AgNO_3$ solution results in complete precipitation of Cl^- and Br^- giving 0.9065 gram of precipitate. The precipitate thus obtained was shaken with dilute solution of NaBr where all AgCl gets converted into AgBr. Mass of the new precipitate was found to be 1.005 g. Determine % mass of $CuCl_2$ and $CuBr_2$ in the original sample.
(A) 25 %, 58% (B) 50%, 50% (C) 75%, 25% (D) 20%, 80%

27. An element (X) reacts with hydrogen leading to formation of a class of compounds that is analogous to hydrocarbons. 5.00 g of X forms 5.625 g of a mixture of two compounds of $X(XH_4 \text{ and } X_2H_6)$ in the molar ratio of 2:1. Determine the molar mass of X.
(A) 28 (B) 58 (C) 72 (D) 83

28. A 2.00 g portion of a sample containing NaBr and Na_2SO_4 was dissolved and diluted to 250 mL. One fifth aliquot portions were titrated by silver nitrate, an average of 42.5 mL solution being required for the aliquot portion. In standardization 1.00 mL $AgNO_3$ is found to be equimolar to 0.0125 g KBr. Calculate percentage of Br in sample.
(A) 42% (B) 52% (C) 33% (D) 12%

29. The molecular mass of an organic acid was determined by the study of its barium salt. 4.290 g of salt was quantitatively converted to free acid by the reaction with 21.64 mL of $0.477\,M\,H_2SO_4$. The barium salt was found to have two mole of water of hydration per Ba^{2+} ion and acid is mono basic. What is molecular weight of anhydrous acid?
(A) 122 (B) 142 (C) 108 (D) 110

30. What volume of 0.010 M $NaOH(aq)$ is required to react completely with 30 g of an aqueous acetic acid solution in which mole fraction of acetic acid is 0.15?
(A) 108.55 lt (B) 18.55 lt (C) 34.66 lt (D) 42 lt

31. A mixture of ethane (C_2H_6) and ethene (C_2H_4) occupies 40 litre at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of O_2 to produce CO_2 and H_2O. Assuming ideal gas behavior, calculate the mole fraction of C_2H_4 and C_2H_6 in the mixture.
(A) 0.34, 0.66 (B) 0.66, 0.34 (C) 0.50, 0.50 (D) 0.20, 0.80

32. A crystalline hydrated salt on being rendered anhydrous, looses 45.6% of its weight. The percentage composition of anhydrous salt is: Al = 10.5% , K = 15.1% , S = 24.8% and O = 49.6%. The empirical formula of the crystalline salt.
(A) $KAlS_2O_8.12H_2O$ (B) $K_2Al_2S_2O_8.12H_2O$
(C) $KAl_2S_2O_8.12H_2O$ (D) None of these

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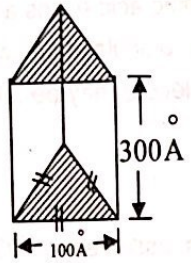
33. A crystalline polymer molecule is uniform prismatic in shape with dimensions as shown in below,



If density of this polymer is 1.2 g/cm^3, the molar mass is.

(A) 1000 (B) 939×10^3 (C) 939 (D) 2300×10^3

MORE THAN ONE CHOICE

1. The density of 3M sodium thiosulphate $(Na_2S_2O_3)$ is $1.25\,g\,mL^{-1}$. Identify the correct statements among the following:
(A) % by weight of sodium thiosulphate is 37.92
(B) The mole fraction of sodium thisoulphate is 0.065
(C) The molarity of Na^+ is 2.53 and $S_2O_3^{2-}$ is 1.25.
(D) The molality of Na^+ is 7.732 and $S_2O_3^{2-}$ is 3.866

2. The density of air is $0.001293\,g/cm^3$ at STP. Identify which of the following statement is correct.
(A) Vapour density is 14.48
(B) Molecular weight is 28.96
(C) Vapour density is $0.001293\,g/cm^3$
(D) Vapour density and molecular weight cannot be determine

3. Which of the following has same mass
(A) 1.0 moles of O_2
(B) 3.011×10^{23} molecules of SO_2
(C) 0.5 moles of CO_2
(D) 1 g atom of sulphur

4. 100 mL of 0.06 M $Ca(NO_3)_2$ is added to 50 mL of 0.06 M $Na_2C_2O_4$. After the reaction is complete.
(A) 0.003 moles of calcium oxalate will get precipitated
(B) 0.003 M of excess of Ca^{2+} will remain in excess
(C) $Na_2C_2O_4$ is limiting reagent.
(D) $Ca(NO_3)_2$ is excess reagent.

5. A sample of mixture of $CaCl_2$ and NaCl weighing 4.44 gm was treated to precipitate all the Ca as $CaCO_3$, which was then heated and quantitatively converted to 1.12g of CaO.
(At. Wt. Ca = 40, Na = 23, Cl = 35.5)
(A) Mixture contains 50% NaCl
(B) Mixture contains 60% $CaCl_2$
(C) Mass of $CaCl_2$ is 2.22 gm
(D) Mass of $CaCl_2$ is 1.11 gm

6. 1 M 100 ml NaCl is mixed with 3 M 100 ml HCl solution and 1 M 200 ml $CaCl_2$ solution.
(A) The ratio of concentration of cation and anion = 3/4
(B) The ratio of concentration of cation and anion = 2
(C) $[Cl^-] = 2M$
(D) $[Cl^-] = 3/2\,M$

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7. Number of hydrogen atoms are equal in
(A) 16 gm CH_4 (B) 52 gm of C_6H_6 (C) 34.2 gm $C_{12}H_{22}O_{11}$ (D) 36 gm water

8. 3 mole of ammonia contains
(A) 9 gm hydrogen
(B) 42 gm nitrogen
(C) Total 18.06×10^{23} molecules
(D) Total 7.226×10^{24} atoms

9. 1g molecule of V_2O_5 contains:
(A) 5 mole of oxygen atom
(B) 2 mole of V atom
(C) 1mole of oxygen atom
(D) 2.5 mole of oxygen atom

10. Which of the following quantities are independent of temperature
(A) Molarity (B) mole fraction (C) molality (D) % (w/v)

11. Which of following will be present in the solution formed when 50mL of 0.1M HCl is mixed with 50mL of 0.1M NaOH?
(A) 4.5 m mol of H^+ (B) 0.05 m mol of OH^- (C) 0.05M NaCl (D) 10^{-7} M of H^+ ion

12. Which of the following expressions is correct (n = no. of moles of the gas, N_A = Avogadro constant, m = mass of molecule of the gas, N = no. of molecules of the gas, M = Molar Mass)
(A) $n = mN_A$ (B) $m = M/N_A$ (C) $N = nN_A$ (D) $m = mn/N_A$

13. Among the following, which solutions contain equal numbers of millimoles?
(A) 100 mL of 0.05 M H_2SO_4
(B) 200 mL of 0.02 M NaOH
(C) 100 mL of 0.10 M $Na_2C_2O_4$
(D) 200 mL of 0.025 M KOH

14. 11.2 L of gas at NTP weighs 14.0 g. The gas could be:
(A) N_2O (B) NO_2 (C) N_2 (D) CO

MATCH THE FOLLOWING

1. Hexachlorophere, $C_{13}H_6Cl_6O_2$ (M wt = 407) is a germicide is soap & helps to clear germs. Match the two columns regarding composition of the germicide.

Column I		Column II	
(I)	wt % of C	(A)	1.47%
(II)	wt % of H	(C)	1: 35.5
(III)	ratio of wt% of H: Cl	(E)	6.5 : 1
(IV)	ratio of mol of C:O	(P)	38.33%

2.

	Column – I		Column – II
(a)	Vapour density of SO_2 with respect to O_2	(P)	22
(b)	Specific gravity of the solid with mass 10 gm and volume 5 cc	(Q)	32
(c)	Molar mass of the compound having V.D. 16	(R)	9
(d)	Number of atoms in 132 amu CO_2	(S)	2

3.

	Column – I		Column – II
(a)	100 ml of 0.2 M $AlCl_3$ solution + 400 ml of 0.1 M HCl solution	(P)	concentration of cation = 0.12 M
(b)	50 ml of 0.4 M KCl + 50 ml H_2O	(Q)	$[SO_4^{2-}] = 0.06M$
(c)	30 ml of 0.2 M K_2SO_4 + 70 ml H_2O	(R)	$[SO_4^{2-}] = 2.5M$
(d)	200 ml 24.5% (w/v) H_2SO_4	(S)	$[Cl^-] = 0.2M$

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4.

Column-I		Column-II	
(A)	$0.5\,\text{mol of } SO_2(g)$	(p)	occupy 11.2L at NTP
(B)	$1\,\text{g of } H_2(g)$	(q)	weights $= 24\,g$
(C)	$0.5\,\text{mole } O_3(g)$	(r)	total no. of atoms $= 1.5 \times N_A$
(D)	$1\,\text{g molecule of } O_2(g)$	(s)	weight 32 gm

COMPREHENSIVE TYPE

PASSAGE-1

The terms mole first used by Ostwald in 1896 refers to the ratio of molecular weight of molecule to mass of one molecule of substance in gm. Also, 1 mole of gaseous compound occupies 22.4 litre at NTP and contains 6.022×10^{23} molecules of gas.

1. Weight of 1 atom of hydrogen is:
(A) 1.66×10^{-24} amu (B) 3.32×10^{-24} g (C) 1.66×10^{-24} g (D) 3.32×10^{-24} amu

2. The amount of sulphur required to produce 100 mole of H_2SO_4 is :
(A) 3.2×10^3 g (B) 32.65 g (C) 32 g (D) 3.2 g

3. A substance contains 3.4% sulphur. If it contains two atoms of sulphur per molecule the molecular weight of substance will be:
(A) 941 (B) 1882 (C) 470.5 (D) 1411.5

4. The volume of air at NTP required for burning 12 g carbon completely is: (Assuming air contains 20% oxygen).
(A) 22.4 litre (B) 112 litre (C) 44.8 litre (D) 50 litre

PASSAGE-2

The concentration of solutions can be expressed in number of ways such as Molarity, Molality, Mole fraction, % weight, % by volume % by strength and many others. All these are inter-convertible if certain data like density of solution, molecular mass of solute and solvent are known. Also, addition of water to a solution changes all these terms, though a change in temperature does not change molality, mole fraction and % by weight terms.

1. A 6.90 M KOH solution in water has 30% by weight of KOH. The density of KOH solution is:
(A) 1.288 g/mL (B) 12.88 g/mL (C) 0.1288 g/ml (D) None of these

2. Two litres of NH_3 at 30° C and 0.20 atm is neutralized by 134 mL of acid H_2SO_4. The molarity of H_2SO_4 is:
(A) 0.12 (B) 0.24 (C) 0.06 (D) 0.03

3. The volume of water required to make 0.20M solution from 1600 ml of 0.2050 M solution
(A) 40 ml (B) 80 ml (C) 120 ml (D) 180 ml

4. What volume of 0.2 M H_2SO_4 is required to produce 34.0 g of H_2S by the reaction?
$$8KI + 5H_2SO_4 \longrightarrow 4K_2SO_4 + 4I_2 + H_2S + 4H_2O$$
(A) 25 litre (B) 50 litre (C) 75 litre (D) 100 litre

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PASSAGE-3

The term mole was introduced by Ostwald in 1896. In Latin word 'moles' meaning heap or pile. A mole is defined as the number of atoms in 12.00 g of carbon – 12. The number of atoms in 12 g of carbon -12 has been found experimentally to be 6.022×10^{23}. This number is also known as Avogadro's number named in honour of Amedeo Avogadro (1776 - 1856).

The mass of one mole atoms of any element is exactly equal to the atomic mass in gram (gram atomic mass) of that element. One mole of a gas occupies 22.4 litre at S.T.P. Atomic mass unit is the unit of atomic mass.

$1\,amu = 1.66\times10^{-24}\,g$

1. Mass of one molecule of water is approximately:
   (A) 1 g (B) 0.5 g (C) 1.66×10^{-24} g (D) 3×10^{-23} g

2. x L N_2 gas at N.T.P. contains 3×10^{23} molecules. The number of molecules in x L ozone at N.T.P. will be:
   (A) 3×10^{23} (B) 4×10^{23} (C) 6.023×10^{23} (D) 3×10^{24}

3. If Avogadro's number is $1\times10^{23}\,mol^{-1}$ then the mass of one atom of oxygen would be:
   (A) $\frac{16}{6.02}$ amu (B) 16×6.02 amu (C) 16 amu (D) 16×10^{-23} amu

4. The maximum number of atoms presents are in:
   (A) 4 g He (B) 4 g O_2 (C) 4 g O_3 (D) 4 g H_2O_2

PASSAGE-4

The concentration of solutions can be expressed in number of ways such that Normality, Molarity, Molality, Mole fractions, Strength , % by weight , % by volume and % by strength. The molarity of ionic compound is usually expressed as formality because we use formula weight of ionic compound. Addition of water to a solution changes all these terms, however increase in temperature does not change molality, mole fraction and % by weight terms.

1. The weight of AgCl precipitated by adding 5.77 g $AgNO_3$ to 4.77 g NaCl in a solution is:
   (A) 4.88 g (B) 5.77 g (C) 4.77 g (D) None of these

2. The weight of H_2SO_4 in 1200 mL of 0.1M solution is:
   (A) 11.76 g (B) 5.83 g (C) 16.42 g (D) 2.92

INTEGER TYPE

1. Number of moles of electrons in 0.5 mole of N^{3-} will be _____.

2. How many gm atoms of carbon are there in 132 gm CO_2.

3. A sample of metal chloride weighing 0.22 g required 0.51g of $AgNO_3$ to precipitate the chloride completely. The specific heat of the metal is 0.057. Find out the valency of metal, if the symbol of the metal is 'M'. (Ag = 108, N = 14, O = 16, Cl = 35.5) [Dulong petit's law says approximate atomic weight × specific heat = 6.4]

4. A complex compound of iron has molar mass = 2800 and it contain 8 % iron by weight. The number of iron atoms in one formula unit of complex compound is

5. If x mL 5 M HCl is mixed with 20 mL, 2 M HCl, a 2.6 M HCl is produced. The x is

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6. A gaseous alkane C_nH_{2n+2} on explosion with O_2 gives CO_2, the volume of O_2 required for complete combustion of alkane to CO_2 formed is in the ratio 7 : 4 the value of n is

7. The number of moles of fullerene (C_{60}) (a soccer ball structure molecule discovered in 1980) in 1.44 kg Fullerene are

8. Weight of a 5% by weight of a NaCl solution to yield 0.3 g of NaCl is

9. Haemoglobin contains 0.25% iron by weight, the molecular weight of Haemoglobin is 89600. calculate the number of Iron atoms per molecule of Haemoglobin.

10. 1g of dry green algae absorbs 4.7×10^{-3} *mole* of CO_2 per hour by photosynthesis. If the fixed carbon atoms were all stored after photosynthesis as starch, $(C_6H_{10}O_5)_n$, how long would it take for the algae to double their own weight assuming photosynthesis takes place at a constant rate? Answer should be reported to the nearest integer value.

EXPERTISE ATTAINERS

1. Cobalt is precipitated with α - nitroso - β - naphtol as $Co[C_6H_{10}O(NO)]_3$ and ignited in a stream of O_2 to Co_3O_4. Alternatively, the precipitate is ignited in stream of hydrogen gas and weighed as Co. what weight of cobalt would have been obtained from the same weight of sample that produced 0.2125 g Co_3O_4? What was the weight of precipitate that gave 0.2125 g Co_3O_4?

2. 0.5 g Fe^{3+} is precipitated as hydrated ferric oxide. During ignition, 90% of iron is converted into Fe_2O_3 and the remainder is present as Fe_3O_4
   (a) What does the ignited precipitate weigh?
   (b) What should it would have weighed if all the iron were in Fe_2O_3 form?

3. A mixture contains NaCl and an unknown chloride MCl.
   (i) 1 g of this is dissolved in water. Excess of acidified $AgNO_3$ solution is added to it. 2.567 g of a white precipitate is formed.
   (ii) 1.0 g of the original mixture is heated to 300^0C. Some vapours come out which are absorbed in
   acidified $AgNO_3$ solution. 1.341 g of a white precipitate is obtained. Find the molecular weight of the unknown chloride.

4. 0.220 g of a sample of a volatile compound, containing carbon, hydrogen and chlorine yielded on combustion in oxygen 0.195 g of CO_2, 0.0804 g of H_2O. 0.120 g of the compound occupied a volume of 37.24 mL at 105^0C and 768 mmHg pressure. Calculate the molecular formula of the compound.

5. One mole of a mixture of N_2, NO_2 and N_2O_4 has a mean molar mass of 55.4. On heating to a temperature at which N_2O_4 is completely dissociated : $N_2O_4 \rightarrow 2NO_2$, the mean molar mass tends to the lower value of 39.57. What is the mole ratio of $N_2 : NO_2 : N_2O_4$ in the original mixture?

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6. Chile salt peter a source of $NaNO_3$ also contains $NaIO_3$. The $NaIO_3$ can be used as a source of Iodine produced in the following reactions:

$$IO_3^- + 3HSO_3^- \longrightarrow I^- + 3H^+ + 3SO_4^{2-}$$
$$5I^- + IO_3^- + 6H^+ \longrightarrow 3I_2 + 3H_2O$$

One litre of chile salt peter solution containing 5.80 gm $NaIO_3$, is treated with stoichiometric quantity of $NaHSO_3$. Now additional amount of same solution is added to the reaction mixture to bring about the second reaction. How many grams of $NaHSO_3$ are required in step 1 and what additional volume of chile salt peter must be added in step II to bring in complete conversion of I^- to I_2?

7. 1 gm sample of $AgNO_3$ is dissolved in 50 mL of water. It is reacted with 50 mL of KI solution. The AgI precipitated is filtered off. Excess of KI in filtrate is titrated with M/10 KIO_3 in presence of 6 M HCl till all I^- converted into ICl. It requires 50 mL of M/10 KIO_3 solution. 20 mL of the same stock solution of KI requires 30 mL of M/10 KIO_3 under similar condition. Calculate % of $AgNO_3$ in sample. The reactions involved are

$AgNO_3 + KI \longrightarrow KNO_3 + AgI(ppt)$, $KIO_3 + 2KI + 6HCl \longrightarrow 3ICl + 3KCl + 3H_2O$

8. Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of natural boron is 10.81. Calculate the percentage of each isotope in natural boron.

9. In the analysis of 0.5 g sample of feldspar, a mixture of chlorides of sodium and potassium is obtained, which weight 0.1180g. Subsequent treatment of the mixed chlorides with silver nitrate gives 0.2451g of silver chloride. What is the percentage of sodium oxide and potassium oxide in the sample?

10. 5.00mL of a gas containing only carbon and hydrogen were mixed with an excess of oxygen (30mL) and the mixture exploded by means of electric spark. After explosion, the volume of the mixed gases remaining was 25mL. On adding a concentrated solution of KOH, the volume further diminished to 15 mL, the residual gas being pure oxygen. All volumes have been reduced to NTP. Calculate the molecular formula of the hydrocarbon gas.

11. (a) 1.0L of a mixture of CO and CO_2 is taken. This mixture is passed through a tube containing red hot charcoal. The volume now becomes 1.6 L. The volumes are measured under the same conditions. Find the composition of mixture by volume.
(b) A Compound contains 28 % of nitrogen and 72 % of a metal by weight. 3 atoms of metal combine with 2 atoms of nitrogen. Find the atomic weight of metal.

12. n-butane(C_4H_{10}) is produced by monobromination of ethane(C_2H_6) followed by Wurtz's reaction. Calculate volume of ethane at NTP required to produce 55g n-butane, if the bromination takes place with 90% yield and the Wurtz's reaction with 85% yield.

13. A solid mixture (5.0g) consisting of lead nitrate and sodium nitrate was heated below 600°C until the weight of the residue was constant. If the loss in weight is 28 %, find the amount of lead nitrate and sodium nitrate in the mixture.

14. 8.0575×10^{-2} kg of Glauber's salt is dissolved in water to obtain $1dm^3$ of solution of density$1077.2kgm^{-3}$. Calculate the molality, molarity and mole fraction of Na_2SO_4 in solution.

15. In a solution of 100mL 0.5M acetic acid, one gram of active charcoal is added, which adsorbs acetic acid. It is found that the concentration of acetic acid becomes 0.49 M. If surface area of charcoal is $3.01 \times 10^2 m^2$. Calculate the area occupied by single acetic acid molecule on surface of charcoal.

16. 20% surface sites have adsorbed N_2. On heating N_2 gas evolved from sites and was collected at 0.001 atm and 298 K in a container of volume is $2.46cm^3$. Density of surface sites is $6.023\times10^{14}/cm^2$ and surface area is 1000 cm^2; find out the number of surface sites occupied per molecule of N_2.

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WINDOW TO JEE MAIN

1. Which of the following concentration factor is affected by change in temperature ? **[AIEEE 2002]**
(A) Molarity (B) Molality (C) Mole fraction (D) Weight

2. Number of atoms in 560g of Fe (atomic mass 56g/mol) is : **[AIEEE 2002]**
(A) Twice that of 70g N (B) Half that of 20g H
(C) Both (A) and (B) (D) None of these

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

4. What volume of hydrogen gas at 273 K and 1 atm pressure will be consumed in obtaining 21.6 gm of elemental boron (atomic mass = 10.8) from the reduction of boron trichloride by hydrogen? **[AIEEE 2003]**
(A) 44.8 lit. (B) 22.4 lit. (C) 89.6 lit. (D) 67.2 lit.

5. 6.02×10^{20} molecules of urea are present in 100 ml of its solution. The concentration of urea solution is **[AIEEE 2004]**
(A) 0.001 M (B) 0.01 M (C) 0.02 M (D) 0.1 M

6. 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 a substance will **[AIEEE 2005]**
(A) decrease twice (B) increase two fold
(C) remain unchanged (D) be a function of the molecular mass of the substance

7. Density of a 2.05M solution of acetic acid in water is 1.02 g/ml. The molality of the solution is : **[AIEEE-2006]**
(A) 1.14 mol/kg (B) 3.28 mol/kg (C) 2.28 mol/kg (D) 0.44 mol/kg

8. How many moles of magnesium phosphate , $Mg_3(PO_4)_2$ will contains 0.25 mole of oxygen atoms?
(A) 0.02 (B) 3.125×10^{-2} (C) 1.25×10^{-2} (D) 2.5×10^{-2} **[AIEEE-2006]**

9. The density (in g/mL) of a 3.60 M sulphuric acid solution that is 29% by mass will be **[AIEEE-2007]**
(A) 1.22 (B) 1.45 (C) 1.64 (D) 1.88

10. The reaction,
$$2Al(s) + 6HCl(aq) \rightarrow 2Al^{3+}(aq) + 6Cl^-(aq) + 3H_2(g)$$
(A) 33.6 L $H_2(g)$ is produced regardless of temperature and pressure for every mole of Al that reacts
(B) 67.2 L $H_2(g)$ at STP is produced for every mole of Al that reacts
(C) 11.2 L $H_2(g)$ at STP is produced for every mole of HCl (aq) consumed
(D) 6 L HCl (aq) is consumed for every 3L H_2 (g) produced **[AIEEE-2007]**

11. A 5.2 molal aqueous solution of methyl alcohol, CH_3OH is supplied. What is the mole fraction of methyl alcohol in the solution
(A) 0.86 (B) 0.086 (C) 0.043 (D) 1.0 **[AIEEE-2007]**

12. The density of a solution prepared by dissolving 120 g of urea (Mol.Mass = 60u) in 1000 g of water is 1.15 g/mL. The molarity of this solution is
(A) 1.02 M (B) 0.50 M (C) 2.05 M (D) 1.78 M **[AIEEE-2007]**

13. The molarity of a solution obtained by mixing 750 mL of 0.5 M HCl with 250 mL of 2 M HCl will be
(A) 1.75 M (B) 0.975 M (C) 0.875 M (D) 1.78 M **[AIEEE-2013]**

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14. Number of atoms in the following samples of substances is the largest in **[JEE Main Online 2013]**
(a) 4.0 g of hydrogen (b) 70.0g of chlorine
(c) 127.0 g of iodine (d) 48.0 g of magnesium

15. The number of protons, electrons and neutrons in a molecule of heavy water are respectively **[JEE Main Online 2013]**
(a) 8, 10, 11 (b) 10, 10, 10 (c) 10, 11, 10 (d) 11, 10, 10

16. 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 Online 2013]**
(a) C_2H_4 (b) C_3H_4 (c) C_6H_5 (d) C_7H_8

17. The density of 3M solution of sodium chloride is 1.252 g mL^{-1}. The molality of the solution will be (molar mass, NaCl = 58.5 g mol^{-1}) **[JEE Main Online 2013]**
(a) 2.60 m (b) 2.18 m (c) 2.79 m (d) 3.00 m

18. 10 mL of 2M NaOH solution is added to 200 mL of 0.5 M of NaOH solution. What is the final concentration? **[JEE Main Online 2013]**
(a) 0.57 M (b) 5.7 M (c) 11.4 M (d) 1.14 M

19. 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 Offline 2014]**
(a) 1:4 (b) 7:32 (c) 1:8 (d) 3:16

20. The amount of $BaSO_4$ formed upon mixing 100ml of 20.8% $BaCl_2$ solution with 50 ml of 9.8% H_2SO_4 solution will be **[JEE Main Online 2014]**
(Ba = 137, Cl = 35.5, S = 32, H = 1 and 0 = 16)
(a) 23.3 g (b) 11.65 g (c) 30.6 g (d) 33.2 g

21. Dissolving 120 g of a compound of (Mol. Wt 60) in 1000g of water gave a solution of density 1.12 g/ml. The molarity of the solution is **[JEE Main Online 2014]**
(a) 1.00M (b) 2.00 M (c) 2.50 M (d) 4.00 M

22. A gaseous compound of nitrogen and hydrogen contains 12.5% (by mass) of hydrogen. The density of the compound relative to hydrogen is 16. The molecular formula of the compound is **[JEE Main Online 20014]**
(a) NH_2 (b) N_3H (c) NH_3 (d) N_2H_4

23. 3g of activated charcoal was added to 50 ml of acetic acid solution (0.06M) in a flask. After an hour it was filtered and the strength of the filtrate was found to be 0.042 M. The amount of acetic acid adsorbed (per gram of charcoal) is **[JEE Main Offline 2015]**
(a) 18 mg (b) 36 mg (c) 42 mg (d) 54 mg

24. $A + 2B + 3C \rightleftharpoons AB_2C_3$
Reaction of $6.0\,g$ of A, 6×10^{23} atoms of B and 0.036 mol of C yields 4.8 g of compound AB_2C_3. If the atomic mass of A & C are 60 and 80 amu respectively the atomic mass of B is (Avogadro No $=6\times10^{23}$) **[JEE Main Online 2015]**
(a) 70 amu (b) 60 amu (c) 50 amu (d) 40 amu

25. A sample of a hydrate of barium chloride weighing 61g was heated until the water of hydration is removed. The dried sample weighed 52g. The formula of the hydrated salt is (atomic mass of Ba = 137 amu, Cl = 35.5 amu) **[JEE Main Online 2015]**
(a) $BaCl_2.H_2O$ (b) $BaCl_2.2H_2O$ (c) $BaCl_2.3H_2O$ (d) $BaCl_2.4H_2O$

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26. An organic compound contains C, H and S. The minimum molecular weight of the compound containing 8% sulphur is: (atomic weight of S = 32 amu) **[JEE Main Online 2016]**
(a) 200 g mol^{-1} (b) 400 g mol^{-1} (c) 600 g mol^{-1} (d) 300 g mol^{-1}

27. 5 L of an alkane requires 25 L of oxygen for its complete combustion. If all volumes are measured at constant temperature and pressure, the alkane is: **[JEE Main Online 2016]**
(a) Ethane (b) Propane (c) Butane (d) Isobutane

WINDOW TO JEE ADVANCED

Objective Questions

1. A gaseous mixture contains oxygen and nitrogen in the ratio of 1:4 by weight. Therefore, the ratio of their number of molecules is **(JEE 1979)**
(A) 1:4 (B) 1:8 (C) 7:32 (D) 3:16

2. The total number of electrons in one molecule of carbon dioxide is **(JEE 1979)**
(A) 22 (B) 44 (C) 66 (D) 88

3. The largest number of molecules is in **(JEE 1979)**
(A) 36 g of water (B) 28 g CO
(C) 46 g of ethyl alcohol (D) 54g of nitrogen pentaoxide (N_2O_5)

4. When the same amount of zinc is treated separately with excess of sulphuric acid and excess of sodium hydroxide, the ratio of volume of hydrogen evolved is **(JEE 1979)**
(A) 1:1 (B) 1:2 (C) 2:1 (D) 9:4

5. 2.76g of silver carbonate on being strongly heated yields a residue weighing **(JEE 1979)**
(A) 2.16g (B) 2.48 g (C) 2.32 g (D) 2.64 g

6. If 0.50 mole of $BaCl_2$ is mixed with 0.20 mole of Na_3PO_4, the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is **(JEE 1981)**
(A) 0.70 (B) 0.50 (C) 0.20 (D) 0.10

7. A molal solution is one that contains one mole of solute in **(JEE 1986)**
(A) 1000g of solvent (B) 1.0 L of solvent (C) 1.0 L of solution (D) 22.4 L of solution

8. In which mode of expression, the concentration of a solution remains independent of temperature? **(JEE 1988)**
(A) Molarity (B) Normality (C) Formality (D) Molality

9. How many moles of electron weights one kilogram? **(JEE 2002)**
(A) 6.023×10^{23} (B) $\frac{1}{9.108}\times10^{31}$ (C) $\frac{6.023}{9.108}\times10^{54}$ (D) $\frac{1}{9.108\times6.023}\times10^{8}$

10. Which has maximum number of atoms? **(JEE 2003)**
(A) 24 g of C(12) (B) 56 g of Fe(56) (C) 27 g of Al(27) (D) 108 g of Ag(108)

11. 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)**
(A) 55.85 (B) 55.95 (C) 55.75 (D) 56.05

12. Dissolving 120g of urea (mol.wt. 60) in 1000g of water gave a solution of density 1.15 g/mL. The molarity of the solution is **(JEE 2011)**
(A) 1.78 M (B) 2.00M (C) 2.05M (D) 2.22M

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13. The ratio of masses of oxygen and nitrogen in a particular gaseous mixture is 1 : 4. The ratio of number of their molecules is
(A) 3 : 16 (B) 1 : 4 (C) 7 : 32 (D) 1 : 8 **(JEE 2014)**

Fill in the blanks

1. The modern atomic mass unit is based on the mass of _____ . **(JEE 1980)**
2. The total number of electrons present in 18 mL of water is _____. **(JEE 1980)**
3. 3.0 g of a salt of molecular weight 30 is dissolved in 250 g water. The molality of the solution is _____. **(JEE 1983)**
4. The weight of 1×10^{22} molecules of $CuSO_4.5H_2O$ is _____. **(JEE 1991)**

Integer type

1. 29.2% (*w/w*) HCl stock solution has a density of 1.25 g mL^{-1}. The molecular weight of HCl is 36.5 g mol^{-1}. The volume (mL) of stock solution required to prepare a 200 mL solution 0.4 M HCl is **(2012)**
2. If the value of Avogadro number is $6.023\times10^{23}\,mol^{-1}$ and the value of Boltzmann constant is $1.380\times10^{-23}\,JK^{-1}$, then the number of significant digits in the calculated value of the universal gas constant is **(2014)**
3. A compound H_2X with molar weight of 80 g is dissolved in a solvent having density of 0.4 g mL^{-1}. Assuming no change in volume upon dissolution, the molality of a 3.2 molar solution is **(2014)**
4. The mole fraction of a solute in a solution is 0.1. At 298 K, molarity of this solution is the same as its molality. Density of this solution at 298 K is 2.0 g cm^{-3}. The ratio of the molecular weights of the solute and solvent, $\left(\frac{MW_{solute}}{MW_{solvent}}\right)$, is **(2016)**

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ANSWER KEY

FOUNDATION BUILDER (OBJECTIVE)

1.	(D)	2.	(D)	3.	(B)	4.	(A)	5.	(D)
6.	(C)	7.	(A)	8.	(A)	9.	(A)	10.	(A)
11.	(D)	12.	(C)	13.	(D)	14.	(D)	15.	(A)
16.	(C)	17.	(B)	18.	(B)	19.	(C)	20.	(A)
21.	(B)	22.	(A)	23.	(D)	24.	(C)	25.	(B)
26.	(D)	27.	(C)	28.	(D)	29.	(C)	30.	(C)
31.	(B)	32.	(C)	33.	(A)	34.	(D)	35.	(B)
36.	(B)	37.	(D)	38.	(B)	39.	(A)	40.	(B)
41.	(B)	42.	(C)	43.	(C)	44.	(A)	45.	(D)
46.	(A)	47.	(C)	48.	(D)	49.	(A)	50.	(A)
51.	(D)	52.	(C)	53.	(A)	54.	(B)	55.	(D)
56.	(A)	57.	(B)	58.	(D)	59.	(D)	60.	(C)
61.	(A)	62.	(B)	63.	(B)	64.	(D)	65.	(A)
66.	(D)	67.	(B)	68.	(A)	69.	(B)	70.	(A)

GET EQUIPPED TO JEE MAIN

1.	(A)	2.	(A)	3.	(A)	4.	(C)	5.	(C)
6.	(A)	7.	(C)	8.	(D)	9.	(B)	10.	(D)
11.	(D)	12.	(D)	13.	(B)	14.	(A)	15.	(C)
16.	(C)	17.	(A)	18.	(D)	19.	(A)	20.	(C)
21.	(D)	22.	(A)	23.	(D)	24.	(A)	25.	(D)
26.	(D)	27.	(D)	28.	(C)	29.	(D)	30.	(A)
31.	(B)	32.	(C)	33.	(A)	34.	(B)	35.	(C)
36.	(C)	37.	(A)	38.	(D)	39.	(D)	40.	(B)
41.	(D)								

FOUNDATION BUILDER SUBJECTIVE

1. [Y atoms] **2.**[6.022×10^{23}] **3.**[$10 \times 6.022 \times 10^{23}$]

4. $10 \times 6.022 \times 10^{23}$, $8 \times 6.022 \times 10^{23}$, $8 \times 6.022 \times 10^{23}$ **5.** 40 **6.** 2.5092×10^{22} atom

7. 0.00288 **8.** [2.894×10^{5} C] **9.** [0.01] **10.** [$0.363N_A$, $0.176N_A$]

11.[1.9099×10^{10} year] **12.**[1000] **13.** [5×10^{16}]

14. [4.91×10^{21}]**15.** [3.6×10^{4} g] **16.** [4.54 L] **17.** [2.69×10^{22}]

18. [200 ml] **19.** [K_2MnP_2] **20.** [$C_{21}H_{30}O_2$] **21.** [n=4]

22. $(C_5H_{14}N_2)$ **23.** (CH) **24.** [19.8×10^{23}] **25.** [0.437]

26. 12.18 **27.** %$NaHCO_3$ = 16.8, % Na_2CO_3= 83.2

28. 40.8% **29.** [27.3 g, 2.736 g O_2, 87.2%] **30.** 3.2

31. $\begin{pmatrix} CH_4 = 60\% \\ C_2H_4 = 40\% \end{pmatrix}$ **32.** [0.0166] **33.** [38 g] **34.** [4.87 g]

35.[%$CaCO_3$=54.34%] **36.** 2840 gm **37.** $\frac{21}{6}$ *moles* **38.** 49.8 %

39. x = 2 y = 1 **40.** 9.795 gm

41. (A) – B, (B) - [A: left moles = (4/3–1/2)], (C) - [7/2] **42.** CO : CO_2 = 3 : 1

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43. [6.125g/lt.] 44. [0.1, 5.6] 45. [6.022×10^{19}] 46. [1.2475]
47. [0.35 M] 48. [0.4 m] 49. [3.205] 50. [1.4228]
51. [166.67 ml] 52. 12.18 53. (5 mole) 54. (2.5 mole)
55. $68g$ 56. A – (O_2), B – (32.625 g), C – (2.375 g) 57. $(226g)$
58. $Cl = 4.85\%$, $Br = 34.19\%$ 59. $4.97\,Lt$ 60. 210

GET EQUIPPED FOR JEE ADVANCE

SINGLE ANSWER CORRECT

1. (A)	2. (C)	3. (B)	4. (A)	5. (C)	6. (C)	7. (A)
8. (D)	9. (D)	10. (C)	11. (C)	12. (D)	13. (B)	14. (A)
15. (B)	16. (C)	17. (A)	18. (B)	19. (A)	20. (B)	21. (B)
22. (C)	23. (A)	24. (B)	25. (B)	26. (A)	27. (A)	28. (B)
29. (A)	30. (B)	31. (A)	32. (A)	33. (B)		

MORE THAN ONE CHOICE

1. (ABD)	2. (AB)	3. (ABD)	4. (ACD)	5. (AC)	6. (AC)	7. (ABD)
8. (ABCD)	9. (AB)	10. (BC)	11. (CD)	12. (BC)	13. (AD)	14. (CD)

MATCH THE FOLLOWING

1. I – P, II – A, III - C, IV – E
2. a – S, b – S, c- Q, d – R
3. a – PS, b – S, c – PQ, d – R
4. A- p ,r,s B-p, C- p,q,r, D-s

COMPREHENSIVE TYPE

PASSAGE – I	1. C	2. A	3. B	4. B
PASSAGE – II	1. A	2. C	3. A	4. A
PASSAGE – III	1. D	2. A	3. C	4. A
PASSAGE – IV	1. A	2. A		

INTEGER TYPE

1. (5)	2. (3)	3. (3)	4. (4)	5. (5)	6. (2)	7.(2)
8. (6)	9. (4)	10. (8)				

EXPERTISE ATTAINER

1. $(0.156g)$,(1.172 g) 2. a) (0.712), b) (0.714) 3. (53.5) 4. $C_2H_4Cl_2$ 5. 0.5 : 0.1 : 0.4,
6. 9.14 gm, 200mL 7. 85%
8. Natural boron contain 20% (10.01) first isotope and 80% other isotope.
9. 10.6% 10. C_2H_4. 11. (a) 40% CO and 60% CO_2 by volume. (b) 24 12. 55.5 L
13. 1.7 g 14. Molarity of solution = 0.25 M molality = 0.24 m Mole fraction of Na_2SO_4= 4.3×10^{-3}
15. $0.5\times10^{-18}\ m^2$ 16. 2

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WINDOW TO JEE MAIN

1.	(A)	2.	(C)	3.	(A)	4.	(D)	5.	(B)
6.	(C)	7.	(C)	8.	(B)	9.	(A)	10.	(C)
11.	(B)	12.	(C)	13.	(C)	14.	(A)	15.	(B)
16.	(D)	17.	(C)	18.	(A)	19.	(b)	20.	(b)
21.	(b)	22.	(d)	23.	(a)	24.	(c)	25.	(b)
26.	(b)	27.	(b)						

WINDOW TO JEE ADVANCED

OBJECTIVE QUESTIONS

1. (C)	2. (A)	3. (A)	4. (A)	5. (A)	6. (D)	7. (A)
8. (D)	9. (D)	10.(A)	11. (B)	12. (C)	13. (C)	

Fill in blanks:

1. C-12 isotope 2. 6.023×10^{24} 3. 0.4 m 4. 4.14g

Integer Type

1.	(8)	2.	(4)	3.	(8)	4.	(9)

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