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ENGINEERING MODULE - 1

CHEMISTRY – CLASS XI

SOME BASIC CONCEPTS OF CHEMISTRY
STOICHIOMETRY - 1 & 2

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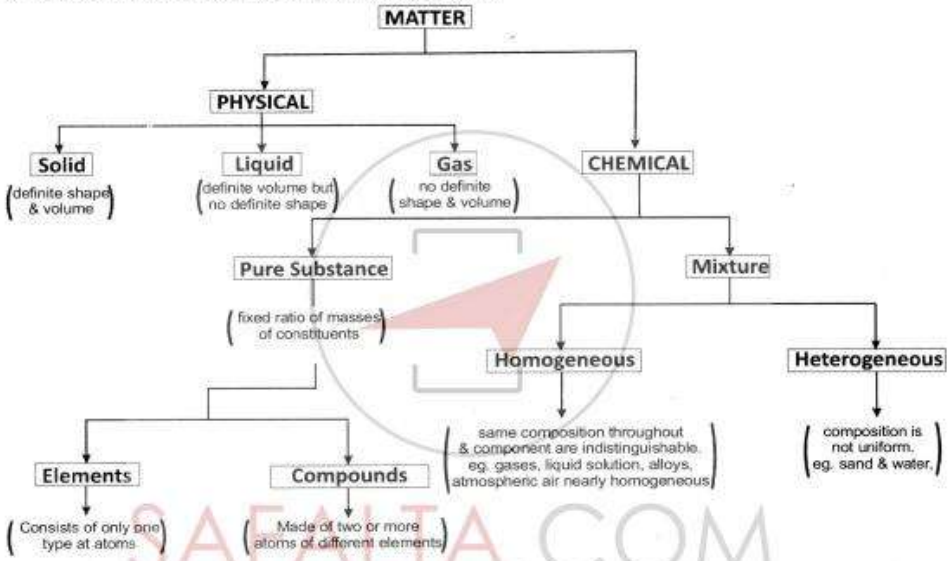
CHAPTER 1 SOME BASIC CONCEPTS OF CHEMISTRY STOICHIOMETRY-1

1. INTRODUCTION

Chemistry deals with the composition, structure and properties of matter. These aspects can be best described and understood in terms of basic constituents of matter: atoms and molecules. That is why chemistry is called the science of atoms and molecules. Can we see, weigh and perceive these entities? Is it possible to count the number of atoms and molecules in a given mass of matter and have a quantitative relationship between the mass and number of these particles (atoms and molecules)? We will like to answer some of these questions in this Unit. We would further describe how physical properties of matter can be quantitatively described using numerical values with suitable units.



2. CLASSIFICATION OF UNIVERSE

Universe is classified into two types, matter and energy.

(A)MATTER : The thing which occupy space and having mass which can be felt by our five senses is called matter.

Matter is further classified into two categories :

(i) Physical classification (ii) Chemical classification

PHYSICAL CLASSIFICATION

It is based on physical state under ordinary conditions of temperature and pressure, so on the basis of two nature of forces matter can be classified into the following three ways :

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

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

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

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

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

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

e.g. hydrogen(H_2), oxygen(0_2), carbon dioxide($C0_2$) etc.

CHEMICAL CLASSIFICATION

It may be classified into two types :

(a) Pure Substance (b) Mixture

(a) Pure Substance : A material containing only one type of substance. Pure Substance can not be separated into simpler substance by physical method.

e.g. : Element = Na, Mg, Ca.....etc.

Compound = HCl, H_2O, CO_2, HNO_3.....etc.

Pure substance is classified into two types :

(a) Element (b) Compound

(i) Element: The pure substance containing only one kind of atoms.

It is classified into 3 types (depend on physical and chemical property)

(i) Metal → Zn, Cu, Hg, Ac, Sn, Pb etc. (ii) Non-metal → N_2, O_2, Cl_2, Br_2, F_2, P_4, S_8 etc.

(iii) Metalloids → B, Si, As, Te etc.

(ii) Compound : It is defined as pure substance containing more than one kind of elements or atoms which are combined together in a fixed proportion by weight and which can be decomposed into simpler sub stance by the suitable chemical method. The properties of a compound are completely different from those of its constituent element.

e.g. HCl, H_2O , H_2SO_4, $HClO_4$, HNO_3 etc.

(b) Mixture : A material which contain more than one type of substances and which are mixed in any ratio by weight is called as mixture. The property of the mixture is the property of its components. The mixture can be separated by simple physical method.

Mixture is classified into two types :

(i) Homogeneous mixture : The mixture, in which all the components are present uniformly is called as homogeneous mixture. Components of mixture are present in single phase.

e.g. Water + Salt, Water + Sugar, Water + alcohol,

(ii) Heterogeneous mixture : The mixture in which all the components are present non-uniformly

e.g. Water + Sand, Water + Oil, blood, petrol etc.

Illustration-1 : Which mixture is called as solution.
(a) Heterogeneous mixture (b) Homogeneous mixture
(c) Both (a) and (b) (d) None of these

Solution :(b) Homogeneous mixture is called as solution.

Illustration-2 : Which of the following is a compound
(a) graphite (b) producer gas (c) cement (d) marble

Solution :(d) Marble = $CaCO_3$ = compound.

Student Task -1

1. Which of the following is example of a Homogeneous mixture.
(a) Water + Alcohol (b) Water + Sand (c) Water + Oil (d) None of these
2. A pure substance can only be:-
(a) A compound (b) An element
(c) An element or a compound (d) A heterogeneous mixture
3. Which one of the following is not a mixture:
(a) Tap water (b) Distilled water (c) Salt in water (d) Oil in water

Ans.: **1. (a)** **2. (c)** **3. (b)**

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3. SOME COMMONLY USED PREFIXES WITH THE BASE UNITS.

Prefix	Symbol	Multiplication Factor	Example
Deci	d	10^{-1}	1 decimetre (dm)=10^{-1} m
Centi	c	10^{-2}	1 centimetre (cm)=10^{-2}m
Milli	m	10^{-3}	1 milimetre (mm)=10^{-3} m
Micro	μ	10^{-6}	1 micrometre (μm)=10^{-6} m
Nano	n	10^{-9}	1 nanometre (nm)=10^{-9}m
Pico	p	10^{-12}	1 picometre (pm)=10^{-12}m
Femto	f	10^{-15}	1 femtometre (fm)=10^{-15}m
Atto	a	10^{-18}	1 attometre (am)=10^{-18}m
Deka	da	10^{1}	1 decametre (dam)=10^{1}m
Hector	h	10^{2}	1 hectormetre (hm)=10^{2}m
Kilo	k	10^{3}	1 kilometre (km)=10^{3}m
Mega	M	10^{6}	1 megametre (Mm)=10^{6}m
Giga	G	10^{9}	1 gigametre (Gm)=10^{9}m
Tera	T	10^{12}	1 terametre (Tm)=10^{12}m
Peta	P	10^{15}	1 petametre (Pm)=10^{15}m
exa	E	10^{18}	1 exametre (Em)=10^{18}m

SIGNIFICANT FIGURES

The total number of digits in a number including the last digit whose value is uncertain is called the number of significant figures.

RULES FOR DETERMINING THE NUMBER OF SIGNIFICANT FIGURES

Rule 1. All non-zero digits as well as the zeros between the non-zero digits are significant.

e.g., 576 cm has three significant figures, 0.48 has two significant figures

Rule 2. Zeros to the left of the first non-zero digit in a number are not significant. (they simply indicate the position of the decimal point)

e.g., 0.05 m has only one significant figure, 0.0045 kg has two significant figures.

Rule 3. If a number ends in zeros but these are to the right of the decimal point, then these zeros are significant.

e.g, 5.0 m has two significant figures, 2.50 has three significant figures
2.500 g has four significant figures, 0.0200kg has three significant figures.

Rule 4. If a number ends in zeros but these zeros are not to the right of a decimal point, these zeros may or may not be significant.

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Illustration-3 : Addition of 6.65×10^4 and 8.95×10^3, in terms of scientific notation will be
(a) 7.545×10^4 (b) 75.45×10^3 (c) 754.5×10^2 (d) 75.45×10^0

Solution :(a) $6.25\times10^4+8.95\times10^3$
$=(6.65+0.895)\times10^4=7.545\times10^4$

Illustration-4 : If 6.65 is to be rounded off it is rounded off to A and if 6.35 is to be rounded off it is rounded off to B . Here, A and B refer to
(a) A $\rightarrow$6.2, B $\rightarrow$6.4 (b) A $\rightarrow$6.1, B $\rightarrow$6.3 (c) A $\rightarrow$6.3,B $\rightarrow$6.4 (d) A $\rightarrow$6.1, B $\rightarrow$ 6.2

Solution (a) If the rightmost digit to be removed is 5, then the preceding number is not changed if it is an even number but it is increased by one if it is an odd number. e.g. if 6.35 is to be rounded by removing 5, we have to increase 3 to 4 giving 6.4 as the result. However, if 6.25 is to be rounded off it is rounded off to 6.2.

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Student Task -2

1. The result of which of the following has/have least significant figure(s)?

   (a) $\frac{0.02856 \times 298.15 \times 0.112}{0.5785}$ (b) 5×5.364

   (c) 0.0125 + 0.7864 + 0.0215 (d) All have same number of significant figure

2. 18.72 g of a substance X occupies 1.81 cm^3. What will be its density measured in correct significant figures?

   (a) 10.3 g/cm^3 (b) 10.34 g/cm^3 (c) 10.4 g/cm^3 (d) 10.3425 g/cm^3

3. The unit ($J\ Pa^{-1}$) is equivalent to

   (a) m^3 (b) cm^{-3} (c) dm^3 (d) None of these

Ans.: 1. (a) 2. (b) 3. (a)

4. LAWS OF CHEMICAL COMBINATION

(a) Law of Mass Conservation (Law of Indestructibility of Matter)

"It was given by Lavoisier and tested by Landolt"

According to this law, the mass can neither be created nor be destroyed in a balanced chemical reaction or physical reaction. But one form is changed into another form is called as law of mass conservation.

If the reactant is completely converted into products, then the sum of the masses of reactants is equal to the sum of the mass of products.

Total mass of reactants = Total mass of products.

If reactants are not completely consumed then the relationship will be:

Total mass of reactants = Total mass of products.+ Mass of unreacted reactants

Example: $H_2 + Cl_2 \rightarrow 2HCl$

Mass in (g) 2 71 2(1+35.5)

2+71=73g 73g

(b) Law of multiple proportion

- This law was given by Dalton in 1804.
- **Law :** If two elements combine to form more than one compound, then the different masses of one element which combine with a fixed mass of the other element, bear a simple ratio to one another.

For example : Nitrogen and oxygen combine to form five stable oxides -

N_2O	Nitrogen 28 parts	Oxygen 16 parts
N_2O_2	Nitrogen 28 parts	Oxygen 32 parts
N_2O_3	Nitrogen 28 parts	Oxygen 48 parts
N_2O_4	Nitrogen 28 parts	Oxygen 64 parts
N_2O_5	Nitrogen 28 parts	Oxygen 80 parts

The masses of oxygen which combine with same mass of nitrogen in the five compounds bear a ratio 16 : 32 : 48 : 64 or 1 : 2 : 3 : 4 : 5.

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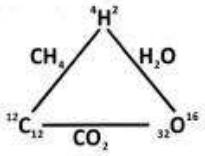
(c) Law of reciprocal proportions

➤ This law was put forward by Richter in 1792. It states as follows :

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



➤ **This law may be illustrated with the help of the following example :**

The elements C and O combine separately with the third element H to form CH_4 and H_2O and they combine directly with each other to form CO_2, as shown in figure.

In CH_4, 12 parts by weight of carbon combine with 4 parts by weight of hydrogen. In H_2O, 2 parts by weight of hydrogen combine with 16 parts by weights of oxygen. Thus the weight of C and O which combine with fixed weight of hydrogen (say 4 parts by weight) are 12 and 32 i.e. they are in the ratio 12 : 32 or 3 : 8.

Now in CO_2, 12 parts by weights of carbon combine directly with 32 parts by weight of oxygen i.e. they combine directly in the ratio 12 : 32 or 3 : 8 which is the same as the first ratio'

Illustration-5 : What weight of $BaCl_2$ would react with 24.4 g of sodium sulphate?

(a) 40 g (b) 45.6 g (c) 49.8 g (d) 42.8 g

Solution : (b) Barium chloride and sodium sulphate react to produce barium sulphate and sodium chloride according to the equation: $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$

xg 24.4 g 46.6g 23.4 g

Let the weight of $BaCl_2$ be x g. According to law of conservation of mass:

Total mass of reactants = Total mass of products

Total mass of reactants = (x + 24.4)g

Total mass of products = (46.6 + 23.4)g

Equating the two masses x + 24.4 = 46.6 + 23.4

x = 46.6 + 23.4 or x = 45.6 g

Hence , the weight of $BaCl_2$ is 45.6 g

Law of Definite Proportion / Law of Constant Composition

"It was given by Proust."

According to this law, a compound can be obtained from different sources. But the ratio of each component (by weight) remain same. i.e it does not depend on the method of its preparation or the source from which it has been obtained.

For example: molecule of ammonia always has the formula NH_3. That is one molecule of ammonia always contains, one atom of nitrogen and three atoms of hydrogen or 17.0 g of NH_3 always contains 14.0 g of nitrogen and 3 g of hydrogen.

Example: Weight of copper oxide obtained by treating 2.16 g metallic copper with nitric acid and subsequent ignition was 2.70 g. In another experiment, 1.15 g of copper oxide on reduction yielded 0.92 g of copper. Show that the results illustrate the law of constant composition.

In I experiment	In II experiment
weight of Cu = 2.16g	weight of CuO = 1.15 g

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weight of CuO = 2.7 g
weight of Oxygen = 2.7 - 2.16 = 0.54 g

Cu	:	O
2.16	:	0.54
$\frac{2.16}{0.54}$	:	$\frac{0.54}{0.54}$
4	:	1

weight of Cu= 0.92 g
weight of Oxygen = 1.15 - 0.92 = 0.23 g

Cu	:	O
0.92	:	0.23
$\frac{0.92}{0.23}$	:	$\frac{0.23}{0.23}$
4	:	1

Law of Gaseous Volume

"It was given by **Gay Lussac**"

According to this law, in the gaseous reaction, the reactants are always combined in a simple ratio by volume and form products, which is simple **ratio by volume** at same temperature and pressure.

Example: For the gaseous reaction : $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$. If 40 mL of hydrogen completely reacts with chlorine then find the required volume of Chlorine & Volume of produced $HCl_{(g)}$?

According to Gay lussac's Law: $\underset{1}{H_{2(g)}} + \underset{1}{Cl_{2(g)}} \rightarrow \underset{2}{2HCl_{(g)}}$

$\because$ 1 mL of $H_{2(g)}$ will react with 1 mL of $Cl_{2(g)}$ and 2 mL of $HCl_{(g)}$ will produce

$\therefore$ 40 mL of $H_{2(g)}$ will react with 40 mL of $Cl_{2(g)}$ and 80 mL of $HCl_{(g)}$ will produce

required volume of $Cl_{2(g)}$ = 40 mL

produced volume of $HCl_{(g)}$ = 80 mL

Avogadro's Law " Equal volume of all gases contain equal number of molecules at same temperature and pressure."

Example:

1	1	2 ← Stoichiometry
$H_{2(g)}$	+ $Cl_{2(g)}$ →	$2HCl_{(g)}$
1 Volume	1 Volume	2 Volume
N molecules	N molecules	2N moleules
1/2molecule	1/2 molecule	1 molecule
1 atom	1 atom	2 atoms

It is correct because molecule is divisible.

5. MOLE CONCEPT

Mole : 1 Mole of a substance is the amount of the substance which contains as many number of elementary entities as the total number of atoms of C-12 are present in 12 gm of C-12.

1 Mole of [Substance] = [Amount of Substance] = 6.022×10^{23} [Entities]

- Substance → Element → GAM
- Substance → Covalent Compound → GMM
- Substance → Ionic compound → GFM
- Entities → Atom
- Entities → Molecules
- Entities → Formula Unit

1 Mole Fe = 56 gm = 6.022×10^{23} atoms

1 Mole H_2O = 18 gm = 6.022×10^{23} molecules

1 Mole NaCl = 58.5 gm = 6.022×10^{23} formula unit

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Atomic Mass Unit (Unified mass): 1 u is the $\frac{1}{12}$ th of the mass of 1 atom of C-12 in gram.

$1\,u = \frac{1}{12} \times$ Mass of 1 atom of C-12

$1\,u = \frac{1}{12} \times \frac{12}{6.022\times10^{23}} = 1.66\times10^{-24}$ gram

$$1u = \frac{1}{N_A} = 1.66\times10^{-24}\,gm = 1\ Anston = 1\ Avogram$$

S.T.P, N.T.P & SATP: All these are conditions of temperature & pressure and are widely used in case of gases.

Condition	Temperature	Pressure	Molar volume
S.T.P	273K	1atm	22.4Litre
N.T.P	273K	1bar	22.7Litre
SATP	298K	1 bar	24.7Litre

Molar volume of gas : It is volume occupied by 1 mole of gas. At STP molar volume of any gas is 22.4 Litre

Example: 1 mole of O_2 = 32 gm = 22.4L (STP) = 6.022×10^{23} molecules

6. METHODS TO DETERMINE NUMBER OF MOLES:

I. When mass is given : Number of moles = $\frac{\text{Given Mass(gm)}}{\text{Molar Mass(gm)}}$

II. When Number of Elementary entities is Given: Number of moles = $\frac{\text{Given number of entities}}{6.022\times10^{23}}$

III. When Volume of a Gas is Given at STP: Number of moles = $\frac{\text{Given Volume(Litre)}}{22.4(L)}$

IV: When volume of a Gas is is Given at Non. STP: Number of moles = $\frac{P.V}{RT}$

P = In Atmosphere
V = In Litre
T = In Kelvins
$R = .0821\,L\ atm\ K^{-1}Mol^{-1}$

V. When Molarity & Volume of a Solution is Given : Number of Moles = M.V (L)

VI. When Normality & Volume of a Solution is given : Number of Moles = $\frac{\text{Normality}}{\text{n-Factor}} \times V(L)$

VII. When Number of Equivalents is Given: Number of moles = $\frac{\text{Number of equivalent}}{\text{n-Factor}}$

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Illustration-6: When 1 L of CO_2 is heated with graphite, the volume of the gases collected is 1.5 L. calculate the number of moles of CO produced at STP.

(a) $\frac{1}{11.2}$ (b) $\frac{28}{22.4}$ (c) $\frac{1}{22.4}$ (d) $\frac{14}{22.4}$

Solution : (c) $CO_2 + C \rightarrow 2CO$

$\underset{1-x}{1} \qquad \underset{2x}{0}$

$(1-x)+2x=1.5$ or $1+x=1.5 \Rightarrow x=0.5$

Moles of 1 L CO at STP = $\frac{2\times0.5}{22.4}=\frac{1}{22.4}$

Illustration-7 : Which of the following represents 180 g of water correctly?

(a) 5 moles of water (b) 1 mole of water

(c) 6.023×10^{3} molecules of water (d) 6.023×10^{24} molecules of water

Solution :(d) 18 g of H_2O=1 mol and 180 g of H_2O=10 mol

6.023×10^{23} molecules of H_2O = 18 g of H_2O.

Student Task -2

1. What will be the weight of CO having the same number of O-atoms as present in 22g of CO_2?
   (a) 28 g (b) 22 g (c) 44 g (d) 72 g
2. If 1 mL of water contains 20 drops then number of molecules in a drop of water is
   (a) 6.23×10^{23} molecules (b) 1.376×10^{26} molecules
   (c) 1.62×10^{21} molecules (d) 4.346×10^{20} molecules
3. In an experiment, 4 g of M_2O_x oxide was reduced to 2.8 g of the metal. If the atomic mass of the metal is 56 g mol^{-1}, the number of O-atoms in the oxide is
   (a) 1 (b) 2 (c) 3 (d) 4

Ans. : 1. (a) 2. (c) 3. (c)

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7. AVERAGE ATOMIC MASS, AVERAGE MOLECULAR MASS, VAPOUR DENSITY

Average Atomic Mass (AAM): It is valid for those elements which have isotopes with varying Percentage abundance in nature.

$$AAM = \frac{\sum AM \times \%Abundance}{100}$$

Average Molecular Mass (AMM) : It is valid for gaseous mixture having varying Percentage of constituent gases.

$$AMM = \frac{W_T}{n_T} = \frac{\sum n.MM}{\sum n}$$

Note: For gases % composition refers to % by volume which in turn is % by moles.

Density: It is of two types (a) Absolute density (b) Relative density

Absolute Density : It is mass per unit volume and is valid for solid and liquid & gas.

Relative Density: It is measured with respect to some reference . In case of Solid & liquid reference is H_2O at 4°C & in case of gas it is H_2 gas at a given temperature and Pressure. Relative density of gas is also called vapour density of gas.

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For Solid and Liquid: $R.D = \frac{\text{Density of Solid or Liquid}}{\text{Density of water at } 4^0C}$

For gas : $R.D = VD = \frac{\text{Density of gas at T \& P}}{\text{Density of } H_2 \text{ at T \& P}}$ $VD = \frac{P_G M_G / RT}{P_{H_2} M_{H_2} / RT}$ $VD = \frac{M_G}{M_{H_2}} = \frac{M_G}{2}$ $VD = \frac{\text{Molar mass of gas}}{2}$

Illustration-8: 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

(a) 55.85 (b) 55.95 (c)55.75 (d) 56.05

Solution : (b) Average atomic weight $= \frac{54\times5+56\times90+57\times5}{100} = 55.95$

Illustration-9 : A gas is found to have the formula $(CO)_x$. Its vapour density is 70. The value of x will be

(a) 7 (b) 4 (c) 5 (d) 6

Solution : (c) Vapour density = 70

Molecular mass = 2×70 = 140

formula is $[CO]_x$

Therefore molecular mass = $(12+16)_x = 140$

$= x \times 28 = 140$

$x = 5$

Student Task -3

1. An alkaloid contains 17.28% of nitrogen and its molecular mass is 162. The number of nitrogen atoms present in one molecule of alkaloid is

   (a) 5 (b) 4 (c) 3 (d) 2

2. Mixture of CO & CO_2 has vapour density 16, then the % of CO_2 in the mixture is

   (a) 25 % (b) 75% (c) 60% (d) 56%

3. Air contains 80% N_2 & 20% O_2 by volume. The average molecular mass of air is

   (a) 28.8 (b) 16 (c) 30 (d)28.6

Ans.: 1 (d) 2. (a) 3. (a)

8. CONCENTRATION TERMS AND THEIR MEASUREMENT

The concentration of a solution reflects the relative proportion of solute and solvent present in the solution. The various concentration terms are

(i) **% w/W** (weight percent or Mass percent)

X % w/W means that x g solute is present in 100 g of solution.

$$\% \text{ w/W} = \frac{\text{Weight of solute}}{\text{Weight of solution}} \times 100$$

(ii) **% w/V** – x % w/V means that x g of solute is present in 100 ml solution.

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

(iii) **% v/V** – x % v/V means that x ml of solute is present in 100 ml solution.

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

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(IV) Molality (m) – It is defined as number of moles of solute present in 1 kilogram of solvent.

$$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent (inkg)}}$$

(v) Molarity (M) – It is defined as number of moles of solute present in 1 litre of solution.

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in litre)}}$$

Suppose, w gram solute is dissolved in V ml solution and molecular weight of solute is m.

$$\text{then, } M = \frac{w/m}{V(\text{in ml})/1000} = \frac{w}{m} \times \frac{1000}{V(\text{in ml})}$$

$\frac{w}{m}$ = Moles of solute.

$\frac{w}{m} \times 1000$ = Millimoles of solute.

So, millimoles of solute = M × V (in millilitre).

Another relation for calculating molarity (M) is

$$M = \frac{\%\text{ by mass of solute} \times d \times 10}{\text{molecular mass of solute}}$$

d = density of solution in gm/mL.

Molarity Equation:

I. $M_1V_1 = M_2V_2$ [Valid when moles are conserved]

II. $M_1V_1 + M_2V_2 = M_3V_3$ [Valid when two solutions of same nature are mixed]

Illustration-10 : Calculate Molarity and Molality of 40% NaOH (w/W). The density of solution is 1.2 g/ml.
(a) 1.2 M, 15.55 M (b) 12 M, 16.66 M (c) 12 M, 15.55 M (d) 16.66 M, 12 M

Solution: (b) 40% NaOH (w/W) means that 40 g pure NaOH is present in 100 g of solution.

$$\text{Volume of solution} = \frac{\text{Mass of solution}}{\text{density}} = \frac{100}{1.2}\text{ml}$$

$$\text{Molarity (M)} = \frac{w/m}{V(\text{in ml})/1000} = \frac{w}{m} \times \frac{1000}{V(\text{inml})}$$

$$\frac{40}{40} \times \frac{1000}{100} \times 1.2 = 12\text{ M}$$

$$\text{Molality (m)} = \frac{w/m}{\text{Mass of solvent (in kg)}} = \frac{40/40}{\frac{(100-40)}{1000}} = \frac{40}{40} \times \frac{1000}{60} = 16.66\text{ m}$$

Illustration-11 : The molarity of $NaNO_3$ solution is 1 M. The density of solution is 1.25 g/ml. Calculate molality of solution.
(a) 0.727 (b) 0.858 (c) 0.622 (d) 0.585

Solution : (b) 1 M means that 1 mole of $NaNO_3$ (i.e. 85 g) is present in 1000 ml of solution.
Mass of solution = Volume of solution × density
= 1000 × 1.25 = 1250 g
Mass of solvent = Mass of solution – Mass of solute

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$= 1250 - 85$

$= 1165\,g$

$$\text{Molality (m)} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent (in kg)}} = \frac{1}{1165/1000} = \frac{1000}{1165} = 0.858\,m$$

Student Task -4

1. A solution is prepared by adding 2 g of a substance A to 18 g of water. calculate the mass per cent of solute.
   (a) 8% (b) 9% (c) 10% (d) 11%
2. A sample of nitric acid is 69% by mass and it has a concentration of 15.44 moles per litre. Its density is
   (a) 1.86 g/cc (b) 1.41 g/cc (c) 2.60 g/cc (d) 1.02 g/cc
3. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70% HNO_3.
   (a) 45.0 g conc. HNO_3 (b) 90.0 g conc. HNO_3 (c) 70.0 g conc. HNO_3 (d) 54.0 g conc. HNO_3

Ans.: 1. (c) 2. (b) 3. (a)

NORMALITY(N)

The normality is the number of equivalents of solute present in one litre (1 dm^3) of the solution

$$N = \frac{1000 \times w_1}{E_1 V(\text{in ml})}$$

Normality = Molarity × n-factor

n-factor : Factor relating molecular weight and equivalent weight n-factor = M / E.

$$\boxed{\text{Equivalent weight} = \frac{MW}{n-\text{Factor}}}$$

The n-factors in case of acids and bases are basicity and acidity respectively, in case of salt is the charge on cation or anion, in case of ions, is the charge on the ions, in case of oxidising agent and reducing agents is the change of oxidation number per mole of the substances.

➤ **Mole fraction** : Suppose, n is the moles of solute and N is the moles of solvent, then,

$$\text{Mole fraction of solute } (X_{solute}) = \frac{n}{n+N}$$

$$\text{Mole fraction of solvent } (X_{solvent}) = \frac{N}{n+N}$$

$$X_{solute} + X_{solvent} = 1$$

$$\left(\text{where, } n = \frac{\text{weight of solute (in g)}}{\text{Molecular weight of solute}}, N = \frac{\text{weight of solvent (in g)}}{\text{Molecular weight of solvent}}\right)$$

Molality can be calculated from mole fraction as follows :

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{Moles of solvent}} \times \frac{1000}{\text{molecular mass of solvent}}$$

$$= \frac{X_{solute}}{X_{solvent}} \times \frac{1000}{\text{molecular mass of solvent}}$$

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$$\text{ppm} = \frac{m_{solute}}{m_{solution}} \times 10^6 \quad \text{(ppm = parts per million)}$$

$$\text{ppb} = \frac{m_{solute}}{m_{solution}} \times 10^9 \quad \text{(ppb = parts per billion)}$$

$$\text{ppt} = \frac{m_{solute}}{m_{solution}} \times 10^{12} \quad \text{(ppt = parts per trillion)}$$

Relation between Molarity (M), Molality (m) and density of solution (d gm/mL)

Let molarity = M, Molecular mass of solute = M'

⇒ M moles of solute is present in 1 litre solution.

⇒ MM' gm of solute is present in 1000 mL solution

⇒ MM' gm of solute is present in 1000 d gm of solution

Mass of solvent (in gm) = mass of solution – mass of solute

Mass of solvent (in gm) = 1000 d – MM'

$$\text{Mass of solvent (in kg)} = \frac{1000d - MM'}{1000}$$

$$\text{molality (m)} = \frac{\text{moles of solute}}{\text{mass of solvent (in kg)}} \quad \text{or} \quad m = \frac{M}{\frac{1000d - MM'}{1000}} \quad \text{or} \quad \frac{1000d - MM'}{1000} = \frac{M}{m}$$

$$\text{or} \quad d - \frac{MM'}{1000} = \frac{M}{m} \quad \text{or} \quad d = \frac{M}{m} + \frac{MM'}{1000}$$

$$\text{or} \quad d = M\left(\frac{1}{m} + \frac{M'}{1000}\right)$$

9. EQUIVALENT WEIGHT

Equivalent Weight: Equivalent weight of a substance (element or compound) is defined as " the number of part by weight of it, that will combine with or displace directly or indirectly 1.008 parts by weight of hydrogen, 8 parts by weight of oxygen, 35.5 parts by weight of chlorine, 108 parts by weight of silver or the equivalent parts by weight of any other element.

Methods of determination of equivalent weights:

(i) **Hydrogen displacement method:** This method is used to determine equivalent weight of those metals which can displace H_2 gas when treated with dil H_2SO_4 or HCl.

Example: Ca, Zn, Sn, Mg, etc.

Procedure: Metal + $H_2SO_4 \rightarrow H_2$

W_1 gm V_1ml (Convert to STP then to Weight)

$$\text{E.W. of Metal} = \frac{\text{Weight of metal taken}}{\text{Weight of } H_2 \text{ evolved at STP}}$$

Illustration-12: 0.205 gm of a metal on treatment with dil HCl evolved 106.6 ml of H_2 gas collected over water at 755 mm pressure at 17°C. The equivalent weight of metal is (Given Aqueous tension at 17°C = 14.4 mm-Hg)

(a) 23.5 (b) 26 (c) 18 (d) 16

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Solution :(a) Pressure of H_2 gas = 755-14.4 = 740.6mm-Hg

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2} \text{ or } \frac{740.6\times106.6}{273+17}=\frac{760\times V_2}{273}, v_2=97.72ml$$

Weight of H_2 gas = $\frac{2}{22400}\times97.72$ E.W = 23.5

(ii) Oxide formation method: This method is used for those metals which can form their oxides relatively easy.

Example: Ca, Mg, Hg, Zn

Problem : $\underset{(W_1g)}{\text{Metal}} + \text{oxygen} \rightarrow \underset{(W_2g)}{\text{Metal oxide}}$, $\underset{(W_1g)}{\text{Metal}} + \text{Nitric Acid} \rightarrow \text{metal nitrate} \rightarrow \underset{(W_2g)}{\text{Metal oxide}} + NO_2$

$$\text{E.W of Metal} = \frac{W_1}{W_2-W_1}\times8$$

Illustration-13 : 0.4 gm of metal when heated in air gave 0.72 gm of metal oxide. The equivalent wt of metal is

(a) 20 (b) 10 (c) 30 (d) 40

Solution : (b) $EW=\frac{0.4}{0.72-0.4}\times8=10$

(iii) Oxide reduction method: It is used for those metals whose oxide can be reduced easily

Example: Fe, Sn, etc.

Procedure: Metal oxide $+H_2 \rightarrow \text{Metal} + H_2O$

W_1 gm W_2 gm

$$\text{E.W. of Metal} = -\frac{W_2}{W_1-W_2}\times8$$

(iv) Chloride formation method: This method is used for those metals which form their chlorides easily.

Example: Na, K, Ag, Au etc.

Procedure: $\underset{W_1 \text{ gm}}{\text{Metal}} + \text{Chlorine} \rightarrow \underset{W_2 \text{ gm}}{\text{Metal chloride}}$

$$\text{E.W of Metal} = \frac{W_1}{W_2-W_1}\times35.5$$

(V) Double decomposition method: This method enables us to find equivalent weight of not only the compound but also of their component ions. It is based on law of equivalence

Procedure: AB + CD $\rightarrow$ AD + CB Applying Law of Equivalence

$$\frac{W_{AB}}{W_{CB}}=\frac{EW_{AB}}{EW_{CB}}=\frac{EW_A+EW_B}{EW_C+EW_B}$$

Illustration-14 : 1.435 gm of AgCl was obtained by treating 1.70 gm of $AgNO_3$ with excess NaCl . The equivalent weight of NO_3^- ion is

(a) 31 (b) 60 (c) 62 (d) 40

Solution : (c) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

Applying Law of Equivalence

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$$\frac{WAgNO_3}{W_{AgCl}}=\frac{EW_{Ag^+}+EW_{NO_3^-}}{EW_{Ag^+}+EW_{Cl^-}} \quad \Rightarrow \frac{1.70}{1.435}=\frac{108+E_{NO_3^-}}{108+35.5}, E_{NO_3^-}=62$$

(vi) **Metal Displacement method:** This is used for metals which can displace other less reactive metal from its salt solution. It is also based on law of Equivalent.

Procedure: Metal 'A' (W_1 gm) + Salt of metal 'B' → Metal 'B' (W_2 gm) + Salt of Metal 'A'

Applying Law of Equivalent. $\frac{W_A}{W_B}=\frac{EW_A}{EW_B}$

Illustration-15 : 1.296 gm of silver metal was displaced when 0.39 gm of copper was added to a solution of Ag Salt . Find EW of

(a) 32.5 (b) 30 (c) 35.5 (d) 38

Solution :(a) $\frac{W_{Cu}}{W_{Ag}}=\frac{E_{Cu}}{E_{Ag}}$ or $\frac{0.39}{1.296}=\frac{E_{Cu}}{108}$ or $E_{Cu}=32.5$

Student Task -5

1. When a metal forms its oxide there is 20% by mass gain. The equivalent weight of metal is

(a) 20 (b) 40 (c) 30 (d) 8

2. Two oxides of a metal contain 36.4% and 53.4% of oxygen by mass respectively. If the formula of first oxide is M_2O then that of the second is

(a) M_2O_3 (b) MO (c) MO_2 (d) M_2O_5

Ans. : **1. (b)** **2. (c)**

10. n-FACTOR AND PRINCIPLE OF EQUIVALENCE

n-Factor: It is an interconversion factor & is expressed as below.

$$n-Factor=\frac{N}{M}=\frac{Number\ of\ equivalents}{Number\ of\ moles}=\frac{MW}{EW}$$

n-Factor depends on nature of substance

S.N	Substance	n-Factor
1.	Element	Valency of Element
2.	Ion	Charge on ion
3.	Salt	Total cationic charge
4.	Acid	Basicity (No. of replaceable H^+ ion
5.	Base	Acidity (No. of replaceable OH^- ion
6.	Oxiding agent	No. of moles of e^- gained by 1 mole OA
7.	Reducing agent	No. of moles of e^- lost by 1 mole RA

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Note: (i) n. Factor of same substance can be different.
(ii) n Factor is valid per mole of substance

Law of Equivalents: According to this law two substances react in equal number of equivalents and form products in same number of equivalents.

Case I. A + B → C + D

Equivalents of A = Equivalent of B = Equivalent of C = Equivalent of D

$N_AV_A = N_BV_B = N_CV_C = N_DV_D$

$$\frac{W_A}{E_A} = \frac{W_B}{E_B} = \frac{W_C}{E_C} = \frac{W_D}{E_D}$$

Case II. A + B + C → D

Equivalent of A + Equivalent of B = Equivalent of C

[Condition both A & B react with C but do not react with each other]

Case III. A + B → C + D

C + E → F + G

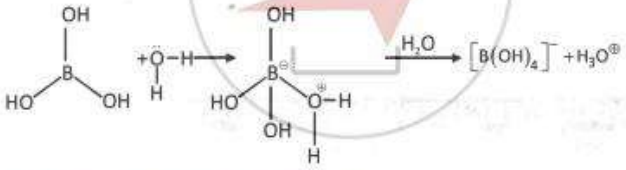
Equivalent of A = Equivalent of B = Equivalent of C = Equivalent of E

[Valid if n-Factor of 'C' is same in both reactions]

Illustration-16 : What is equivalent weight of H_3BO_3. Assume molar mass to be M.

(a) M (b) $\frac{M}{3}$ (c) 3M (d) 2M

Solution :(a)



n- Factor of H_3BO_3 is 1 Hence $EW = \frac{MW}{n_f} = \frac{M}{1} = M$

Illustration-17 : What volume of $\frac{M}{10}H_2SO_4$ reacts with 100 ml $\frac{M}{10}$ NaOH

(a) 25 ml (b) 50 ml (c) 100 ml (d) 200 ml

Solution : (b)

H_2SO_4 NaOH

$N_1V_1 = N_2V_2$

$M_1n_1V_1 = M_2n_2V_2$

$\frac{1}{10} \times 2 \times V_1 = \frac{1}{10} \times 1 \times 100$

$V_1 = 50$ ml

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Student Task -6

1. What mass of $CaCO_3$ reacts completely with 100 mL 0.1 M H_2SO_4. (Molar mass of $CaCO_3$ = 100)
   (a) 5 g (b) 10 g (c)30 g (d)50 g
2. What is equivalent weight of H_2SO_4 in the reaction (M. Mass of H_2SO_4 = 98 gm.)
   $NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$
   (a) 98 g (b) 49 g (c) 50 g (d) 97g
3. 1.2 g mixture of Na_2CO_3 and K_2CO_3 was dissolved in water to form 100 cm^3 of a solution. 20 cm^3 of this solution required 40 cm^3 of 0.1 N HCl for neutralisation. Calculate the weight of Na_2CO_3 .
   (a) 0.6 g (b) 0.3 g (c) 0.5 g (d) 6 g

Ans.: 1. (b) 2. (a) 3. (a)

11. METHODS TO DETERMINE ATOMIC MASS

(i) By Equivalent mass : By application of the relation: $\boxed{\text{At. mass} = \text{Eq. mass} \times \text{Valency}}$

Knowing approx. atomic mass and exact equivalent mass, first valency is calculated and then the exact atomic mass.

(ii) By Dulong and Petit's method: For solid elements (except Be, B, C and Si), according to **Dulong and Petit's law**

At. mass ×Specific heat = 6.4 approx. ∴ Approx. atomic mass $= \frac{6.4}{\text{Sp.heat}}$

Exact atomic mass = Eq. wt. ×Valency where Valency $= \frac{\text{Approx. atomic mass}}{\text{Eq.mass}}$ (Take nearest whole no.)]

(iii) From ratio of heat capacities. For gases, we have

Ratio ($\gamma = C_p / C_v$)	1.66	1.40	1.30	1.26
Atomicity	1	2	3	4

Molecular mass can be found from vapour density (Mol. mass = 2×V.D)

Atomic mass of the gaseous element = $\frac{\text{Mol. mass}}{\text{Atomicity}}$

(iv) Volatile chloride method: (Form vapour density measurements for elements forming volatile chlorides)
Molecular mass of the chloride = 2 ×V.D.
If x is the valency of the element (M), then formula of its chloride will be MCl_x. Hence,
Mol. mass of the chloride MCl_x = At. mass of M + 35.5x = x (E + 35.5)

$\therefore\ x(E + 35.5) = 2 \times \text{V.D.} \text{ or } x = \frac{2 \times \text{V.D.}}{E + 35.5}$

Knowing the equivalent mass E of the element, the value of x can be calculated. Then
Atomic mass = Eq. mass × Valency.

(v) Isomorphism method: Compounds having similar molecular formulae and identical crystal structure are called isomorphous. The method is based upon the fact that elements in isomorphous compounds have same valencies, e.g.,
(a) K_2SO_4, K_2CrO_4, K_2SeO_4 are iso-morphous. Hence, valency of S, Cr and Se= 6.
(b) $ZnSO_4.7H_2O$, $FeSO_4.7H_2O$,$MgSO_4.7H_2O$ are iso-morphous. Hence, valency of Zn, Fe, Mg = 2.

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Knowing valency, atomic mass = Eq. mass × Valency.

(vi) from percentage of an element in a given compound: For example, potassium chromate (K_2CrO_4) is found to contain 26.78% of Cr. Its atomic mass can be calculated as follows:

Suppose atomic mass of Cr = a

$\therefore$ Mol. mass of $K_2CrO_4 = 2\times39 + a + 4\times16 = 142 + a$

$\therefore$ % of Cr in K_2CrO_4 $\frac{a\times100}{142+a} = 26.78$ which on solving gives a = 52.0

Illustration-18 : The oxide of an element contains 67.67% of oxygen and the vapour density of its volatile chloride is 79. Calculate the atomic weight of the element.

(a) 14.00 (b) 14.82 (c) 15.28 (d) 15.00

Solution : (c) Calculation of equivalent weight: weight of oxygen = 67.67 g

Weight of element = 100-67.67 = 32.33g

$\because$ 67.67 g of oxygen combines with 32.33 g of element

$\therefore$ 8 g of oxygen combines with $\frac{32.33\times8}{67.67} = 3.82g$

$\therefore$ Equivalent weight of the element = 3.82

Suppose M represents one atom of the element and x is its valency. The molecular formula of the volatile chloride would be MCl_x.

Formula weight of chloride = $3.82\times x + 35.5\,x = 39.32\,x$

But molecular weight of chloride = 2 ×V.D. $\Rightarrow 39.32x = 2\times79 \Rightarrow x = \frac{2\times79}{39.32} = 4$

Now atomic weight = Equivalent weight ×valency of element = $3.82\times4 = 15.28$

Illustration-19 : Vapour density of a gas is 16. If the ratio of specific heat at constant pressure and specific heat at constant volume is 1.4. Then find out its atomic weight.

(a) 16 (b) 18 (c) 17 (d) 15

Solution : (a) Given : $\frac{C_p}{C_v} = 1.4 = \gamma$ and vapour density = 16

We know that Molecular weight = 2 ×vapour density

$\therefore$ Molecular weight = $2\times16 = 32$

Here $\gamma = 1.4$ so atomicity will be 2.

Atomic weight = $\frac{\text{Molecular weight}}{\text{Atomicity}} = \frac{32}{2} = 16$

Student Task -7

1. Specific heat of a metal is $0.031\frac{^\circ C\times cal}{g}$, and its equivalent weight is 103.6. Calculate the exact atomic weight of the metal.

(a) 207.2 (b) 206. 5 (c) 205. 3 (d) None of these

2. A chloride of an element contains 49.5% chlorine. The specific heat of the element is $0.064\frac{^\circ C\times cal}{g}$. Calculate the equivalent mass, valency and atomic mass of the element.

(a) 107 (b) 108.63 (c) 109 (d) 110

3. Potassium chromate is isomorphous to potassium sulphate (K_2SO_4). It is found to contain 26.78% chromium. Calculate the atomic mass of chromium (K=39.10)

(a) 58 (b) 52 (c) 48 (d) 49.

Ans. : 1. (a) 2. (b) 3. (b)

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12. GRAVIMETRIC ANALYSIS

Gravimetric analysis is an analytical technique based on the measurement of mass of solid substances and/or volume of gaseous species.

The gravimetric analysis is broadly classified into three heads.

(a) Mass – mass relationship,

(b) Mass – volume relationship and

(c) Volume – volume relationship.

A. MASS-MASS RELATIONSHIP

This relates the mass of a species (reactant or product) with the mass of another species (reactant or product) involved in a chemical reaction.

Let us consider a chemical reaction, $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$

Let the mass of $CaCO_3$ taken be x g and we want to calculate the mass of CaO obtained by heating x g $CaCO_3$.

Then the moles of $CaCO_3$ taken would be $\frac{x}{M_1}$ (where M_1 represents the molar mass of $CaCO_3$). According to the balanced reaction, the molar ratio of $CaCO_3$ and CaO is 1 : 1, so same number of moles $\left(\frac{x}{M_1}\right)$ of CaO would be formed. Now for converting the moles of CaO into mass of CaO obtained, we need to multiply the moles of CaO with the molar mass of CaO. Let the molar mass of CaO be M_2, so the mass of CaO obtained by heating x g of $CaCO_3$ would be $\left(\frac{x}{M_1} \times M_2\right)$ g.

B. MASS-VOLUME RELATIONSHIP

This establishes the relationship between the mass of a species (reactant or product) and the volume of a gaseous species (reactant or product) involved in a chemical reaction. Let us take x gm of $CaCO_3$ in a vessel of capacity V L and the vessel is heated so that $CaCO_3$ decomposes as

$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$

We want to find out the volume of CO_2 evolved at STP by heating x g of $CaCO_3$. Then

Moles of $CaCO_3 = \frac{x}{M_1}$

Moles of CO_2 evolved = $\frac{x}{M_1}$ (since molar ratio of $CaCO_3$ and CO_2 is 1 : 1)

$\therefore$ volume of CO_2 evolved at STP = $\left(\frac{x}{M_1} \times 22.4\right)$ L

But, if the volume of CO_2 evolved is to be calculated at pressure P atm and temperature T K. Then, moles of CO_2 evolved = $\frac{x}{M_1}$.

Volume of CO_2 evolved at pressure P and temperature T = $\frac{x}{M_1} \times \frac{RT}{P}$ (using PV = nRT).

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C. VOLUME-VOLUME RELATIONSHIP

This relationship deals with the volume of a gaseous species (reactant or product) with the volume of another gaseous species (reactant or product) involved in a chemical reaction.

Let us consider the reaction, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$. We are given x L of N_2 at pressure P atm and temperature T K and we want to know the volume of H_2 required to react with it at the same pressure and temperature.

$$\text{Moles of } N_2 = \frac{P \times x}{RT}$$

$$\text{Moles of } H_2 \text{ required} = \frac{3 \times P \times x}{RT} \text{ (since molar ratio of } N_2 \text{ \& } H_2 \text{ is 1 : 3)}$$

$$\therefore \text{ volume of } H_2 \text{ required at same pressure \& temperature} = \frac{3 \times P \times x \times RT}{RT \times P} = 3 \times L$$

This result could also have been obtained by knowing that for a gaseous reaction, at the same pressure and temperature, the moles of gas is directly proportional to volume of the gas ($V \propto n$ since P & T are constant) or molar ratio and volume ratio are same.

Thus, when x L of N_2 is taken at pressure P atm and temperature T K, then at the same pressure and temperature, the volume of H_2 required would be 3 x L (since the volume ratio of N_2 & H_2 would be same as molar ratio i.e. 1 : 3). But if the volume of H_2 required is to be calculated at another pressure P' atm and temperature T' K, then

$$\text{Moles of } H_2 \text{ required} = \frac{3 \times P \times x}{RT}$$

$\therefore$ volume of H_2 required at pressure P' atm & temperature T' K

$$= \frac{3 \times P \times x \times RT'}{RT \times P'} = \left(\frac{3x \times PT'}{P'T}\right) L$$

Illustration-20 : How much zinc should be added to 0.01 mol $AgNO_3$ solution to displace all the silver in the solution?

(a) 0.485 gm (b) 0.327 gm (c) 0.529 gm (d) 0.398 gm

Solution : (b) The involved balanced reaction would be

$Zn + 2AgNO_3 \rightarrow Zn(NO_3)_2 + 2Ag$

Moles of $AgNO_3$ in the solution = 0.01

Moles of Zn to be added to solution = 0.005

(since $AgNO_3$ and Zn are reacting in the molar ratio of 2 : 1)

$\therefore$ mass of Zn to be added to solution = 0.005 × 65.4 = 0.327 g

Illustration-21 : NaCl of 95% purity is used to prepare salt cake (Na_2SO_4) by the reaction, $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$ If the product (Na_2SO_4) is only 85% pure, what weight of NaCl is used up in producing 1 kg of the impure salt cake

(a) 678.2 gm (b) 982.1 gm (c) 737.2 gm (d) 528.1 gm

Solution :(c) Let the weight of NaCl used up in producing 1 kg of impure product be x g.

$$\text{Mass of pure NaCl} = \frac{x \times 95}{100}$$

$$\text{Moles of pure NaCl} = \frac{x \times 95}{100 \times 58.5}$$

$$\text{Moles of pure } Na_2SO_4 = \frac{x \times 95}{100 \times 58.5} \times \frac{1}{2}$$

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Mass of pure $Na_2SO_4 = \frac{x \times 95}{100 \times 58.5} \times \frac{1}{2} \times 142 = \frac{1000 \times 85}{100}$

$\therefore x = 737.2$ g

Illustration-22: $KClO_3$ decomposes on heating in two possible ways as

$$KClO_3 \xrightarrow{\Delta} KCl + 3/2\ O_2$$

$$4KClO_3 \xrightarrow{\Delta} KCl + 3KClO_4$$

when 15 g of $KClO_3$ were heated in an experiment, analysis of the product showed that 5.21 g of KCl and 4.59 g of $KClO_4$ were formed. What was the weight of $KClO_3$ remaining undecompossed?

(a) 2.90 gm (b) 2.36 gm (c) 3.52 gm (d) 2.00 gm

Solution : (b) In order to calculate the weight of $KClO_3$ remaining undecomposed, we need to find out the total weight of $KClO_3$ that decomposes. The weight of $KClO_3$ that decomposes in second reaction would be known using the $KClO_4$ data. Using $KClO_4$ data, we would also calculate the weight of KCl obtained in second reaction. Since, total weight of KCl obtained is known to us, so the weight of KCl obtained in first reaction would also be known, using this we will find out the weight of $KClO_3$ decomposed in first reaction.

Moles of $KClO_4$ obtained $= \frac{4.59}{138.5}$

Moles of KCl obtained in IInd reaction $= \frac{4.59}{138.5} \times \frac{1}{3} = 0.011$ (since molar ratio of $KClO_4$ and KCl in IInd reaction is 3 : 1)

Moles of $KClO_3$ that decomposes in IInd reaction $= \frac{4.59}{138.5} \times \frac{4}{3}$ (since molar ratio of $KClO_4$ and $KClO_3$ in IInd reaction is 3 : 4)

$\therefore$ mass of $KClO_3$ that decomposes in IInd reaction $= \frac{4.59}{138.5} \times \frac{4}{3} \times 122.5 = 5.41$ g

Moles of KCl obtained in Ist reaction $= \left(\frac{5.21}{74.5} - 0.011\right) = 0.07 - 0.011 = 0.059$

Moles of $KClO_3$ that decomposes in Ist reaction = 0.059
(since molar ratio of KCl and $KClO_3$ in Ist reaction is 1 : 1)
Mass of $KClO_3$ that decomposes in Ist reaction = 0.059 × 122.5 = 7.23 g
Total mass of $KClO_3$ that decomposes in both the reactions = (5.41 + 7.23) = 12.64 g
$\therefore$ mass of $KClO_3$ that remain undecompossed = 15 – 12.64 = **2.36 g**

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Student Task -8

1. Stoichiometric ratio of sodium dihydrogen orthophosphate and sodium hydrogen orthoposphate required for the synthesis of $Na_5P_3O_{11}$ is
   (a) 1.5:3 (b) 3 : 1.5 (c) 1 : 1 (d) 2 : 3
2. An aqueous solution containg 6.5 g of NaCl of 90% purity was subjected to electrolysis. After the complete electrolysis, after the complete electrolysis, the solution was evaporated to get solid NaOH. The volume of 1 M acetic acid required to neutralise NaOH obtained above is
   (a) 1000 cm^3 (b) 2000 cm^3 (c) 100 cm^3 (d) 200 cm^3
3. The weight of iron which will be converted into its oxide (Fe_3O_4) by the action of 18 g of steam on it will be (Atomic weight of Fe = 56)
   (a) 168 g (b) 84 g (c) 42 g (d) 21 g

Ans.: 1. (b) 2. (c) 3. (c)

13. POAC (PRINCIPLE OF ATOM CONSERVATION)

According to this principle during a reaction atoms remain conserved. It is only valid to the actual amount of reactant which is reacted.

Example: For a compound Ax By

Mole of A = x × moles of Ax By taken

Mole of B = y × moles of Ax By taken

or y × moles of A = x ×moles of B

Illustration-23 : A mixture of magnesium chloride and magnesium sulphate is known to contain 0.6 moles of chloride ion and 0.2 moles of sulphate ions. For quantitative estimation of Mg, above mixture is treated with set of reagents to form $Mg_2P_2O_7$, moles of $Mg_2P_2O_7$ produced is:
(a) 0.5 (b) 0.25 (c)0.8 (d) 0.7

Solution : (b) 0.6 mole $Cl^- \Rightarrow$ 0.3 mol $MgCl_2$

0.2 mol $SO_4^{2-} \Rightarrow$ 0.2 mol $MgSO_4$

POAC on Mg

$0.3\times1+0.2\times1=n\times2$

Illustration-24 : One mole mixture of FeO and Fe_3O_4 containing equal moles of each on reaction with excess O_2 gives n moles of Fe_2O_3. n is:
(a) 1 (b) 2 (c) $\frac{2}{3}$ (d) None of these

Solution :(a) $\frac{1}{2}\times1+\frac{1}{2}\times3=n\times2$(POAC on Fe)

Student Task -9

1. Human lungs can absorb 8 gm O_2 per hour by respiration . If all oxygen atoms are converted to carbohydrates ($C_6H_{12}O_6$) how long will it take to produce 180 gm $C_6H_{12}O_6$?
   (a) 8 hours (b) 12 hours (c) 10 hours (d) 6 hours
2. A 1.50 g sample of an ore containg silver was dissolved, and all of the Ag was converted to 0.124 g of Ag_2S. What was the percentage of silver in the ore?
   (a) 6.41% (b) 7.20 % (c) 8.27% (d) 10.8

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3. 1.44 gram of Titanium (Ti) reacted with excess of O_2 and produced x gram of non-stoichiometric compound $Ti_{1.44}O$. the value of x will be: [Ti =48]
(a) 2.77 g (b)3.77 g (c) 1.77 g (d) 3.0 g

Ans.: 1. (b) 2. (b) 3. (c)

14. THE LIMITING REAGENT

Let the initial moles of MnO_2 and HCl be $\dot{n}_{MnO_2}$ and $\dot{n}_{HCl}$ respectively

Thus, in the given chemical reaction, after infinite time, one of the reactants will be completely consumed while the other would be left in excess. Thus, the reactant which is completely consumed when a reaction goes to completion and which decides the yield of the product is called limiting reagent.

For example, if in the given case $\dot{n}_{HCl} > 4\dot{n}_{MnO_2}$, and there is no $MnCl_2$ and H_2O in the beginning, then

	MnO_2 +	$4HCl \rightarrow$	$MnCl_2$ +	Cl_2 +	$2H_2O$
Initially	$\dot{n}_{MnO_2}$	$\dot{n}_{HCl}$	0	0	0
After ∞ time	0	$\dot{n}_{HCl} - 4\dot{n}_{MnO_2}$	$\dot{n}_{MnO_2}$	$\dot{n}_{MnO_2}$	$2\dot{n}_{MnO_2}$

Thus, MnO_2 is the limiting reagent and the yield of all the products is governed by the amount of MnO_2 taken initially.

Similarly, if in the given case $\dot{n}_{HCl} < 2\dot{n}_{MnO_2}$ and no $MnCl_2$, Cl_2 & H_2O are present initially, then

	MnO_2 +	$4HCl \rightarrow$	$MnCl_2$ +	Cl_2 +	$2H_2O$
Initially	$\dot{n}_{MnO_2}$	$\dot{n}_{HCl}$	0	0	0
After ∞ time	$2\dot{n}_{MnO_2} - \frac{\dot{n}_{HCl}}{4}$	0	$\frac{\dot{n}_{HCl}}{4}$	$\frac{\dot{n}_{HCl}}{4}$	$\frac{\dot{n}_{HCl}}{2}$

Here, HCl would become limiting reagent & the products yield are decided by the amount of HCl taken initially.

Illustration-25 : The reaction, $2C + O_2 \rightarrow 2CO$ is carried out by taking 24 g of carbon and 96 g O_2, find out the mole of CO formed?

(a) 2 (b) 5 (c) 4 (d) 3

Solution : (a)

	2C +	$O_2 \rightarrow$	2CO
Mole before reaction $\frac{24}{12} = 2$ $\frac{96}{32} = 3$	2	3	0
Mole after reaction	0	2	2

$\because$ mole ratio of $C : O_2 : CO :: 2 : 1 : 2$; So, 2 mole of CO or 56 gm CO is formed

Illustration-26: A sample of Mg was burnt in air to give a mixture of MgO and Mg_3N_2. The ash was dissolved in 60 Meq of HCl and the resulting solution was back titrated with NaOH. 12 Meq of NaOH were required to react the end point. An excess of NaOH was then added and the solution distilled. The ammonia released was then trapped in 10 Meq of second acid solution. Back titration of this solution required 6 Meq of the base. Calculate the percentage of Mg burnt to the nitride.

(a) 30.01% (b) 28.00% (c) 27.27% (d) 27.98%

Solution : (c) Let total milli-mole of Mg used for MgO and Mg_3N_2 be a and b respectively.

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	$2Mg + O_2$	$\rightarrow$	$2MgO$
Before reaction	a		0
After reaction	0		a
	$3Mg + N_2$	$\rightarrow$	Mg_3N_2
Before reaction	b		0
After reaction	0		b/3

Now (a + b/3) , milli-mole of MgO and Mg_3N_2 are present in the mixture.

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$; $Mg_3N_2 + 8HCl \rightarrow 3MgCl_2 + 2NH_4Cl$

or the solution contains a milli-mole of $MgCl_2$ from MgO and b milli-mole of $MgCl_2$ from Mg_3N_2 and $\frac{2b}{3}$ milli-mole of NH_4Cl.

Also milli-mole of HCl used for this purpose = $2a + \frac{8b}{3}$

for MgO for Mg_3N_2

Now milli-mole of HCl or Meq of HCl (monobasic acid) = 60 – 12 = 48

$$2a + \frac{8b}{3} = 48 \quad \text{.....(1)}$$

Further, milli-mole of NH_4Cl formed = milli-mole of NH_3 liberated
= milli-mole of HCl used for absorbing NH_3

$$\therefore \quad \frac{2b}{3} = 4 \text{ or } \quad b = 16 \quad \text{.....(2)}$$

From (1) $2a + \frac{8 \times 6}{3} = 148$ or $a = 16$

Thus, % of Mg used for $Mg_3N_2 = \frac{6}{(6+16)} \times 100 = \mathbf{27.27\%}$

15. EMPIRICAL AND MOLECULAR FORMULAE

Empirical Formula: the empirical formula of a compound is the chemical formula which expresses the simplest whole number ratio of the atoms of the various elements present in one molecule of the compound.

Molecular formula: The molecular formula of a compound is the chemical formula which represents the true formula of its molecule. It expresses the actual number of atoms of various elements present in one molecule ofthe compounds.

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S.No.	compound	MolecularFormula	EmpiricalFormula
1	Benzene	C_6H_6	CH
2	Acetylene	C_2H_2	CH
3	Glucose	$C_6H_{12}O_6$	CH_2O
4	Formaldehyde	CH_2O	CH_2O

Note: (i) Two different compounds can have same empirical formulae

(ii) A compound can have same empirical fomula & molecular formula.

Relation Between Empirical and Molecular Formulae

Molecular formula = n ×Empirical formula

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$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$, Molecular mass = 2 × Vapour density.

Quantitative analysis of organic compounds

1. Estimation of carbon and hydrogen : By **Leibig's** combustion method.

$$\%\text{ of C} = \frac{12}{44} \times \frac{\text{Mass of } CO_2}{\text{Mass of organic compound}} \times 100$$

2. Estimation of nitrogen : There are two methods for the estimation of nitrogen.

- **Duma's method**

$$\therefore \quad \%\text{ of N} = \frac{28}{22400} \times \frac{\text{Volume of } N_2 \text{ at N.T.P.}}{\text{Mass of organic compound}} \times 100$$

- **Kjeldahl's method** : This method cannot be used for
  - Organic compounds containing nitrogen in the ring such as pyridine, quinoline, etc.
  - Organic compounds containing nitrogen (-NO_2) and diazo (-N=N-) groups.

$$\%\text{ of N} = \frac{1.4 \times N \times V}{W}$$

N = Normality of acid.
V = Volume of acid used for neutralisation of NH_3.
W = Weight of organic substance.

3. Estimation of halogens: By **Carius** method.

$$\%\text{ of X} = \frac{\text{Atomic mass of halogen} \times \text{Mass of silver halide}}{(108 + \text{At. mass of halogen}) \times \text{Mass of organic compound}} \times 100$$

$$\text{(i) \% of Cl} = \frac{35.5}{143.5} \times \frac{\text{Mass of AgCl}}{\text{Mass of organic compound}} \times 100$$

$$\text{(ii) \% of Br} = \frac{80}{188} \times \frac{\text{Mass of AgBr}}{\text{Mass of organic compound}} \times 100$$

$$\text{(iii) \% of I} = \frac{127}{235} \times \frac{\text{Mass of AgI}}{\text{Mass of organic compound}} \times 100$$

$$\%\text{ of Sulphur} = \frac{\text{Mass of sulphur}}{\text{Mass of organic compound}} \times 100$$

4. Estimation of sulphur : By **Carius** method.

$$\%\text{ of S} = \frac{32}{233} \times \frac{\text{Mass of } BaSO_4}{\text{Mass of organic compound}} \times 100$$

5. Estimation of phosphorus : By **Carius** method.

$$\%\text{ of P} = \frac{62}{222} \times \frac{\text{Mass of Magnesium Pyrophosphate}}{\text{Mass of organic compound}} \times 100$$

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Illustration-27 : An organic compound has an empirical formula (CH_2O). Its vapour density is 45. The molecular formula of the compound is

(a) CH_2O (b) C_2H_5O (c) C_2H_2O (d) $C_3H_6O_3$

Solution :(d) Mol. wt. = 2×vapour desity = 2×45=90

Empirical formula weight = 12+2 +16 =30

$$\therefore \quad n=\frac{\text{mol.wt.}}{\text{empirical formula wt.}}=\frac{90}{30}=3$$

$\therefore$ Molecular formula of the compound = $(CH_2O)_3 = C_3H_6O_3$

Illustration-28 : In Duma's method for estimation of nitrogen, 0.3 g of an organic compound gave 50 mL of nitrogen collected at 300 K temperature and 715 mm pressure. The percentage composition of nitrogen in the compound (Aqueous tension at 300 K = 15 mm) is

(a) 15.46% (b) 17.46% (c) 18.36 % (d) 28%

Solution :(b) volume of N_2 at STP is calculated followed by percentage of N_2 . volume of nitrogen collected at 300 K and 715 mm pressure is 50mL.

$$\text{Volume of nitrogen at STP} = \frac{p_1V_1\times 273}{760\times T_1}$$

Where, p_1 = actual pressure

= atmospheric pressure - aqueous tension

= 715 -15 = 700 mm

V_1 = volume of nitrogen 50 mL

T_1 = room temperature = 300 K

$$\text{Volume of nitrogen at STP} = \frac{273\times 700\times 50}{300\times 760}=41.9\,\text{mL}$$

22400 mL of N_2 at STP weighs = 28 g

$$\text{41.9 mL of nitrogen weighs} = \frac{28\times 41.9\times 100}{22400\times 0.3}=17.46\%$$

Student Task -10

1. In the Kjeldahl's method for estimation of nitrogen present in a soil sample, ammonia evolved from 0.75 g of sample neutralised 10 mL of 1 M H_2SO_4. The percentage of nitrogen in the soil is

(a)37.33 (b) 45.33 (c) 35.33 (d) 45.33

2. An organic compound containing C, H and O has 49.3% carbon, 6.84% hydrogen and its vapour density is 73. Molecular formula of the compound is

(a) $C_3H_5O_2$ (b) $C_4H_{10}O_2$ (c) $C_6H_{10}O_4$ (d) $C_3H_{10}O_2$

3. For the reaction, $X+2Y\rightarrow Z$, 5 moles of X and 9 moles of Y will produce

(a) 5 moles of Z (b) 8 moles of Z (c) 14 moles of Z (d) 4.5 moles of Z

Ans.: **1. (a)** **2. (c)** **3. (d)**

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16. SEQUENTIAL REACTION ,PARALLEL REACTION, PERCENTAGE YIELD

Sequential Reaction: In these reactions, a reactant gives a product which in turn further reacts to give another product & so on.

Example: $A \longrightarrow B \longrightarrow C \longrightarrow D$.

Parallel reaction: In these reactions, a reactant gives two or more product by parallel path.

Example: $A \rightarrow B$, $A \rightarrow C$

Percentage yield: It is defined as;

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

Illustration-29 : (i) $Cl_2 + 2KOH \xrightarrow{50\%\,\text{Yield}} KCl + KClO + H_2O$

(ii) $3KClO \xrightarrow{70\%\,\text{Yield}} KICO_3 + 2KCl$

(iii) $4KClO_3 \xrightarrow{60\%\,\text{Yield}} 3KClO_4 + KCl$

Find the weight of Cl_2 needed for production of 100 gm $KClO_4$

(a) 936.4 gm (b) 436.4 gm (c) 976.25 gm (d) 536.6 gm

Solution :(c) Let moles of Cl_2 required is 'n'.

$$\text{Moles of } KClO_4 = n \times \frac{50}{100} \times \frac{1}{3} \times \frac{70}{100} \times \frac{3}{4} \times \frac{60}{100}$$

$$\text{or } \frac{100}{138.5} = n \times \frac{50}{100} \times \frac{1}{3} \times \frac{70}{100} \times \frac{3}{4} \times \frac{60}{100}$$

or n = 13.75 moles

Hence weight of Cl_2 = 13.75×71 = 976.25 gm

Illustration-30 : When 12 gm carbon reacts with 20 gm O_2 then CO & CO_2 are formed. The weight of CO & CO_2 formed are

(a) 21 gm , 11 gm (b) 11 gm, 21 gm (c) 6 gm, 8gm (d) 12 gm, 10 gm

Solution :(b)

$$C + \frac{1}{2}O_2 \rightarrow CO \xrightarrow{\frac{1}{2}O_2} CO_2$$

Initially:	1 Mole (L.R)	0.625 mole	-	-
Finally:	0	0.625-0.5	1 mole	-
Further:	0	0.125	1-0.25	0.25

$$\text{Moles of } CO_2 = \frac{1}{4} = 44 \times \frac{1}{4} = 11\text{gm}$$

$$\text{Moles of CO} = \frac{3}{4} = 28 \times \frac{3}{4} = 21\text{gm}$$

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Student Task -11

1. In the set of reaction given below find moles of D formed if initially moles of A is 1.
   (i)$2A \rightarrow 5B$, (ii)$3B \rightarrow 2C$, (iii)$5C \rightarrow 7D$
   (a) 7/3 (b) 5/7 (c) 3/5 (d) 5/3
2. Following sequence of reactions occur when initially 2 moles of 'A' are taken. The moles of 'E' will be
   (i) $3A \xrightarrow{60\%\text{Yield}} 5B$ (ii)$2B \xrightarrow{70\%\text{Yield}} 7C + 2D$ (iii) $5C \xrightarrow{50\%\text{Yield}} 3E + 2F$
   (a) 3.56 (b) 2.92 (c) 1.47 (d) 4.32
3. When 12 gm carbon reacts with O_2, $\frac{3}{4}$ mole of CO & $\frac{1}{4}$ mole of CO_2 are formed. Find weight of O_2 used.
   (a) 10 gm (b) 5 gm (c) 20 gm (d) 25 gm

Ans.: **1. (a)** **2. (c)** **3. (c)**

17. SOME IMPORTANT REACTION

There are some chemical reactions, which a student should remember in order to solve problems on stoichiometry. These are categorised as

A. COMBINATION OF ELEMENTS WITH OXYGEN

(i) Heating mercury at its boiling point in air.
$Hg + O_2 \rightarrow 2HgO$ (red mercuric oxide)

(ii) Heating magnesium in air. It forms mostly magnesium oxide and some magnesium nitride.
$2Mg + O_2 \rightarrow 2MgO$
$3Mg + N_2 \rightarrow Mg_3N_2$

(iii) Calcium behaves similarly.
$2Ca + O_2 \rightarrow 2CaO$
$3Ca + N_2 \rightarrow Ca_3N_2$

(iv) Silver does not combine with oxygen, as Ag_2O is unstable to heat.

(v) Many non-metals burn in O_2 forming their respective oxides.
$2H_2 + O_2 \rightarrow 2H_2O$; $S + O_2 \rightarrow SO_2$; $P_4 + 5O_2 \rightarrow P_4O_{10}$
$C + O_2 \rightarrow CO_2$;
$N_2 + O_2 \xrightleftharpoons{3000^\circ C} 2NO$
Cl_2, Br_2 and I_2 do not directly combine with oxygen.

B. ACTION OF HEAT ON CERTAIN OXIDES

(i) Mercuric oxide and silver oxide are unstable to heat and decompose readily.
$2HgO \xrightarrow{\Delta} 2Hg + O_2$; $2Ag_2O \xrightarrow{\Delta} 4Ag + O_2$

(ii) Various higher oxides, dioxides, mixed oxides and peroxides are decomposed to oxygen and a lower oxide.
$2Pb_3O_4 \rightarrow 6PbO + O_2$; $2PbO_2 \rightarrow 2PbO + O_2$
$3MnO_2 \rightarrow Mn_3O_4 + O_2$; $2BaO_2 \rightarrow 2BaO + O_2$

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C. COMPOUNDS RICH IN OXYGEN DECOMPOSE TO GIVE OXYGEN

(i) $2KNO_3 \rightarrow 2KNO_2 + O_2\uparrow$

(ii) $\underset{\text{(purple)}}{2KMnO_4} \rightarrow \underset{\text{(green)}}{K_2MnO_4} + \underset{\text{(black)}}{MnO_2} + O_2\uparrow$

(iii) $\underset{\text{(orange-red)}}{4K_2Cr_2O_7} \rightarrow \underset{\text{(yellow)}}{4K_2CrO_4} + \underset{\text{(green)}}{2Cr_2O_3} + 3O_2\uparrow$

Potassium chlorate when heated just above its melting point decomposes into potassium perchlorate and potassium chloride. This reaction is called **disproportionation** or auto-oxidation and auto-reduction. On heating further, $KClO_4$ decomposes to KCl and oxygen.

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

$KClO_3 \rightarrow KCl + 2O_2$

D. ACTION OF HEAT ON NITRATES

Generally heavy metal nitrates decompose to metal oxides, reddish brown nitrogen dioxide gas and oxygen.

(i) Lead nitrate decomposes to PbO, NO_2 & O_2.

$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2\uparrow + O_2$

litharge or lead (II) oxide
(red when hot and yellow when cold)

(ii) Cupric nitrate decomposes to CuO, NO_2 & O_2.

$\underset{\text{(green)}}{2Cu(NO_3)_2} \rightarrow \underset{\text{(black)}}{2CuO} + 4NO_2 + O_2$

(iii) Zinc nitrate decomposes to ZnO, NO_2 & O_2.

$2Zn(NO_3)_2 \rightarrow 2ZnO + 4NO_2 + O_2$

(zinc oxide, yellow when hot and white when cold)

Knowing the colours of some oxides will be useful in qualitative analysis.

(iv) Nitrates of mercury and silver, whose oxides are unstable, decompose into the metals, NO_2 and O_2.

$Hg(NO_3)_2 \rightarrow Hg + 2NO_2 + O_2$

$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

(v) Alkali metal nitrates decompose to give the metal nitrites and O_2 (no reddish brown NO_2 gas).

$2KNO_3 \rightarrow 2KNO_2 + O_2$

$2NaNO_3 \rightarrow 2NaNO_2 + O_2$

(vi) Ammonium nitrate on heating leaves no residue and forms nitrous oxide and steam.

$NH_4NO_3 \rightarrow N_2O + 2H_2O$

E. ACTION OF HEAT ON AMMONIUM COMPOUNDS

Generally an ammonium compound decomposes into ammonia and an acid or acidic oxide if the acid is unstable to heat.

(i) $NH_4Cl \rightarrow NH_3 + HCl$

(ii) $(NH_4)_2SO_4 \rightarrow 2NH_3 + H_2SO_4$

(iii) $(NH_4)_3PO_4 \rightarrow 3NH_3 + H_3PO_4$

(iv) $(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$

(v) Ammonium compounds which do not give ammonia on heating are ammonium nitrate, ammonium nitrite and ammonium dichromate.

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$NH_4NO_3 \rightarrow N_2O + 2H_2O$

$NH_4NO_2 \rightarrow N_2 + 2H_2O$

$(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$ (Green fluffy chromic oxide)

F. ACTION OF HEAT ON METALLIC CARBONATES

(I) Generally metallic carbonates decompose to give metal oxides and CO_2.

$CaCO_3 \xrightarrow{900°C} CaO + CO_2\uparrow$

$MgCO_3 \rightarrow MgO + CO_2\uparrow$

$\underset{\text{(pale green)}}{CuCO_3} \rightarrow \underset{\text{(black)}}{CuO} + CO_2\uparrow$

$PbCO_3 \rightarrow \underset{\text{(yellow)}}{PbO} + CO_2\uparrow$

$ZnCO_3 \rightarrow ZnO + CO_2\uparrow$

(ii) Carbonates of strongly electropositive metals (alkali metals except lithium) do not decompose on heating.

(iii) Silver carbonate decomposes to give the metal, CO_2 & O_2.

$2Ag_2CO_3 \rightarrow 4Ag + 2CO_2 + O_2$

(iv) Ammonium carbonate (smelling salt) decomposes to given NH_3, H_2O & CO_2. All the products are in gaseous phase and there is no residue left.

$(NH_4)_2CO_3 \rightarrow 2NH_3 + H_2O + CO_2$

G. ACTION OF HEAT ON METALLIC BICARBONATES

Only $NaHCO_3$ and $KHCO_3$ are solids; others are known in solution. All bicarbonates decompose to give the metal carbonates, H_2O & CO_2.

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2\uparrow$

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2\uparrow$

$Mg(HCO_3)_2 \rightarrow MgCO_3 + H_2O + CO_2\uparrow$

H. ACTION OF HEAT ON CERTAIN HYTDRATED CHLORIDES

Hydrated halides on heating are converted to oxides, H_2O and halo acids.

(i) $MgCl_2.6H_2O$ does not get completely dehydrated because $MgCl_2$ is hydrolysed by water to give basic $MgCl_2$.

$MgCl_2.6H_2O \rightarrow Mg(OH)Cl + 5H_2O + HCl$

(ii) $Al_2Cl_6.12H_2O \rightarrow Al_2O_3 + 6HCl + 9H_2O$

(iii) $SnCl_2.2H_2O$ undergoes hydrolysis to form basic chloride.

$SnCl_2.2H_2O \rightarrow Sn(OH)Cl + H_2O + HCl$

(iv) On heating, certain halides of metal ions in higher oxidation state changes to halides of lower oxidation state.

$2FeCl_3 \rightarrow 2FeCl_2 + Cl_2$; $2CuCl_2 \rightarrow Cu_2Cl_2 + Cl_2$.

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I. ACTION OF HEAT ON SOME OTHER COMPOUNDS

(i) When sodium sulphite is heated, it undergoes disproportionation reaction.

$4Na_2SO_3 \rightarrow 3Na_2SO_4 + Na_2S$

(ii) Sodium thiosulphate $Na_2S_2O_3.5H_2O$ loses water of hydration and becomes anhydrous salt, which on further heating gives a mixture of sodium sulphate, sodium sulphide and sulphur.

$Na_2S_2O_3.5H_2O \rightarrow Na_2S_2O_3 + 5H_2O$

$4Na_2S_2O_3 \rightarrow 3Na_2SO_4 + Na_2S + 4S$

(iii) When hydrated copper sulphate (blue vitriol) is heated, CuO & SO_2 formed.

$CuSO_4.5H_2O \xrightarrow{100°C} CuSO_4.H_2O + 4H_2O$

$CuSO_4.H_2O \xrightarrow{230°C} CuSO_4 + H_2O$

$CuSO_4 \xrightarrow{750°C} CuO + SO_3$

$2SO_3 \rightarrow 2SO_2 + O_2$

(iv) Gypsum $CaSO_4.2H_2O$, when heated to 120 – 130°C forms a hemihydrate called Plaster of Paris.

$CaSO_4.2H_2O \rightarrow CaSO_4.1/2\ H_2O + 3/2\ H_2O$

If heated above 200°C, it forms anhydrous calcium sulphate which does not set with water.

(v) Green vitriol, $FeSO_4.7H_2O$, when heated forms Fe_2O_3, SO_2, SO_3 & H_2O

$2FeSO_4.7H_2O \rightarrow Fe_2O_3 + SO_2 + SO_3 + 14H_2O$

(vi) $\underset{\text{(Epsom salt)}}{MgSO_4 \cdot 7H_2O} \xrightarrow{\Delta} MgSO_4 + 7H_2O$

$MgSO_4 \xrightarrow{\Delta} MgO + SO_3$

(vii) $\underset{\text{(purple)}}{Al_2(SO_4)_3 \cdot 18H_2O} \xrightarrow{\Delta} \underset{\text{(white)}}{Al_2O_3} + 3SO_3 + 18H_2O$

(viii) $Cr_2(SO_4)_3 \cdot 18H_2O \xrightarrow{\Delta} \underset{\text{(green)}}{Cr_2O_3} + 3SO_3 + 18H_2O$

(ix) $\underset{\text{(yellow)}}{Fe_2(SO_4)_3} \xrightarrow{\Delta} \underset{\text{(blackish brown)}}{Fe_2O_3} + 3SO_3$

(x) $\underset{\text{(light green)}}{2FeSO_4} \xrightarrow{\Delta} Fe_2O_3 + SO_3 + SO_2$

J. ACID-BASE REACTIONS

(i) A strong acid liberates a relatively weaker acid from its salt. The common strong acids are perchloric acid, sulphuric acid, hydrochloric acid and nitric acid. The weaker acids are carbonic acid, sulphurous acid, hydrocyanic acid and most of organic acids. Thus concentrated sulphuric acid displaces most other acids from their salts.

$KCl + H_2SO_4 \rightarrow KHSO_4 + HCl$

$KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$

$Ca_3(PO_4)_2 + 2H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$

$CH_3CO_2Na + HCl \rightarrow CH_3CO_2H + NaCl$

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(ii) Almost all acids displace carbonic acid from carbonates and bicarbonates. Since carbonic acid is unstable, it decomposes liberating CO_2 with effervescence (Test for acids).

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2\uparrow$

$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2\uparrow$

$KHCO_3 + HNO_3 \rightarrow KNO_3 + H_2O + CO_2\uparrow$

(iii) A strong base can displace a weak base from a salt of strong acid and weak base.

$NH_4Cl + NaOH \rightarrow NaCl + NH_4OH.$

(iv) A salt of strong acid and strong base does not react with any acid or base.

K. SOME OTHER USEFUL REACTIONS

(i) $O_3 + 2KI + H_2O \rightarrow 2KOH + I_2 + O_2$

(ii) $BaCO_3 + 2HCl \rightarrow BaCl_2 + CO_2 + H_2O$

(iii) $BaCl_2 + H_2CrO_4 \rightarrow BaCrO_4 + 2HCl$

(iv) $2BaCrO_4 + 6KI + 8H_2SO_4 \rightarrow 3I_2 + 2BaSO_4 + 3K_2SO_4 + Cr_2(SO_4)_3 + 8H_2O$

(v) $2CuSO_4 + 4KI \rightarrow Cu_2I_2 + I_2 + 2K_2SO_4$

(vi) $2MnO^-_4 + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{+2} + 10CO_2 + 8H_2O$

(vii) $2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow 2MnSO_4 + 5Fe_2(SO_4)_3 + K_2SO_4 + 8H_2O$

(viii) $Mn_3O_4 + 2FeSO_4 + 4H_2SO_4 \rightarrow 3MnSO_4 + Fe_2(SO_4)_3 + 4H_2O$

(ix) $2NH_2OH + 4Fe^{3+} \rightarrow N_2O + H_2O + 4Fe^{2+} + 4H^+$

(x) $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

(xi) $KMnO_4 + 5KI + 4H_2SO_4 \rightarrow 3K_2SO_4 + MnSO_4 + 5/2\ I_2 + 4H_2O$

(xii) $K_2Cr_2O_7 + 6KI + 7H_2SO_4 \rightarrow 4K_2SO_4 + Cr_2(SO_4)_3 + 3I_2 + 7H_2O$

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UNSOLVED EXERCISE

Section-A
(Straight Objective Type)

LEVEL - I

Topic 1 : Based on Mole

1. 10 g $CaCO_3$ contains:
(a) 1.0 mole $CaCO_3$ (b) 1. g-atom of Ca
(c) 6×1.0^{22} atoms of Ca (d) 0.1 equivalent of Ca

2. Which of the following has highest mass?
(a) 20 g phosphorus
(b) 5 moles of water
(c) 2 equivalent of Na_2CO_3
(d) 1.2×10^{24} atoms of hydrogen

3. Specific volume of a cylindrical virus particle is 6.02×10^{-2} mL / g, having the radius and length 7Å and 1.0 Å respectively. What is the molecular weight of virus:
(a) 1.54 kg/mol (b) 1.54×10^{4} kg / mol
(c) 4.68×10^{4} kg / mol (d) 2.08×10^{4} kg / mol

4. Percentage of Se(at.wt = 78.4) in peroxidase anhydrous enzyme is 0.5% by weight. The minimum mol.wt. of enzyme is:
(a) 1.568×10^{3} (b) 1.568×10^{4}
(c) 25.68 (d) 4.316×10^{4}

5. What weight of NH_3 contains same number of atoms as in 4g-atom of oxygen:
(a) 17 g (b) 68 g
(c) 42 g (d) 34 g

6. The largest number of molecules is in:
(a) 36 g H_2O (b) 28 g CO
(c) 46g C_2H_5OH (d) 54 g N_2O_5

7. How many moles of electron weigh one kilogram?
(a) 6.023×10^{23} (b) $\frac{1}{9.108}\times10^{23}$
(c) $\frac{6.023\times10^{54}}{9.108}$ (d) $\frac{1}{9.108\times6.023}\times10^{8}$

8. Which has the maximum number of atoms?
(a) 24 g C (12) (b) 56 g Fe (56)
(c) 27 g Al (27) (d) 108 g Ag (108)

9. 20 g of an ideal gas contains only atoms of S and O occupies 5.6 L at 1 atm and 273 K. What is the molecular mass of gas?
(a) 64 (b) 80
(c) 78 (d) None of these

10. Total number of moles of oxygen atoms in 3 litre O_3 (g) at 27°C and 8.21. atm are:
(a) 3 (b) 2
(c) 4 (d) None of these

11. Rearrange the following (I to IV) in the order of increasing masses:
(I) 0.5 mole of O_3
(II) 0.5 gm atom of oxygen
(III) 3.011×10^{23} molecules of O_2
(IV) 5.6 litre of CO_2 at 1 atm and 273 K
(a) II < IV < III< I (b) II < I < IV < III
(c) IV < II < III < I (d) I < II < III < IV

Topic 2 : Equivalent Weight

12. In the combustion of 5.00 g of a metal, 9.44 g of metal oxide are formed. Hence, equivalent mass of the metal is
(a) 4.44 g (b) 9.00 g
(c) 5.00 g (d) 2.22 g

13. The same amount of a metal combines with 0.20 g of oxygen and with 3.17 g of a halogen. Hence equivalent mass of halogen is
(a) 7 g (b) 80 g
(c) 35.5 g (d) 9 g

14. Arsenic forms two oxides, one of which contains 65.2% and the other 75.7% of the element. Hence, equivalent masses of arsenic are in the ratio
(a) 1 : 2 (b) 3 : 5
(c) 13 : 15 (d) 2 : 1

15. A certain compound has the molecular formula X_4O_6. If 10g of X_4O_6 has 5.72 gX, atomic mass of X is
(a) 32 amu (b) 37 amu
(c) 42 amu (d) 98 amu

Topic 3 : Stoichiometry & Concentration Methods

16. 500 mL of 0.250 M Na_2SO_4 solution is treated with 15.00 g of $BaCl_2$. Moles of $BaSO_4$ formed are
(a) 0.72 (b) 0.072
(c) 0.168 (d) 0.0168

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17. If 0.30 mol of zinc are added to 0.52 mol of HCl, the moles of H_2 formed are
(a) 0.52 (b) 0.30
(c) 0.26 (d) 0.60

18. The mass of $CaCO_3$ is required to react with 25 mL of 0.75 M HCl is
(a) 0.94 g (b) 9.4 g
(c) 0.094 g (d) 0.49 g

19. Sulphur trioxide is prepared by the following two reactions :

$$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$$

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

How many grams of SO_3 are produced from 1 mol of S_8 ?
(a) 1280.0 (b) 640.0
(c) 960.0 (d) 320.0

20. One mole of potassium chlorate ($KClO_3$) is thermally decomposed and excess of aluminium is burnt in the gaseous product. How many moles of Al_2O_3 are formed
(a) 1 (b) 1.5
(c) 2 (d) 3

21. What volume of hydrogen gas at 273 K and 1 atm pressure will be consumed in obtaining 21.6 g of elemental boron (atomic mass = 10.8) from the reduction of boron trichloride by hydrogen?
(a) 44.8 L (b) 22.4 L
(c) 89.6 L (d) 67.2 L

22. When a 2.00 gm sample of rock containing lime stone was dissolved in acid 0.44 gm of CO_2 was generated. If the rock contains no carbonate other than $CaCO_3$, what was the percent of $CaCO_3$ by mass in the limestone?
(a) 50% (b) 64%
(c) 86% (d) 92%

23. A 7.66 g sample of hydrated sodium sulphate, $Na_2SO_4 . xH_2O$, forms 4.06 g of anhydrous Na_2SO_4. What is value of x

Molar mass ($gmol^{-1}$)	
Na_2SO_4	142

(a) 0.2 (b) 3.6
(c) 5 (d) 7

Topic 4 : Empirical and Molecular Formulas

24. A metal nitride M_3N_2 contains 28% of nitrogen The atomic mass of metal M is
(a) 24 (b) 54
(c) 9 (d) 87.62

25. Simplest formula of compound containing 50% of element X (at. mass 10) and 50% of element Y (at.mass 20) is
(a) XY (b) X_2Y
(c) XY_2 (d) X_2Y_3

26. A compound having the empirical formula$(C_3H_4O)_n$ has a molar mass of 170 $\pm$5. The molecular formula of this compound is
(a) C_3H_4O (b) $C_6H_8O_2$
(c) $C_6H_{12}O_3$ (d) $C_9H_{12}O_3$

27. Cortisone is a molecular substance containing 21 atoms of carbon per molecule. The mass percentage of carbon in cortisone is 69.98 %. What is the molar mass of cortisone?
(a) 176.5 (b) 252.2
(c) 287.6 (d) 360.1

28. A gaseous hydrocarbon on complete combustion gives 3.38 g of CO_2 and 0.690 g of H_2O and no other product. The empirical formula of the hydrocarbon is
(a) CH (b) CH_2
(c) CH_3 (d) The data is not complete

29. The molar mass of a crystalline compound is 200 g mol^{-1}. If it contains 45% of water of crystallization then number of water molecules of crystallization is
(a) 2.5 (b) 3
(c) 5 (d) 2

30. In a compound the mass ratio of N_2 to O_2 is 7 : 12, its molecular formula is a simple multiple of
(a) N_2O_3 (b) NO
(c) N_2O_5 (d) NO_2

31. The empirical formula of a compound is CH_2O_2. If its vapour density is 92, its molecular formula would be
(a) CH_2O_2 (b) $C_2H_4O_4$
(c) $C_4H_8O_8$ (d) $C_3H_6O_6$

32. A polymer has molar mass = 68000 g mol^{-1} . If it contains 0.33% of Fe by mass, the no. of atoms of Fe in each molecule of the polymer is [Given, AT. Mass of Fe=56]
(a) 6 (b) 4
(c) 3 (d) 8

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33. What is the empirical formula of vanadium oxide, if 2.74 g of the metal oxide contains 1.53 g of metal?
(a) V_2O_3 (b) VO
(c) V_2O_5 (d) V_2O_7

34. A gaseous hydrocarbon given upon combustion 0.72 g of water and 3.08 g of CO_2. The empirical formula of the hydrocarbon is:
(a) C_3H_4 (b) C_6H_5
(c) C_7H_8 (d) C_2H_4

35. The percentage by mass of C, H and Cl in a compound are C 52.2%, H 3.7% and Cl 44.1%. How many carbon atoms are in the simplest formula of the compound?
(a) 3 (b) 4
(c) 6 (d) 7

Topic 5 : Average Atomic Mass, Average Molecular Mass, Vapour Density, Percentage Yield

36. Density of dry air containing only N_2 and O_2 is 1.15 g/L at 740 mm of Hg and 300 K. What is % composition of N_2 by mass in the air?
(a) 78% (b) 85.5%
(c) 72.7% (d) 62.75%

37. The vapour density of a mixture containg NO_2 and N_2O_4 is 27.6 . The mole fraction of N_2O_4 in the mixture is :
(a) 0.1 (b) 0.2
(c) 0.5 (d) 0.8

38. One mole of element X has 0.444 times the mass of one mole of element Y. One atom of element X has 2.96 times the mass of one atom of ^{12}C. What is the atomic mass of Y?
(a) 80.72 (b) 15.77
(c) 46.67 (d) 40.0

39. 1.44 gram of titanium (At. mass = 48) reacted with excess of O_2 and produce x gram of non-stoichiometric compound $Ti_{1.44}O$. The value of x is:
(a) 2 (b) 1.77
(c) 1.44 (d) None of these

40. Phosphoric acid (H_3PO_4) prepared in a two step process is.
(1) $P_4 + 5O_2 \rightarrow P_4O_{10}$
(2) $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
We allow 62 g of phosphorus to react with excess oxygen which form P_4O_{10} in 85% yield. In the step (2) reaction 90% yield of H_3PO_4 is obtained. Mass of H_3PO_4 produced is:
(a) 37.485 g (b) 149.949 g
(c) 125.47 g (d) 564.48 g

41. An ideal gaseous mixture of ethane (C_2H_6) and ethene (C_2H_4) occupies 28 litre at 1 atm and 273 K.the mixture reacts completely with 128 g O_2 to produce CO_2 and H_2O. Mole fraction at C_2H_6 in the mixture is:
(a) 0.6 (b) 0.4
(c) 0.5 (d) 0.8

42. Ethanol is the substance commonly called alcohol. the density of liquid alcohol is 0.8 gm/ml at 293 K. If 1.2 mole of ethanol are needed for a particular experiment, what volume of ethanol should be measured out?
(a) 55.2 ml (b) 57.5 ml
(c) 69 ml (d) 47.9 ml

43. A sample of impure air contains 80% N_2, 10% O_2 5% CO_2 and 5 % Ar by volume. The average molecular weight of sample is (At. wt. of Ar = 40)
(a) 29.4 (b) 29.8
(c) 30.0 (d) 29.6

44. Naturally occurring thallium consists of two stable isotopes, Tl-203 and Tl-205 (atomic masses = 203.0 and 205.0, respectively) and has an average atomic mass of 204.4. What is the percentage of Tl-205?
(a) 14.0% (b) 70%
(c) 50.0% (d) 64.7%

45. The density of vapours of a particular volatile diatomic species A_2 was found to be 10 miligram / ml at 1 atm and 273 K. Its atomic weight is given by (Assume ideal gas behaviour)
(a) 20 (b) 112
(c) 224 (d) 56

46. Equal weight of X (At. wt. = 36) and Y (At. wt. = 24) are reacted to form the compound X_2Y_3. Then:
(a) X is the limiting reagent
(b) Y is the limiting reagent
(c) no reactant is left over and mass of X_2Y_3 formed is double the mass of X taken
(d) none of the above

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47. $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$

In an experiment, to prepare bromobenzene according to the equation, a student reacted 20.0 g of C_6H_6 with 0.310 mol of bromine. If 28.0 g of C_6H_5Br was obtained, what was the percentage yield?

(a) 31.5 (b) 40.3
(c) 57.6 (d) 69.7

48. For the reaction : $2X + 3Y \rightarrow 3Z$, the combination of 2.00 moles of X with 2.00 moles of Y produces 1.75 moles of Z. What is the percent yield of this reaction?

(a) 43.8% (b) 58.3 %
(c) 66.7% (d) 87.5%

49. 0.05 mole of $LiAlH_4$ in ether solution was placed in a flask containing 74g (1 mole) of t-butyl alcohol. The product $LiAlHC_{12}H_{27}O_3$ weighed 12.7 g. If Li atoms are conserved, the percentage yield is

(Li = 7, Al = 27, H = 1, C = 12, O = 16)

(a) 25% (b) 75%
(c) 100% (d) 15%

50. Diborane, B_2H_6, can be prepared by the reaction;

$3NaBH_4 + 4BF_3 \rightarrow 3NaBF_4 + 2B_2H_6$ If this reaction has a 70 percent yield, how many moles of $NaBH_4$ should be used with excess BF_3 in order to obtain 0.200 mol of B_2H_6?

(a) 0.200 mol (b) 0.210 mol
(c) 0.300 mol (d) 0.429 mol

LEVEL - II

1. 4.4 g of CO_2 and 2.24 L of H_2 at STP are mixed in a container. The total number of molecules present in the container will be

(a) 6.023×10^{23} (b) 1.2046×10^{23}
(c) 6.023×10^{22} (d) 6.023×10^{24}

2. When the same amount of zinc is treated separately with excess of H_2SO_4 and excess of NaOH, the ratio of volumes of H_2 evolved is

(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 9 : 4

3. The normality of a solution of H_2SO_4 (d = 1.84 g/mL) containing 98% H_2SO_4 by weight is

(a) 36.8 (b) 18.4
(c) 9.2 (d) 4.9

4. For the conversion of 0.24 g NaH_2PO_4 in a solution to monohydrogen phosphate, 21.5 mL of NaOH is needed. The molarity of NaOH will be

(a) 0.093 (b) 0.93
(c) 0.087 (d) 0.083

5. 1.0 g of a mixture of $CaCO_3$ and NaCl reacts completely with 120 mL of N/10 HCl. The percentage of NaCl in the mixture of

(a) 40% (b) 50%
(c) 60% (d) 66%

6. 0.7 g of $Na_2CO_3.xH_2O$ is dissolved in 100 mL of H_2O, 20 mL of solution which requires 19.8 mL of 0.1 N HCl. The value of x is

(a) 4 (b) 3
(c) 2 (d) 1

7. 10.78 g of H_3PO_4 in 550 mL solution is 0.40 N. Thus, this acid

(a) has been neutralised HPO_4^{2-}
(b) has been neutralised to PO_4^{3-}
(c) has been changed to H_3PO_2
(d) has been neutralised to $H_2PO_4^-$

8. The percentage of sodium in a breakfast cereal be labeled as 110 m g of sodium per 100 g of cereal is

(a) 11% (b) 1.10%
(c) 0.11% (d) 10.1%

9. The hydrated salt, $Na_2SO_4.nH_2O$, undergoes 55.9% loss in weight on heating and becomes anhydrous.The value of n will be

(a) 5 (b) 3
(c) 7 (d) 10

10. When a metal is burnt, its weight is increased by 24%. The equivalent weight of the metal will be

(a) 25 (b) 24
(c) 33.3 (d) 76

11. H_3PO_4 is a tribasic acid and one of its salt is NaH_2PO_4. What volume of 1 M NaOH solution should be added to 12 g of NaH_2PO_4 to convert it into Na_3PO_4

(a) 100 mL (b) 200 mL
(c) 80 mL (d) 300 mL

12. Sulphuryl chloride SO_2Cl_2 reacts with H_2O to give mixture of H_2SO_4 and HCl. Aqueous solution of 1 mol of SO_2Cl_2 will be neutralised by

(a) 3 mole of NaOH (b) 2 mol of $Ca(OH)_2$
(c) Both (d) None of these

13. 100 mL of a sample of hard water requires 25.1 mL of 0.002 N H_2SO_4 for complete reaction. The hardness of water (density 1 g/mL) based on $CaCO_3$ is

(a) 200 ppm (b) 250 ppm
(c) 251 ppm (d) 258 ppm

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14. If Takshila Classes is written by a graphite pencil, it weighs 3.0×10^{-10} gm. How many carbon atoms are present in it? ($N_A = 6 \times 10^{23}$)
(a) 1.5×10^{13} (b) 5×10^{12}
(c) 2×10^{33} (d) 1.5×10^{10}

15. 1.61 gm of anhydrous $ZnSO_4$ was placed in moist air. After few days its weight was found to be 2.87 gm. What is the molecular formula of hydrated salt? [Zn=65]
(a) $ZnSO_4.H_2O$ (b) $ZnSO_4.3H_2O$
(c) $ZnSO_4.7H_2O$ (d) $ZnSO_4.10H_2O$

16. A rock contains 1.02% Al_2O_3 and 1.80% SiO_2 (by mass). Apart from Free SiO_2, Some SiO_2 in the rock is present as kaolin ($Al_2O_3.2SiO_2$). All Al_2O_3 in the rock is present as kaolin. the mass percentage of free SiO_2 in the rock is: (Al = 27, Si=28)
(a) 1.2% (b) 0.6%
(c) 1.8% (d) 0.8%

17. In the blood of a infant there are about 1.3×10^{12} red blood cells, which contain a total of 0.15 gm of iron ions. On an average, how many iron ions are present, in each red blood cell of an infant? [Fe = 56]
(a) 8.8×10^{23} (b) 4.7×10^{13}
(c) 1.2×10^{9} (d) 3.0×10^{8}

18. An unknown compound contains 8% sulphur by mass. calculate:
(P) Least molecular weight of the compound and
(Q) Molecular weight if one molecule contains 4 atoms of S

	P	Q
(a)	200,	400
(b)	300,	400
(c)	400,	1600
(d)	400,	1200

19. A sample of a hydrate of barium chloride weighing 61 g was heated unit all the water of hydration is removed. The dried sample weighed 52 g. The formula of the hydrated salt is: (atomic mass, Ba = 137 amu, Cl=35.5 amu)
(a) $BaCl_2.2H_2O$ (b) $BaCl_2.4H_2O$
(c) $BaCl_2.H_2O$ (d) $BaCl_2.3H_2O$

20. The percentage by mole of NO_2 in a mixture of NO_2(g) and NO(g) having average molecular mass 34 is:
(a) 25% (b) 20%
(c) 40% (d) 75%

21. The density of a pure liquid (mol wt. 70) is 1.2 gm/ml. If 2 ml of liquid contain 35 drops, then number of molecules in 2 mL of liquid is:
(a) $\frac{1.2}{(35)^2} \times N_A$ (b) $\frac{1}{35} \times N_A$
(c) $\frac{1.2}{35} \times N_A$ (d) $1.2\ N_A$

22. A container when is empty weighs 50 gm. After certain liquid of density 25gm/ dm^3 is filled its mass becomes equal to 100 gm. The volume of the container will be:
(a) 0.25 dm^3 (b) 0.5 dm^3
(c) 1 dm^3 (d) 2 dm^3

23. Vapour density of a metal chloride is 66. Its oxide contains 53% metal. The atomic weight of metal is: [At. wt. Cl =35.5]
(a) 21 (b) 54
(c) 27 (d) 37

24. 40 gm of a carbonate of an alkali metal or alkaline earth metal containing some inert impurities was made to react with excess HCl solution. The liberated CO occupied 12.315 litre at 1 atm and 300 K. The correct option is:
(a) Mass of impurity is 1 gm and metal is Be
(b) Mass of impurity is 3 gm and metal is Li
(c) Mass of impurity is 6 gm and metal is Li
(d) Mass of impurity is 2 gm and metal is Mg

25. 0.6 mol of barium chloride in solution is mixed with 0.2 mol of sodium phosphate, the amount of barium phosphate produced is:
(a) 0.1 mol (b) 0.3 mol
(c) 0.4 mol (d) 0.5 mol

26. A 1.871 gram sample of an unknown metallic carbonate is decomposed by heating to form the metallic oxide and 0.656 g of carbon dioxide according to the equation
$MCO_3(s) \rightarrow MO(s) + CO_2(g)$ What is the metal?
(a) Ca (b) Mn
(c) Ni (d) Zn

27. Iodine adds to the double bonds in fatty acids (one iodine molecule per double bond). How many double bonds are in a molecule of arachidonic acid (Molar mass = 304.5 g/mol) if 0.125 g of the acid require 0.417 g of iodine?
(a) 2 (b) 3
(c) 4 (d) 8

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28. In a certain operation 358 g of $TiCl_4$ is reacted with 96 g of Mg. Calculate % yield of Ti if 32 g of Ti is actually obtained [At. wt. Ti = 48, Mg = 24].
(a) 35.46% (b) 66.6%
(c) 100% (d) 60%

29. Calculate the volume of Cl_2 gas (in ml) liberated at 1 atm 273 K when 1.74 gm MnO_2 reacts with 2.19 gm HCl according to the following reaction with % yield 40.
$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$
(a) 336 ml (b) 112 ml
(c) 134.4 ml (d) 44.8 ml

30. If 240 g of carbon is taken in a container to convert it completely to CO_2 but in industry it has been found that 280 g CO was also formed along with CO_2. find the percentage yield of CO_2. The reactions occurring are:
$C + O_2 \rightarrow CO_2 ; C + \frac{1}{2}O_2 \rightarrow CO$
(a) 25% (b) 50%
(c) 75 % (d) 100%

31. NX is produced by the following step of reactions
$M + X_2 \rightarrow MX_2$
$3MX_2 + X_2 \rightarrow M_3X_8$
$M_3X_8 + N_2CO_3 \rightarrow NX + CO_2 + M_3O_4$
How much M (metal) is consumed to produce 206 gm of NX? (Take at. wt. of M=56, N= 23, X = 80)
(a) 42 gm (b) 56 gm
(c) $\frac{14}{3}$ gm (d) $\frac{7}{4}$ gm

32. One commercial system removes SO_2 emission from smoke at 95°C by the following set of reactions:
$SO_2(g) + Cl_2(g) \rightarrow SO_2Cl(g)$ .....(i)
$SO_2Cl_2 + 2H_2O \rightarrow H_2SO_4 + 2HCl$ .....(ii)
$H_2SO_4 + Ca(HO)_2 \rightarrow CaSO_4 + 2H_2O$ .....(iii)
Assuming the process to be 95% efficient, how many moles of $CaSO_4$ may be produced from 128g SO_2? [Ca=40, S=32, O =16]
(a) 1.9 moles (b) 2 moles
(c) 3.8 moles (d) 0.95 moles

33. 5 moles of A, 6 moles of Z are mixed with sufficient amount of C to finally produce F. then find the maximum moles of F which can be produced. Assuming that the product formed can also be reused. Reactions are:
$A + 2Z \rightarrow B$ .....(i)
$B + C \rightarrow Z + F$ .....(ii)
(a) 3 moles (b) 4.5 moles
(c) 5 moles (d) 6 moles

34. To find formula of a compound composed of iron and carbon monoxide $Fe_x(CO)_y$, the compound is burned in pure oxygen and following reaction occurs:
$Fe_x(CO)_y + O_2 \rightarrow Fe_2O_3 + CO_2$
If 19.6 gm of $Fe_x(CO)_y$ is burnt and 8 gm Fe_2O_3 is formed, then empirical formula of $Fe_x(CO)_y$ is:
(a) $Fe_2(CO)_5$ (b) $Fe(CO)_4$
(c) $Fe(CO)_3$ (d) $Fe(CO)_5$

35. 10^{21} molecules are removed from 200 mg of CO_2. The moles of CO_2 left are
(a) 2.88×10^{-3} (b) 28.2×10^{-3}
(c) 288×10^{-3} (d) 28.8×10^{3}

36. The only incorrect information related with 9.6 g ozone is
(a) contains 0.2 g molecules of ozone
(b) contains 0.6 g atoms of oxygen
(c) occupy 4.48 L at 273 K and 1 bar
(d) occupy 448 L at 273° C and 2 atm

37. 5.85 g of NaCl is dissolved in 1 L of pure water. The number of ions in 1mL of this solution is
(a) 6.02×10^{19} (b) 1.2×10^{22}
(c) 1.2×10^{20} (d) 6.02×10^{20}

38. Which one of the following pairs of gases contains the same number of molecules
(a) 16 g of O_2 and 14 g of N_2
(b) 8 g of O_2 and 22 g of CO_2
(c) 28 g of N_2 and 22 g of CO_2
(d) 32 g of CO_2 and 32 g of N_2

39. Total number of protons, neutrons and electrons present in 14 mg of $_6C^{14}$ is
(Take $N_A = 6 \times 10^{23}$)
(a) 1.2×10^{22} (b) 1.2×10^{25}
(c) 7.2×10^{21} (d) 1.08×10^{22}

40. 1.61 gm of $Na_2SO_4 . 10H_2O$ contains same number of oxygen atoms as present in
(a) 0.98 gm H_2SO_4 (b) 0.08 gm SO_2
(c) 1.78 gm $H_2S_2O_7$ (d) 0.05 gm $CaCO_3$

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41. Vanillin, $C_8H_8O_3$ (M = 152 g/mol), is the molecule responsible for the vanila flavour in food. How many oxygen atoms are present in a 45.0 mg sample of vanillin ?

(a) 1.78×10^{20} (b) 5.35×10^{20}

(c) 1.78×10^{23} (d) 5.35×10^{23}

42. A metallocene derivative (molecular weight = 282) has approximately $\frac{100}{3}$ % sulphur by mass. Number of S atoms in 2.82 kg of metallocene derivative is [S = 32], [$N_A = 6.022 \times 10^{23}$]

(a) $10\ N_A$ (b) $3\ N_A$

(c) $30\ N_A$ (d) $6.6\ N_A$

43. 113.5 mL of NO_2 at STP was liquefied, the density of the liquid being 1.15 g mL^{-1}. Calculate the volume of NO_2 (g) and NO(g) having average molecular mass 34 is

(a) 25% (b) 20%

(c) 40% (d) 75%

44. The relative density of a mixture of CO_2(g) and H_2O (g) w.r.t. gaseous hydrogen atoms is 30. The mol% of the CO_2 is

(a) $\frac{600}{13}$ (b) $\frac{2400}{13}$

(c) $\frac{2000}{13}$ (d) none of these

45. 28 gm lithium is mixed with 48 gm O_2 to react according to the following reaction

$$Li + O_2 \longrightarrow Li_2O$$

The mass of Li_2O formed is

(a) 30 gm (b) 15 gm

(c) 60 gm (d) 45 gm

46. Methyl benzoate is prepared by the reaction between benzoic acid and methanol, according to the equation

$$\underset{\text{Benzoic acid}}{C_6H_5COOH} + \underset{\text{Methanol}}{CH_3OH} \longrightarrow \underset{\text{Methyl benzoate}}{C_6H_5COOCH_3} + H_2O$$

In an experiment 24.4 gm of benzoic acid were reacted with 70.0 mL of CH_3OH. The density of CH_3OH is 0.79 g mL^{-1}. The methyl benzoate produced had a mass of 21.6 g. What is the percentage yield of product ?

(a) 91.7% (b) 79.4%

(c) 71.5% (d) 21.7%

47. The mineral beryl contains 5.03% beryllium by mass and contains three beryllium atoms per formula unit. Determine the formula mass of beryl. [Be = 9]

(a) 950 g/mol (b) 537 g/mol

(c) 270 g/mol (d) 179 g/mol

Section-B
(One or More Than One Correct Answer Type)

1. An aqueous solution contains 10% by mass CH_3COOH. Which is/are correct for this solution. (Assume density of solution is 2 gm/ml)

(a) Mole fraction of CH_3COOH = 1/31

(b) Molarity = 3.33 M

(c) Molality = $\frac{1}{1.85}$ m

(d) ppm of CH_3COOH = 185

2. There are two samples of HCl having molarity 1 M and 0.25 M. Find volume (respectively) of these sample taken in order to prepare 0.75 M HCl solution. (Assume no water is used)

(a) 660 ml, 340 ml (b) 100 ml, 500 ml

(c) 400 ml, 200 ml (d) All of these

3. A mixture of two metals A and B whose equivalent weights are 30 and 90 displaces hydrogen from an acid. If 0.40 gm of the mixture displaces 74.6 c.c. of hydrogen at NTP. Choose the correct options

(a) Mixture contains 0.1 gm of A

(b) Mixture contains 0.3 gm of B

(c) Mixture contains 0.5 gm of A

(d) Mixture contains 0.2 gm of B

4. Which of the following represent 32 g of the substance

(a) One mole of oxygen atoms

(b) One gram-atom of sulphur

(c) 22.4 L of O_2 at STP

(d) One mole of sulphur molecules

5. Which of the following statement is (are) correct?

(a) H_2SO_4 and H_3PO_3 both are dibasic

(b) H_3BO_3 and H_3PO_4 both are tribasic

(c) H_3BO_3 and H_3PO_2 both are monobasic

(d) HNO_3 and HCl both are monobasic

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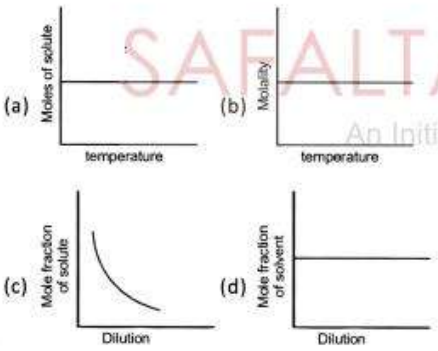
6. Which one are correct about the solution that contains 3.42 ppm $Al_2(SO_4)_3$ and 1.42 ppm Na_2SO_4?
   (a) $[Al^{3+}]=[Na^+]$
   (b) $[SO_4^{2-}]=[Na^+]=[Al^{3+}]$
   (c) $[SO_4^{2-}]=[Na^+]+[Al^{3+}]$
   (d) $[SO_4^{2-}]=[Na^+]$
7. 1 U is equal to:
   (a) 931.48 MeV (b) 1.67×10^{-24}
   (c) $\frac{1}{12}$ th mass of C^{12} (d) 1 dalton
8. $\frac{1}{N_A}$ is equal to:
   (a) 1.67×10^{-27} kg (b) 1 U
   (c) 1 Anston (d) Logschmidt number
9. H_3BO_3 is :
   (a) Monobasic acid
   (b) Lewis acid
   (c) Electron pair acceptor
   (d) Na_3BO_3 exist as ionic compound
10. Which of the following graphs correctly represents the variations?



11. 1 mole of H_3PO_3 reacts with NaOH in solution. Select the correct statements:
   (a) 1 mole of NaOH will replace 1 N H^+ ion from H_3PO_3
   (b) 2 moles of NaOH will replace 2 N H^+ ions from H_3PO_3
   (c) 3 moles of NaOH will replace 3 N H^+ ions from H_3PO_3
   (d) On complete neutralisation of H_3PO_3, the equivalent weight of H_3PO_3 = 41
12. 1 g atom of nitrogen represents :
   (a) 6.02×10^{23} N_2 molecules
   (b) 22.4 litre of N_2 at 1 atm and 273 K
   (c) 11.2 litre of N_2 at 1 atm and 273 K
   (d) 14 g of nitrogen
13. 1 g molecule of V_2O_5 contains
   (a) 5 mole of oxygen atom
   (b) 2 mole of V atom
   (c) 1 mole of oxygen atom
   (d) 2.5 mole of oxygen atom
14. Which of the following concerntration terms is/are affected by a change in temperature ?
   (a) Molarity (b) Molality
   (c) Normality (d) Specific gravity
15. 1 mole of $Ba(OH)_2$ will exactly neutralize:
   (a) 0.5 mole HCl (b) 1 mole of H_2SO_4
   (c) 1 mole of H_3PO_3 (d) 2 mole of H_3PO_2
16. The pair of species having difference percentage (mass) of carbon is
   (a) CH_3COOH and $C_6H_{12}O_6$
   (b) CH_3COOH and C_2H_5OH
   (c) $HCOOCH_3$ and HCOOH
   (d) C_2H_5OH and CH_3OCH_3
17. 30 mL of CH_3OH (d = 0.8 g/cm³) is mixed with 60 mL of C_2H_5OH (d = 0.92 g/cm³) at 25°C to form a solution of density 0.88 g.cm³. Select the correct option :
   (a) Molarity and molaltiy of resulting solution are 6.33 and 13.59 respectively
   (b) The mole fraction of solute and molality are 0.385 and 13.59 respectively
   (c) Molarity and % change in volume are 13.59 and zero respectively
   (d) Mole fraction of solvent and molality are 0.615 and 13.59 respectively
18. 16 g of oxygen has same number of molecules as in
   (a) 16 g of CO (b) 28 g of N_2
   (c) 14 g of N_2 (d) 1.0 g of H_2
19. Which of the following solutions have the same concentration ?
   (a) 20 g of NaOH in 200 mL of solution
   (b) 0.5 mol of KCl in 200 mL of solution
   (c) 40 g of NaOH in 100 mL of solution
   (d) 20 g of KOH in 200 mL of solution

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20. A vessel contains 4.4 g of CO_2. It means that it contains
(a) 0.1 mol of CO_2
(b) 6.02×10^{22} molecules of CO_2
(c) 8 g atoms of oxygen
(d) 1120 mL of CO_2 at S.T.P.

Section-C
(Passage Based)

Passage-1

A chemical equation is balanced and calculations are done based on the balanced equation. This is the principle of stoichiometry. Thus a balanced equation is used to calculate mass, volume or amount of the reactants and products, when we know the quantity of anyone of the products formed. In an experiment, 8 g methane gas and 24 g of oxygen were burnt. A large amount of heat is liberated as per the equation

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

1. Which one is limiting reactant
(a) CH_4 is the limiting reactant
(b) O_2 is the limiting reactant
(c) CO_2 is the limiting reactant
(d) Both (a) and (b)

2. How many moles of CO_2 are formed
(a) 3.75 mole (b) 0.375 mole
(c) 0.0375 mole (d) 0.1875 mole

3. For complete combustion methane, mass of oxygen required is
(a) 64.0 g (b) 80. g
(c) 24.0 g (d) 32.0 g

Passage-2

Equivalent mass of a substance may be calculated as

$$\text{Equivalent mass} = \frac{\text{Molecular mass}}{\text{n-factor}} = \frac{\text{Atomic mass}}{\text{n-factor}}$$

n-factor = Basicity of acid or acidity of base n-factor = Number of moles of electrons gained or lost per mole of oxidising agent or reducing agent

n-factor = Total positive or negative valency of salt

Concept of n-factor is very important for redox as well as for non-redox reactions

4. When $KMnO_4$ is titrated against $FeSO_4.(NH_4)_2SO_4.6H_2O$ in acidic medium then equivalent mass of $KMnO_4$ will be
(a) $\frac{\text{Molecular mass}}{10}$ (b) $\frac{\text{Molecular mass}}{5}$
(c) $\frac{\text{Molecular mass}}{3}$ (d) $\frac{\text{Molecular mass}}{2}$

5. Equivalent mass of FeC_2O_4 in the following reaction $FeC_2O_4 \rightarrow Fe^{3+} + CO_2$
(a) Molecular mass/1 (b) Molecular mass/2
(c) Molecular mass/3 (d) Molecular mass/4

6. Equivalent mass of H_3PO_2 when it undergoes disproportionation to PH_3 and H_3PO_3 will be
(a) Molecular mass/2 (b) Molecular mass/4
(c) Molecular mass/24 (d) 3 Molecular mass/4

Section-D
(Matrix-Match)

1. **Match the following :**

Column-I	Column-II
(A) 0.5 mole of SO_2	(p) 12×10^{23} atoms
(B) One mole of O_2	(q) 32.0 g
(C) 22 g of CO_2	(r) 3×10^{23} molecules
(D) Two mole of CH_4	(s) 9×10^{23} atoms

2. **Match the following :**

Column-I Compounds	Column-II Equivalent Weight
(A) $Na_2S_2O_3$	(p) $\frac{M}{4}$
(B) SO_2 as reducing agent	(q) $\frac{M}{3}$
(C) $CaCO_3$	(r) $\frac{M}{2}$
(D) FeC_2O_4	(s) M

3. **Match the following**

Column-I	Column-II
(A) $Br_2 \rightarrow Br^- + BrO_3^-$	(p) n-factor is 8
(B) $CrO_4^{2-} \rightarrow Cr^{3+}$	(q) Oxidation
(C) $Cu_2S \rightarrow Cu^{2+} + SO_2$	(r) Disproportionation
(D) $FeS_2 \rightarrow Fe_2O_3 + SO_2$	(s) E = M/11
	(t) $3e^-$ s to be added during balancing

Section-E
(Integer Type)

1. $2C + O_2 \rightarrow 2CO$
Determine the number of moles of CO formed when 24 gm of carbon and 96 g of O_2 reacts with each other.

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2. 0.16 g of a dibasic acid required 25 ml of decinormal NaOH solution for complete neutralization.The molecular mass of the acid is X then what is the value of $\left(\frac{X-8}{12}\right)$.
3. 1 g of a metal required 50 ml of 0.5 N HCl to dissolve it. If the equivalent mass of metal is y then what is the value of y/10.
4. The mass of one atom of an element is 1.71×10^{-22} g. How many sulphur atoms are present in a molecule of this allotrope ?
5. Density of ozone relative to methane under the same temperature and pressure conditions is?
6. How many moles of Zn (FeS_2) can be made from 2 mole zinc, 3 mole iron and 5 mole sulphur?
7. For the reaction $2P + Q \longrightarrow R$,8 mol of P and 5 mol of Q will produce total moles of R equal to:
8. 5 moles of VO and 6 moles of Fe_2O_3 are allowed to react completely according to reaction

   $VO + Fe_2O_3 \longrightarrow FeO + V_2O_5$
9. 0.4 g of a polybasic acid H_nA (basicity = n) requires 0.5 g of NaOH for complete neutralization. The value of n would be [M.M of H_nA = 64]
10. The value of x, if hydrated salt $A_2SO_4 \cdot xH_2O$ undergoes 45% loss in mass on heating and becomes anhydrous, is : (where atomic weight of A is 7)

Section-F
(Takshila Challengers)

1. The ratio of the weight of one litre of a gas to the weight of 1.0 L oxygen gas both measured at STP is 2.22. The molecular weight of the gas would be:
   (a) 14.002 (b) 35.52
   (c) 71.5 (d) 199.5
2. 20 ml of a mixture of CO_2 and C_2H_4 was mixed with solution back to the original room temperature a contraction of 12 ml was observed. What is the volume percentage of CO_2 in the original mixture?
   (a) 6% (b) 14%
   (c) 70% (d) 30%
3. Equal weight of NaCl and KCl are dissolved separately in equal volumes of solutions. Molarity of the two solutions will be:
   (a) equal
   (b) that of NaCl will be less than that of KCl solution
   (c) that of NaCl will more than that of KCl solution
   (d) that of NaCl will be half than that of KCl solution
4. What volume of 0.150 M H_2SO_4 would be required to completely neutralize a mixture of 20.0 mL of 0.200 M NaOH and 40.0 mL of 0.0500 M $Ca(OH)_2$?
   (a) 20.0 mL (b) 26.7 mL
   (c) 40.0 mL (d) 53.mL
5. 300 ml, 2 M H_2SO_4 solution is mixed with 200 ml, 2 M $Ba(OH)_2$ solution then find final molarity of sulphate ion in diluted solution, if resulting solution is diluted to 4 times. ($BaSO_4$) formed is precipitated
   (a) 0.2 M (b) 0.8 M
   (c) 0.3 M (d) 0.1 M
6. Nitration of aniline by $HNO_3 + H_2SO_4$ mixture gives 51% para nitro derivative while 47% is meta nitro derivative and rest 2% ortho nitro derivative at 15°C. In order to obtain 276 gm of p-nitro aniline what minimum mass of aniline should be taken?
   (a) 514.2 gm (b) 563.gm
   (c) 364.7 gm (d) 476.7 gm
7. 76 gram of silver salt of dibasic acid on heating left a residue of 54 gram silver. Silver salt contains Ag, C and O only and C and O in mole ratio of 1 : 2 then find the mass of CO_2 gas liberated during ignition of 76 gm silver salt. (Ag = 108)
   (a) 2.2 gm (b) 0.22 gm
   (c) 44 gm (d) 22 gm
8. An oxide of element A was analysed and found to have mass ratio of A to oxygen equal to 7 : 3. Then formula of oxide can be: [Atomic mass of A = 56]
   (a) A_2O_2 (b) A_2O_3
   (c) AO (d) A_2O
9. Two pure substances of equal molar passes are α and β [where $\alpha = AHCO_3$] and ($\beta = BCO_3$) and they decompose as shown:

   $2\alpha \xrightarrow{\Delta} H_2O + CO_2 + A_2CO_3$ .... (i)

   $\beta \xrightarrow{\Delta} BO + CO_2$ .....(ii)

   6.2 g of mixture of H_2O and CO_2 is obtained by 16.8 g of α . Find out the molar mass of α and β and value of $\alpha\left(\frac{\alpha+\beta}{2}\right)$
   (a) 84. each, 168.0 (b) 57.9 each, 3360
   (c) 59.39 each, 3528 (d) 84 each, 7056

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10. A metal carbonate decomposes according to following reaction

$M_2CO_3(s) \rightarrow M_2O(s) + CO_2(s)$

Percentage loss in mass on complete decomposition of M_2CO_3 (s) Atomic mass of M = 102) is:

(a) $\frac{100}{3}\%$ (b) $\frac{50}{3}\%$

(c) $\frac{25}{3}\%$ (d) 15%

Section-G
(Previous Years Questions)
JEE(Main/Advanced) & BITS

1. Which of the following concentration factor is affected by change in temperature? **[2002]**

(a) Molarity (b) Molality
(c) mole fraction (d) weight fraction

2. In an organic compound of molar mass 108 g mol^{-1}, C, H and N atoms are present in 9 : 1 : 3.5 by weight. Molecular formula can be **[2002]**

(a) $C_6H_8N_2$ (b) $C_7H_{10}N$
(c) $C_5H_6N_3$ (d) $C_4H_{18}N_3$

3. Number of atoms in 560 gram of Fe (atomic mass 56 g mol^{-1}) is **[2002]**

(a) twice that of 70 g N
(b) half that of 20g H
(c) both (a) and (b)
(d) None of the above

4. What volume of hydrogen gas, at 273 K and 1 atm pressure will be consumed in obtaining 21.6 g of elemental boron (atomic mass = 10.8) from the reduction of boron trichloride by hydrogen ? **[2003]**

(a) 67.2 L (b) 44.8 L
(c) 22.4 L (d) 89.6 L

5. 25 ml of a solution of barium hydroxide on titration with a 0.1 molar solution of hydrochloric acid gave a titre value of 35 ml. The molarity of barium hydroxide solution was **[2003]**

(a) 0.14 (b) 0.28
(c) 0.35 (d) 0.07

6. 6.02×10^{20} molecules of urea are present in 100 ml of its solution. The concentration of urea solution is **[2004]**

(a) 0.02 M (b) 0.01 M
(c) 0.001 M (d) 0.1 M

7. To neutralize completely 20 mL of 0.1 M aqueous solution of phosphorous acid (H_3PO_3), the volume of 0.1 M aqueous KOH solution required is : **[2004]**

(a) 40 mL (b) 20 mL
(c) 10 mL (d) 60 mL

8. Two solutions of a substance (non-electrolyte) are mixed in the following manner. 480 mL of 1.5 M first solution 520 mL of 1.2 M second solution. What is the molarity of the final mixture ? **[2005]**

(a) 2.70 M (b) 1.344 M
(c) 1.50 M (d) 1.20 M

9. 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: **[2005]**

(a) be a function of the molecular mass of the substance
(b) remain unchanged
(c) increase two fold
(d) decrease twice

10. How many moles of magnesium phosphate, $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms ? **[2006]**

(a) 0.02 (b) 3.125×10^{-2}
(c) 1.25×10^{-2} (d) 2.5×10^{-2}

11. Density of a 2.05 M solution of acetic acid in water is 1.02 g/mL. The molality of the solution is : **[2006]**

(a) 1.14 mol kg^{-1} (b) 3.28 mol kg^{-1}
(c) 2.28 $mol^{-1}kg^{-1}$ (d) 0.44 mol kg^{-1}

12. In the reaction,

$2Al(s) + 6HCl(aq) \rightarrow$

$2Al^{3+}(aq) + 6Cl^{-}(aq) + 3H_2(g)$ **[2007]**

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(a) 6 L HCl(*aq*) is consumed for every 3L $H_2(g)$ produced
(b) 33.6 L $H_2(g)$ is produced regardless of temperature and pressure for every mole Al that reacts
(c) 67.2 L $H_2(g)$ at STP is produced for every mole Al that reacts
(d) 11.2 L $H_2(g)$ at STP is produced for every mole HCl(*aq*) consumed

13. The density (in g mL^{-1}) of a 3.60 M sulphuric acid solution that is 29% H_2SO_4 (molar mass = 98g mol^{-1}) by mass will be :

[2007]

(a) 1.64 (b) 1.88
(c) 1.22 (d) 1.45

14. A 5.2 molal aqueous solution of methyl alcohol, CH_3OH, is supplied. What is the mole fraction of methyl alcohol in the solution.

[2011]

(a) 0.190 (b) 0.086
(c) 0.050 (d) 0.100

15. The molality of a urea solution in which 0.0100 g of urea, $[(NH_2)_2CO]$ is added to 0.3000 dm^3 of water at STP is

[2011]

(a) 33.3 M (b) 3.33×10^{-2} M
(c) 0.55 M (d) 5.55×10^{-4} M

16. The density of a solution prepared by dissolving 120g of urea (mol. Mass = 60u) in 1000 g of water is 1.15 g/ml. The molarity of this solution is

[2012]

(a) 1.78 M (b) 1.02 M
(c) 2.05 M (d) 0.50 M

17. The molarity of a solution obtained by mixing 750 mL of 0.5 (M) HCl with 250 mL of 2 (M) HCl will be :

[2013]

(a) 0.875 M (b) 1.00 M
(c) 1.75 M (d) 0.975 M

18. A gaseous hydrocarbon gives upon combustion 0.72g of water and 3.08g. of CO_2 The empirical formula of the hydrocarbon is :

[2013]

(a) C_2H_4 (b) C_3H_4
(c) C_6H_5 (d) C_7H_8

19. Experimentally it was found that a metal oxide has formula $M_{0.98}O$. Metal M, is present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be:

[2013]

(a) 7.01% (b) 4.08%
(c) 6.05% (d) 5.08%

20. The ratio of masses of oxygen and nitrogen in a particular gaseous mixture is 1 : 4. The ratio of number of their molecules is

[2014]

(a) 7 : 32 (b) 1 : 8
(c) 3 : 16 (d) 1 : 415.

21. A sample of a hydrate of barium chloride weighing 61 g was heated until all the water of hydration is removed. The dried sample weighed 52 g. The formulae of the hydrated salt is: (atomic mass, Ba=137 amu, Cl= 35.5 amu)

[2015]

(a) BaCl. H_2O (b) $BaCl_2.2H_2O$
(c) $BaCl_2 . 3H_2O$ (d) $BaCl_2.4H_2O$

22. $A + 2B + 3C \rightleftharpoons AB_2C_3$.Reaction of 6.0 g of A, 6.0×10^{23} atoms of B, and 0.036 mol of C yields 4.8 g of compound AB_2C_3. If the atomic masses of A and C are 60 and 80 amu, respectively, the atomic mass B of is (Avogadro constant = 6×10^{23} mol^{-1})

2015]

(a) 70 amu (b) 60 amu
(c) 30 amu (d) 40 amu

23. The molecular formula of a commercial resin used for exchanging ions in water softening is $C_8H_7SO_3Na$(Molecular weight = 206). What would be the maximum uptake of CA^{2+} ions by the resin when expressed in mole per gram resin?

[2015]

(a) 1/103 (b) 1/206
(c) 2/309 (d) 1/412

24. 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:

[2016]

(a) Isobutane (b) Ethane
(c) Butane (d) propane

25. An organic compound contains C, H and S. The minimum molecular weight of the compound containing 8% sulphur is: (atomic weight of S =32)

[2016]

(a) 600 (b) 200
(c) 400 (d) 300

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26. The amount of arsenic pentasulphide that can be obtained when 35.5 g arsenic acid is treated with excess H_2S in the presence of conc. HCl (assuming 100% Conversion) is: **[2016]**

(a) 0.25 mol (b) 0.50 mol
(c) 0.333 mol (d) 0.125 mol

27. The volume of 0.1 N dibasic acid is sufficient to neutralize 1 g of a base that furnishes 0.04 mol of OH^- in aqueous medium is: **[2016]**

(a) 400 mL (b) 600 mL
(c) 200 mL (d) 800 mL

28. At 300 K and 1 atm, 15 mL of a gaseous hydrocarbon requires 375 mL air containg 20% O_2 by volume for complete combustion. After combustion the gases occupy 330 mL. Assuming that the water formed is in liquid form and the volumes were measured at the same temperature and pressure, the formula of the hydrocarbon is **[2016]**

(a) C_3H_8 (b) C_4H_8
(c) C_4H_{10} (d) None

Section-H
(NCERT Window)

1. Calculate the molecular mass of the following :
(i) H_2O (ii) CO_2 (iii) CH_4

2. Calculate the mass per cent of different element present in sodium sulphate (Na_2SO_4)

3. Calculate the mass of sodium acetate (CH_3COONa) required to make 500 mL of 0.375 molar aqueous solution. Molar mass of sodium acetate is 82.0245 g mol^{-1}.

4. Calculate the concentration of nitric acid in moles per litre in a sample which has a density 1.41 g mL^{-1} and the mass per cent of nitric acid in it being 69%.

5. Determine the molecular formula of an oxide of iron in which the mass per cent of iron and oxygen are 69.9 and 30.1 respectively.

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

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

7. If the density of methanol is 0.793 kg L^{-1}, what is the volume needed for making 2.5 L of its 0.25 M solution?

8. In a reaction $A + B_2 \rightarrow AB_2$; Identify the limiting reagent. If any, in the following reaction mixtures.
(i) 300 atoms of A + 200 molecules of B
(ii) 2 mol A + 3 mol B
(iii) 100 atoms of A + 100 molecules of B
(iv) 5 mol A + 2.5 mol B
(v) 2.5 mol A + 5 mol B

9. Dinitrogen and dihydrogen react with each other to produce ammonia according to the following chemical equation $N_2(g) + H_2(g) \rightarrow 2NH_3(g)$
(i) Calculate the mass of ammonia produced if 2.00 × 10^3 g dinitrogen reacts with 1.00 × 10^3 g of dihydrogen.
(ii) Will any of the two reactants remain unreacted?
(iii) If yes, which one and what would be its mass ?

10. How are 0.50 mol Na_2CO_3 and 0.50 M Na_2CO_3 different?

11. 200 ml 40% H_2SO_4 (d = 1.30 g/ml) is mixed with 300 ml 30% H_2SO_4 (d = 1.20 g/ml). What will be molarity of resulting solution.

12. What mass of $CaCO_3$ is required to react completely with 200 ml M/10 H_2SO_4.

13. Equal weights of O_2 and O_3 contain total number of atoms in the ratio x : y. Then find out value of x/y.

14. What will be the mass of one of C - 12 in grams?

15. How many significant figures should be present in the answer of the following calculations?

$$\frac{2.5 \times 1.25 \times 3.5}{2.01}$$

16. What is the symbol for SI unit of mole? How is the mole defined ?

17. What is the difference between molality and molarity ?

18. Calculate the mass percent of calcium, phosphorus and oxygen in calcium phospate $Ca_3(PO_4)_2$.

19. Define the law of multiple proportions. Explain it with two examples. How does this law point to the existence of atoms?

20. A box contains some identical red coloured balls, labelled as A, each weighing 2 grams. Another box contains identical blue coloured balls, labelled as B, each weighing 5 grams. Consider the combinations AB, AB_2, A_2B and A_2B_3 and show that law of multiple proportions is applicable.

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ANSWER KEY

Section-A : (Straight Objective Type)

LEVEL - I

Topic 1 : Based on Mole

1. (c) 2. (d) 3. (b) 4. (b) 5. (b) 6. (a) 7. (c)
8. (a) 9. (c) 10. (d) 11. (a)

Topic 2 : Equivalent Weight

12. (b) 13. (a) 14. (b) 15. (a)

Topic 3 : Stoichiometry & Concentration Methods

16. (b) 17. (c) 18. (a) 19. (b) 20. (a) 21. (d) 22. (a)
23. (d)

Topic 4 : Empirical and Molecular Formulas

24. (a) 25. (b) 26. (d) 27. (d) 28. (a) 29. (c) 30. (a)
31. (c) 32. (b) 33. (c) 34. (c) 35. (d)

Topic 5 : Average Atomic Mass, Average Molecular Mass, Vapour Density, Percentage Yield

36. (c) 37. (b) 38. (a) 39. (b) 40. (b) 41. (b) 42. (c)
43. (b) 44. (b) 45. (b) 46. (c) 47. (d) 48. (d) 49. (c)
50. (d)

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LEVEL - II

1. (b) 2. (a) 3. (a) 4. (a) 5. (a) 6. (c) 7. (a)
8. (c) 9. (c) 10. (c) 11. (a) 12. (b) 13. (c) 14. (a)
15. (c) 16. (b) 17. (c) 18. (c) 19. (a) 20. (a) 21. (c)
22. (d) 23. (c) 24. (b) 25. (a) 26. (d) 27. (c) 28. (a)
29. (c) 30. (b) 31. (a) 32. (a) 33. (c) 34. (d) 35. (a)
36. (a) 37. (c) 38. (a) 39. (a) 40. (c) 41. (b) 42. (c)
43. (b) 44. (a) 45. (d) 46. (b) 47. (b)

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Section-B : (One or More Than One Correct Option)

1. (a, b, c)	2. (a)	3. (a, b)	4. (a, d)	5. (a, b, d)	6. (a, d)	7. (a, d)
8. (a, b, c)	9. (a, b, d)	10. (a, d)	11. (a, b, d)	12. (c, d)	13. (a, b)	14. (a, c)
15. (b, c, d)	16. (a, d)	17. (a, c, d)	18. (c, d)	19. (c, b)	20. (a, b)	

Section-C : (Passage Based)

1. (b)	2. (b)	3. (d)	4. (b)	5. (c)	6. (d)

Section-D : (Matrix-Match)

1. A → (q,r,s), B → (p,q), C → (r,s), D → (q)
2. A → (s), B → (r), C → (r), D → (q)
3. A → (r), B → (t), C → (p,q), D → (q,s)

Section-E : (Integer Type)

1. (2)	2. (5)	3. (1)	4. (6)	5. (3)	6. (2)	7. (4)
8. (2)	9. (2)	10. (5)				

Section-F : (Takshila Challengers)

1. (c)	2. (c)	3. (c)	4. (b)	5. (d)	6. (c)	7. (d)
8. (b)	9. (d)	10. (b)				

Section-G : (Previous Years) JEE(Main/Advanced) & BITS

1. (a)	2. (a)	3. (c)	4. (a)	5. (d)	6. (b)	7. (a)
8. (b)	9. (b)	10. (b)	11. (c)	12. (d)	13. (c)	14. (b)
15. (d)	16. (c)	17. (a)	18. (d)	19. (b)	20. (a)	21. (b)
22. (c)	23. (d)	24. (d)	25. (c)	26. (d)	27. (a)	28. (d)

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