CHEMISTRY

MOLE CONCEPT

Achiever's Comprehensive Course (ACC)

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PHYSICAL CHEMISTRY

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1. MOLE

A mole is the amount of substance that contains as many species [Atoms, molecules, ions or other particles] as there are atoms in exactly 12 gm of C-12.

$$\boxed{1\, mole = 6.022 \times 10^{23} \text{ species}}$$

2.1 Atomic mass

Atomic mass of an element can be defined as the number which indicates how many times the mass of one atom of the element is heavier in comparison to $\frac{1}{12}$th part of the mass of one atom of Carbon-12.

$$\text{Atomic mass} = \frac{[\text{Mass of an atom of the element}]}{\frac{1}{12} \times [\text{Mass of an atom of carbon-12}]} = \frac{\text{Mass of an atom in amu}}{1 \text{ amu}}$$

2.2 Atomic mass unit (amu) or Unified mass (u)

The quantity [$\frac{1}{12}$ × mass of an atom of C–12] is known as atomic mass unit.

The actual mass of one atom of C-12 = 1.9924×10^{-26} kg

$$\therefore\ 1 \text{ amu} = \frac{1.9924 \times 10^{-26}}{12} \text{ kg}$$

$$= 1.66 \times 10^{-27} \text{ kg} = 1.66 \times 10^{-24} \text{ gm} = \frac{1}{N_A} \text{ gm}$$

2.3 Gram atomic mass

The gram atomic mass can be defined as the mass of 1 mole atoms of an element.

e.g., Mass of one oxygen atom = 16 amu = $\frac{16}{N_A}$ gm.

Mass of N_A oxygen atom = $\frac{16}{N_A} . N_A = 16$ gram

Illustration

(a) What is the mass of one atom of Cl? (b) What is the atomic mass of Cl?

(c) What is the gram atomic mass of Cl?

Sol. (a) Mass of one atom of Cl = 35.5 amu.

(b) Atomic mass of Cl = $\frac{\text{Mass of an atom in amu}}{1\text{amu}} = \frac{35.5\text{amu}}{1\text{amu}} = 35.5$

(c) Gram atomic mass of Cl = [Mass of 1 Cl atom × N_A]

$= 35.5 \text{ amu} \times N_A = \frac{35.5}{N_A} \times N_A \text{ gram} = 35.5 \text{ gram}$

Exercise

(a) What is the mass of one atom of S?

(b) What is the atomic mass of S ?

(c) What is the gram atomic mass of S?

Ans. (a) 32 amu, (b) 32, (c) 32 gram

3.1 Molecular mass

Molecular mass is the number which indicates how many times one molecule of a substance is heavier in comparison to $\frac{1}{12}$th of the mass of one atom of C-12.

$$\text{Molecular mass} = \frac{\text{Mass of one molecule of the substance (in amu)}}{\frac{1}{12} \times [\text{Mass of an atom of C-12}]}$$

$$= \frac{\text{Mass of one molecule of the substance (in amu)}}{1\text{amu}}$$

3.2 Gram Molecular mass

Gram molecular mass can be defined as the mass of 1 mole of molecules.

e.g., Mass of one molecule of O_2 = 32 amu = $\frac{32}{N_A}$ gram.

Mass of N_A molecules of $O_2 = \frac{32}{N_A} \times N_A \text{gm} = 32 \text{ gm}$

Illustration

(a) What is the mass of one molecule of HNO_3?

(b) What is the molecular mass of HNO_3?

(c) What is the gram molecular mass of HNO_3?

Sol. (a) Mass of one molecule of $HNO_3 = (1 + 14 + 3 \times 16)$ amu = 63 amu.

(b) Molecular mass of $HNO_3 = \frac{63\ amu}{1\ amu} = 63$

(c) Gram molecular mass of HNO_3 = Mass of 1-molecule of $HNO_3 \times N_A$

$$= 63 \text{ amu} \times N_A = \frac{63}{N_A} \text{gm} \times N_A = 63 \text{ gram}$$

Exercise

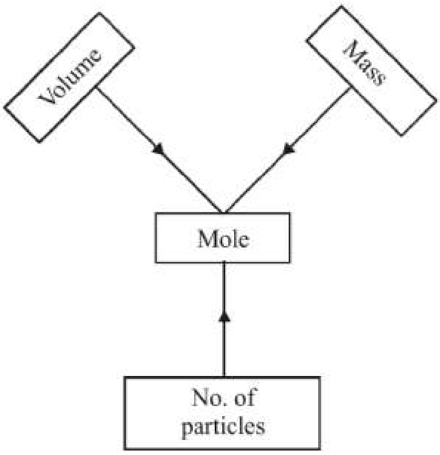
(a) What is the mass of one molecule of H_2SO_4.

(b) What is the molecular mass of H_2SO_4.

(c) What is the gram molecular mass of H_2SO_4.

Ans. (a) 98 amu (b) 98 (c) 98 gram

4. METHODS TO CALCULATE MOLES



4.1 From number of particles :

$$\text{No. of mole} = \frac{\text{Given no. of Paritcles [atoms/molecules/ ions]}}{N_A}$$

Illustration

A piece of Cu contains 6.022×10^{24} atoms. How many mole of Cu atoms does it contain?

Sol. No. of mole $= \dfrac{6.022 \times 10^{24}}{N_A} = \dfrac{6.022 \times 10^{24}}{6.022 \times 10^{23}} = 10$ mole

Exercise

5 mole of CO_2 are present in a gaseous sample. How many molecules of CO_2 are present in the sample?

Ans. $5\ N_A$

4.2 From given Mass :

(a) For atoms : No. of mole $= \dfrac{\text{Given mass of the substance(gm)}}{\text{Gram atomic mass}} =$ No. of g-atoms

(b) For molecules : No. of mole $= \dfrac{\text{Given mass of the substance(gm)}}{\text{Gram molecular mass}} =$ No. of g-molecules

Illustration

What will be the mass of 5 mole of SO_2?

Ans. Molecular mass of $SO_2 = 64$ gm

$5 = \dfrac{\text{mass (gm)}}{64}$

$\therefore$ mass = 320 gm

Exercise

(a) How many mole of O atoms are present in 88 gm CO_2?
(b) What will be the mass of 10 mole of H_3PO_4?

Ans. (a) 4 mole (b) 980 gm

4.3 From the given volume of a gas :

$$n = \frac{\textit{volume of gas at 1 bar pressure and 273 K (in litre)}}{22.7}$$

S.T.P.: 1 bar pressure and 273 K.

$$n = \frac{\text{volume of gas at 1 atm and 273K(in litre)}}{22.4}$$

Note: According to old IUPAC agreement, STP condition was 1 atm pressure and 273 K temperature but according to new agreement it is 1 bar pressure and 273K temperature. Although many books are still using the condition of 1 atm and 273K for STP.

If volume is given under any other condition of temperature and pressure, then use the ideal gas equation to find the no. of moles.

$$\boxed{\text{No. of mole(n)} = \frac{PV}{RT}}$$

Units of Pressure :

1 atm = 76 cm Hg = 760 torr = 1.01325 bar = 1.01325×10^5 pa.

Units of temperature :

$$\boxed{K = {}^\circ C + 273}$$

Value of R :

R = 0.0821 litre-atm/mole.K
= 8.314 J/mole.K = 1.987 $\approx$ 2 cal/mole.K

Units of volume :

$$1\,dm^3 = 10^3\,cm^3 = 1\,litre = 10^{-3}\,m^3 = 10^3\,ml$$
$$1\,m^3 = 10^3\,litre$$

Illustration

A sample of He gas occupies 5.6 litre volume at 1 atm and 273 K. How many mole of He are present in the sample?

Sol. No. of mole = $\frac{5.6}{22.4} = 0.25$

Exercise

How much volume will be occupied by 2 mole CO_2 gas at STP?

Ans. 45.4 L

Note : We can use the following relationship as per requirement of question.

$$\text{No. of mole} = \frac{\text{No. of particle}}{N_A} = \frac{\text{mass (gm)}}{[\text{gm at. or mol. mass}]}$$

$$= \frac{V(\ell)\text{ occupied by a Gas at STP}}{22.7} = \frac{V(\ell)\text{ occupied by a Gas at 1atm and 273K}}{22.4}$$

Illustration

How many molecules of O_2 are present in 5.6 litres of O_2 at 1 atm and 273 K?

Sol. $\frac{\text{No. of molecules}}{N_A} = \frac{V(\ell) \text{ at 1 atm and 273 K}}{22.4}$

$\frac{\text{No. of molecules}}{N_A} = \frac{5.6}{22.4} = \frac{1}{4} \Rightarrow \text{No. of molecule} = \frac{N_A}{4} = 1.505 \times 10^{23}$

Exercise

How many molecules of water are present in 9 gram of water?

Ans. 3.011×10^{23}

5. LAWS OF CHEMICAL COMBINATION

5.1 Law of conservation of mass (Lavoisier – 1774) :

In any physical or chemical change, mass can neither be created nor be destroyed.

It means :

Total mass of the reactants = total mass of the products.

This relationship holds good when reactants are completely converted into products.

In case the reacting material are not completely consumed the relationship will be –

Total mass of the reactants = Total mass of the products + mass of unreacted reactants

Limitation : In nuclear reactions, some mass of reactant is converted into energy, so mass of reactant is always less than that of product.

Illustrations

1.7 gram of silver nitrate dissolved in 100 gram of water is taken. 0.585 gram of sodium chloride dissolved in 100 gram of water is added to it and chemical reaction occurs. 1.435 gm of AgCl and 0.85 gm $NaNO_3$ are formed. Show that these results illustrate the law of conservation of mass.

Sol. Total mass before chemical change = mass of $AgNO_3$ + Mass of NaCl + Mass of water

$= 1.70 + 0.585 + 200 = 202.285$ gram

Total mass after the chemical reaction = mass of AgCl + Mass of $NaNO_3$ + Mass of water

$= 1.435 + 0.85 + 200 = 202.285$ gram

Thus in the given reaction

Total mass of reactants = Total mass of the products.

Exercise

If 6.3 gram of $NaHCO_3$ are added to 15 gram CH_3COOH solution. The residue is found to weigh 18 gram. What is the mass of CO_2 released in this reaction?

Ans. 3.3 gram

5.2 Law of constant composition : [Proust 1799]

A chemical compound always contains the same element combined together in fixed proportion by mass.

Limitations : In case of isotopes, ratio is not fixed

e.g.	$^{12}CO_2$	$^{14}CO_2$
	12: 32	14 : 32
	3 : 8	7 : 16

Illustration

1.08 gram of Cu wire was allowed to react with nitric acid. The resulting solution was dried and ignited when 1.35 gram of copper oxide was obtained. In another experiment 2.3 gram of copper oxide was heated in presence of Hydrogen yielding 1.84 gram of copper. Show that the above data are in accordance with law of constant composition?

Sol. **Case-I**

$$Cu \xrightarrow{HNO_3} Cu(NO_3)_2 \xrightarrow{\Delta} CuO$$

1.08 gram 1.35 gram

1.35 gram CuO contains $\longrightarrow$ 1.08 gram Cu.

$$100 \text{ gram CuO contains} \longrightarrow \frac{1.08}{1.35} \times 100 = 80 \text{ gram Cu}$$

% Cu in CuO = 80%

% O in CuO = 20%

Case-II

$$CuO + H_2 \longrightarrow Cu + H_2O$$

2.3 gram 1.84 gram

2.30 gram CuO contains $\longrightarrow$ 1.84 gram Cu.

$$100 \text{ gram CuO contains} \longrightarrow \frac{1.84 \times 100}{2.30} = 80 \text{ gram Cu}$$

% Cu in CuO = 80%

% O in CuO = 20%

Both sample have the same composition & hence the data are in accordance with law of constant composition.

Exercise

7.95 gram of cupric oxide was reduced by heating in a current of hydrogen and the weight of copper that remained was 6.35 gram. In another experiment, 19.05 gram of Cu was dissolved in the nitric acid and the resulting copper nitrate is converted into cupric oxide by ignition. The weight of cupric oxide formed was 23.85 gram. Show that these results illustrate the law of constant composition.

5.3 Law of multiple proportion : [Dalton 1806]

When two elements combine to form two or more compounds, the different masses of one element which combine with a fixed mass of the other element, bear a simple ratio to one another.

Illustration

Two compounds each containing only tin and oxygen had the following composition.

	Mass % of Tin	Mass % of oxygen
Compound A	78.77	21.23
Compound B	88.12	11.88

Show that these data illustrate the law of multiple proportion?

Sol.

In compound A

21.23 parts of oxygen combine with 78.77 parts of tin.

1 part of oxygen combine with $\frac{78.77}{21.23} = 3.7$ parts of Sn.

In compound B

11.88 parts of oxygen combine with 88.12 parts of tin.

1 part of oxygen combined with $\frac{88.12}{11.88} = 7.4$ parts of tin.

Thus the mass of Tin in compound A and B which combine with a fixed mass of oxygen are in the ratio 3.7 : 7.4 or 1 : 2. This is a simple ratio. Hence the data illustrate the law of multiple proportion.

Exercise

Carbon and oxygen are known to form two compounds. The carbon content in one of these is 42.9% while in the other it is 27.3%. Show that these data are in agreement with the law of multiple proportion.

5.4 Law of reciprocal proportion : [Richter 1794]

When two different elements combine with the same mass of a third element, the ratio in which they do so will be same or simple multiple if both directly combined with each other.

Illustration

The % composition of NH_3, H_2O and N_2O_3 is as given below :

$NH_3 \longrightarrow$ 82.35% N and 17.65% H.

$H_2O \longrightarrow$ 88.9% O and 11.1% H

$N_2O_3 \longrightarrow$ 63.15% O and 36.85% N

On the basis of above data prove the law of reciprocal proportion?

Sol. (i) For NH_3 1-part of hydrogen reacts with $= \dfrac{82.35}{17.65} = 4.67$ part N.

(ii) For H_2O 1-part of hydrogen reacts with $= \dfrac{88.90}{11.10} = 8.01$ part O.

Thus the ratio N : O = 4.67 : 8.01 = 1: 1.71

(iii) For N_2O_3 : N and O reacts with each other N : O = 36.85 : 63.15 = 1 : 1.71

Because the two ratios are same, thus law of reciprocal proportion is proved.

5.5 Gay-Lussac's law of gaseous volumes [Gay-Lussac–1808] :

When gases combined or produced in a chemical reaction, they do so in a simple ratio by volume provided all the gases are at same temperature and pressure.

6. SIGNIFICANCE OF CHEMICAL EQUATIONS

A chemical equation describes the chemical process both qualitatively and quantitatively. The stoichiometric coefficients in the chemical equation give the quantitative information of the chemical process. These coefficients represent the relative number of molecules or moles of the reactants and products, e.g.,

	$2\,NH_3\,(g)$	$\rightarrow$	$N_2\,(g)$	+	$3\,H_2\,(g)$
	2 molecules		1 molecule		3 molecules
or	2 N molecules		N molecules		3 N molecules
or	2 moles		1 mole		3 moles

Again, Avogadro's principle states that under the same conditions of temperature and pressure, equal volumes of gases contain the same number of molecules. Thus, for homogeneous gaseous reactions, the stoichiometric coefficients of the chemical equation also signify the relative volumes of each reactant and product under the same conditions of temperature and pressure, e.g.,

	$H_2(g)$	+	$I_2\,(g)$	$\rightarrow$	$2\,HI\,(g)$
	1 molecule		1 molecule		2 molecule
or	1 mole		1 mole		2 mole
or	1 volume		1 volume		2 volume (T & P constant)
or	1 pressure		1 pressure		2 pressure (T & V constant)

6.1 LIMITING REAGENT

The reactant which gives least amount of product on being completely consumed is known as limiting reagent. It may also be defined as the reactant that is completely consumed when a reaction goes to completion. It comes into the picture when reaction involves two ore more reactants. For solving such reactions, first step is to calculate Limiting Reagent.

Calculation of Limiting Reagent:

Method-I : By calculating the required amount by the equation and comparing it with given amount. [Useful when only two reactant are there]

Method-II : By calculating amount of any one product obtained taking each reactant one by one irrespective of other reactants. The one giving least product is *limiting reagent*.

Method-III : Divide given moles of each reactant by their stoichiometric coefficient, the one with least ratio is *limiting reagent*. [Useful when number of reactants are more than two.]

Illustration

If 20gm of $CaCO_3$ is treated with 20gm of HCl, how many grams of CO_2 can be generated according to following reaction?

$CaCO_3(g) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$

Sol. Mole of $CaCO_3 = \frac{20}{100} = 0.2$

Mole of $HCl = \frac{20}{36.5} = 0.548$

$\left[\frac{Mole}{Stoichiometric\ co\text{-}efficient}\right]$ for $CaCO_3 = \frac{0.2}{1} = 0.2$

$\left[\frac{Mole}{Stoichiometric\ co\text{-}efficient}\right]$ for $HCl = \frac{0.548}{2} = 0.274$

So $CaCO_3$ is limiting reagent

According to reaction :

100 gm of $CaCO_3$ gives 44gm of CO_2

20 gm $CaCO_3$ will give $\frac{44}{100} \times 20 = 8.8$ gm CO_2

Exercise

Calculate the mass of carbon tetrachloride can be produced by the reaction of 144gm of carbon with 71 gm of Chlorine.

Ans. 77 gm

6.2 PROBLEMS RELATED WITH MIXTURE

Illustration

4 gram of a mixture of $CaCO_3$ and Sand (SiO_2) is treated with an excess of HCl and 0.88 gm of CO_2 is produced. What is the percentage of $CaCO_3$ in the original mixture?

Ans. $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

$SiO_2 + HCl \rightarrow$ No reaction

$CaCO_3 = x$ gm

100 gm $CaCO_3$ gives $\longrightarrow$ 44 gm CO_2

x gm $CaCO_3$ gives $\longrightarrow$ 0.88 gm CO_2

$$\Rightarrow \quad \frac{100}{x} = \frac{44}{0.88} \quad \Rightarrow \quad x = 2 \text{ gram}$$

$$\% \, CaCO_3 = \frac{2}{4} \times 100 = 50\%$$

Exercise

44 gram sample of a natural gas, consisting of methane [CH_4] and ethylene [C_2H_4] was burned in excess of oxygen yielding 132 gm CO_2 and some H_2O as products. What is the mole % of ethylene in the sample?

Ans. 50%

6.3 PERCENTAGE YIELD

In gener59al, when a reaction is carried out in the laboratory we do not obtain the theoretical amount of product. The amount of product that is actually obtained is called the actual yield. Knowing the actual yield and theoretical yield, the % yield can be calculated by the following formula–

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoritical yield}} \times 100\,\%$$

Illustration

For the reaction

$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

1.12 gram of CaO is reacted with excess of hydrochloric acid and 1.85 gm $CaCl_2$ is formed. What is the % yield of the reaction?

Sol. $CaO + 2HCl \rightarrow CaCl_2 + H_2O$

56 gm CaO will produce 111 gm $CaCl_2$

1.12 gram of CaO will produce $\rightarrow \frac{111}{56} \times 1.12 = 2.22$ gm

Thus Theoretical yield = 2.22 gm

Actual yield = 1.85 gm

$\% \text{ yield} = \frac{1.85}{2.22} \times 100 = 83.33\ \%$

Exercise

Calculate the mass of KCl that is produced from 1 mole of $KClO_3$ if % yield of reaction is 80?

Ans. 59.6 gm

6.4 PERCENTAGE PURITY

Depending upon the mass of the product, the equivalent amount of reactant present can be determined with the help of given chemical equation. Knowing the actual amount of the reactant taken and the amount calculated with the help of a chemical equation, the purity can be determined, as

$$\text{Percentage purity} = \left[\frac{\text{Amount of reactant calculated from the chemical equation}}{\text{Actual amount of reactant taken}}\right] \times 100\,\%$$

Illustration

Calculate the amount of (CaO) in kg that can be produced by heating 200 kg lime stone that is 90% pure $CaCO_3$.

Sol. Mass of Pure $CaCO_3 = \frac{200 \times 90}{100} = 180$ kg

$CaCO_3 \longrightarrow CaO + CO_2$

100 kg   56 kg

180   x

$\frac{100}{180} = \frac{56}{x} \Rightarrow x = 100.8$ kg

Exercise

Calculate the mass of coal sample in kg containing 0.05% mass of iron pyrite [FeS_2] that can produced 44.8 litre of SO_2 at 1atm and 273 with 40% reaction yield?

$$FeS_2 + \frac{5}{2}O_2 \longrightarrow FeO + 2SO_2$$

Ans. 600 kg

6.5 PROBLEMS RELATED WITH SEQUENTIAL REACTION

Illustration

$KClO_4$ can be prepared by Cl_2 and KOH by a series of reactions as given below

$Cl_2 + 2KOH \longrightarrow KCl + KClO + H_2O$

$3KClO \longrightarrow 2KCl + KClO_3$

$4KClO_3 \longrightarrow 3KClO_4 + KCl$

(i) Calculate mass of Cl_2 in gram required to produce 1385 gm $KClO_4$?

(ii) Calculate the total mass of KCl produced in I^{st}, 2^{nd} and 3^{rd} reaction?

Sol. **(i)** Let mole of Cl_2 required = x

$Cl_2 + 2KOH \longrightarrow KCl + KClO + H_2O$

x x x

$3KClO \longrightarrow 2KCl + KClO_3$

x $\frac{2x}{3}$ $\frac{x}{3}$

$4KClO_3 \longrightarrow 3KClO_4 + KCl$

$\frac{x}{3}$ $\frac{x}{4}$ $\frac{x}{12}$

Mole of $KClO_4$ formed $= \frac{1385}{138.5} = 10$

$\frac{x}{4} = 10$, x = 40

∴ Mass of Cl_2 required for the reaction = 40 × 71 = 2840 gm

(ii) KCl produced from I^{st}, II^{nd} and III^{rd} reaction $= \left(x + \frac{2x}{3} + \frac{x}{12}\right)$ mole

$= \frac{21x}{12}$ mole $= \frac{21}{12} \times 40 = 70$ mole

∴ Mass of KCl produced = 70 × 74.5 = 5215 gram

Exercise

Sulphur trioxide may be prepared by the following two reactions

$S_8 + 8O_2 \longrightarrow 8SO_2$

$2SO_2 + O_2 \longrightarrow 2SO_3$

How many gram of SO_3 will be produced from 1 mole of S_8.

Ans. 640 gram

6.6 PROBLEM RELATED WITH PARALLEL REACTIONS

Illustration

If 6 moles of $KClO_3$ are decomposed according to following reactions calculate the moles of $KClO_4$ produced if mole of O_2 produced are 3?

$KClO_3 \longrightarrow KCl + \frac{3}{2}O_2$ ... (i)

$4KClO_3 \longrightarrow 3KClO_4 + KCl$ ... (ii)

Sol. Let x-mole $KClO_3$ reacts in reaction (i) and y mole $KClO_3$ reacts in reaction (ii)

$KClO_3 \longrightarrow KCl + \frac{3}{2}O_2$ ... (i)

x mole $\frac{3x}{2}$ mole

$4KClO_3 \longrightarrow 3KClO_4 + KCl$ ... (ii)

y mole

From question $x + y = 6$

and $\frac{3x}{2} = 3$

$\therefore$ $x = 2$ mole and $y = 4$ mole

It means 4 mole $KClO_3$ reacts in reaction (ii)

From reaction (ii)

4 mole $KClO_3$ gives 3 mole $KClO_4$

Ans. 3 mole

Exercise

$A_2 + 2B_2 \longrightarrow A_2B_4$ and $\frac{3}{2}A_2 + 2B_2 \longrightarrow A_3B_4$

Two substances A_2 and B_2 are allowed to react completely to form A_2B_4 and A_3B_4 mixture, leaving none of the reactions. Using this information. Calculate the composition of final mixture when 5/4 mole of A_2 and 2 mole of B_2 is taken?

Ans. $A_3B_4 = 0.5$ mole, $A_2B_4 = 0.5$ mole

6.7 PRINCIPLE OF ATOM CONSERVATION

The principle of conservation of mass, expressed in the concepts of atomic theory means the conservation of atoms. And if atoms are conserved, moles of atoms shall also be conserved. This is known as the principle of atom conservation. This principle is in fact the basis of the mole concept.

In order to solve problems of nearly all stoichiometric calculations, let us first see how this principle works. Choose an example,

$$KClO_3\,(s) \rightarrow KCl\,(s) + O_2\,(g)$$

Apply the principle of atom conservation (POAC) for K atoms.

Moles of K atoms in reactant = mole of K atoms in products

Moles of K atoms in $KClO_3$ = moles of K atoms in KCl.

Now, since 1 molecule of $KClO_3$ contains 1 atom of K

or 1 mole of $KClO_3$ contains 1 mole of K, similarly, 1 mole of KCl contains 1 mole of K

Thus, mole of K atoms in $KClO_3 = 1 \times$ moles of $KClO_3$

and Mole of K atoms in KCl = $1 \times$ moles of KCl

$\therefore$ mole of $KClO_3$ = mole of KCl

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

The above equation gives the weight relationship between $KClO_3$ and KCl which is important in stoichiometric calculations.

Again, applying the principle of atom conservation for O atoms,

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

But since 1 mole of $KClO_3$ contains 3 moles of O and 1 mole of O_2 contains 2 moles of O,

Thus, mole of O in $KClO_3 = 3 \times$ moles of $KClO_3$

Moles of O in $O_2 = 2 \times$ moles of O_2

$\therefore$ $3 \times$ moles of $KClO_3 = 2 \times$ moles of O_2

or
$$3 \times \frac{\text{wt. of } KClO_3}{\text{mol. wt. of } KClO_3} = 2 \times \frac{\text{wt. of } O_2}{\text{mol. wt. of } O_2}$$

Mole of O_2 may also be expressed in volume.

Illustration

All carbon atoms present in $KH_3(C_2O_4)_2.2H_2O$ weighing 254 gm is converted to CO_2. How many gram of CO_2 were obtained?

Sol. Apply P.O.A.C. on carbon atom

$4 \times$ mole of $KH_3(C_2O_4)_2.2H_2O = 1 \times$ mole of CO_2

$$4 \times \frac{254}{254} = 1 \times \frac{w_{CO_2}}{44}$$

$\therefore$ Mass of $CO_2 = 4 \times 44 = 176$ gram

Exercise

A sample of KNO_3 weighing W, gram undergo a series of reaction in such a way that all nitrogen atom are converted to $K_2Zn_3[Fe(CN)_6]_2$. How many gram of the product were obtained ?
[Given M.wt of $KNO_3 = M_1$, M.wt of $K_2Zn_3[Fe(CN)_6)]_2 = M_2$]

Ans. $\frac{W_1M_2}{12M_1}$

7.1 AVERAGE ATOMIC MASS

$$\text{Average atomic mass} = \frac{\text{total mass}}{\text{total mole of atoms}}$$

Let a sample contains n_1 mole of atoms with atomic mass M_1 and n_2 mole of atoms with atomic mass M_2. then

$$M_{av} = \frac{n_1M_1 + n_2M_2}{n_1 + n_2}$$

Illustration

Find the average atomic mass of a mixture containing 25% by mole Cl^{37} and 75% by mole Cl^{35} ?

Sol. $n_1 = 25$ $M_1 = 37$
$n_2 = 75$ $M_2 = 35$

$$M_{av} = \frac{25 \times 37 + 75 \times 35}{25 + 75} = 35.5$$

Exercise

Ag^{107} and Ag^{109}
average atomic mass = 108.5 find % by mole of each isotope

Ans. $Ag^{107} = 25\%$, $Ag^{109} = 75\%$

7.2 AVERAGE MOLECULAR MASS

$$\text{Average molecular mass} = \frac{\text{total mass}}{\text{total mole of molecules}}$$

Let a sample contains n_1 mole of molecules with molecular mass M_1 and n_2 mole of molecules with molecular mass M_2, then

$$M_{av} = \frac{n_1M_1 + n_2M_2}{n_1 + n_2}$$

Illustration

Air is a mixture of O_2 and N_2 in which O_2 is present 20% by mole and N_2 is present 80% by mole. Find out the average molecular mass of air ?

Sol. $n_1 = 20$ $M_1 = 32$

$n_2 = 80$ $M_2 = 28$

$$M_{av} = \frac{n_1M_1 + n_2M_2}{(n_1 + n_2)} = \frac{20 \times 32 + 80 \times 28}{(20 + 80)} = 28.8$$

Exercise

Two gases A and B [M.wt of A = 20 and M. wt of B = 30] are mixed in the mole ratio a : b and the average molecular mass of the gas mixture is 24. What will be the average molar mass of the gas mixture, if gases A and B are mixed in the ratio b : a ?

Ans. 26

8. EMPIRICAL & MOLECULAR FORMULA

Empirical formula of a compound represents the ratio of different atoms present in a molecule.
Molecular formula of a compound represents the exact no. of atoms present in a molecule.
For Hydrogen peroxide, Empirical formula = HO, Molecular formula = H_2O_2

Steps for writing the empirical formula

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

(i) Divide the percentage of each element by its atomic mass. This will give the relative number of moles of atoms of various elements present in the compound.

(ii) Divide the quotients obtained in the above step by the smallest of them so as to get a simple ratio of moles of various elements.

(iii) Multiply the figures so obtained, by a suitable integer, if necessary, in order to obtain a whole number ratio.

(iv) Finally write down the symbols of the various elements side by side and put the above number as the subscripts to the lower right hand corner of each symbol. This will represent the empirical formula of the compound.

Steps for writing the molecular formula

(i) Calculate the empirical formula as described above.

(ii) Find out the empirical formula mass by adding the atomic masses of all the atoms present in the empirical formula of the compound.

(iii) Divide the molecular mass (determined experimentally by some suitable method) by the empirical formula mass and find out the value of n.

Illustration

Calculate the empirical formula for a compound that contains 26.6% potassium, 35.4% chromium and 38.1% oxygen by mass ?
Given : [Atomic wt : - K = 39; Cr = 52; O = 16]

Sol.

Element	Mass Percentage	Atomic mass	Relative no. of atoms	Simple Ratio
K	26.6	39	$\frac{26.6}{39} = 0.68$	$\frac{0.68}{0.68} = 1$
Cr	35.4	52	$\frac{35.4}{52} = 0.68$	$\frac{0.68}{0.68} = 1$
O	38.1	16	$\frac{38.1}{16} = 2.38$	$\frac{2.38}{0.68} = 3.5$

K : Cr : O   1 : 1 : 3.5
2 : 2 : 7 (whole no. ratio)

Empirical formula :- $K_2Cr_2O_7$

Exercise

A carbon compound containing only carbon and oxygen has an approximate molecular mass of 290. On analysis it is found to contain 50% by mass of each element what is the molecular formula of the compound?

Ans. $C_{12}O_9$

9. VAPOUR DENSITY

Some times in numericals molecular mass of volatile substance is not given, instead vapour density is given. Vapour density can be defined as

$$V.D. = \frac{\text{Density of gas at a given T and P}}{\text{Density of } H_2 \text{ at same T and P}}$$

or, $$V.D = \frac{M_{gas}}{2}$$

$$M_{gas} = 2 \times V.D.$$

Illustration

A compound of nitrogen and oxygen was found to contain 7 : 16 by mass N and O respectively. Calculate molecular formula of the compound if V.D. is 46 ?

Sol. Let mass of N = 7 K gram

Mass of O = 16 K gram

Element	Mass	Atomic mass	Relative no. of atoms	Simple ratio
N	7 K	14	$\frac{7K}{14} = 0.5K$	$\frac{0.5\,K}{0.5\,K} = 1$
O	16 K	16	$\frac{16\,K}{16} = K$	$\frac{K}{0.5\,K} = 2$

N : O = 1 : 2

Empirical formula = NO_2

$(\text{Empirical formula})_n = \text{molecular formula}$

$$n = \frac{\text{M.mass}}{\text{empirical formula mass}} = \frac{2 \times \text{V.D}}{46} = \frac{2 \times 46}{46} = 2$$

Molecular formula $= (NO_2)_2 = N_2O_4$

10. EXPERIMENTAL METHODS FOR DETERMINATION OF ATOMIC MASS & MOLECULAR MASS

10.1 For determination of atomic mass :-

DULONG'S & PETIT'S LAW

In case of heavy solid elements, it is observed that product of atomic mass and specific heat capacity is almost constant.

$$\text{Atomic mass} \times \text{Specific heat capacity (Cal/gm }^{o}\text{C)} \approx 6.4$$

It should be remembered that this law is an empirical observation and this gives an approximate value of atomic mass.

Illustration :

The approximate specific heat capacity of a metal is 0.836 J/gm °C. Find out the approximate atomic mass of the metal?

Ans. Atomic mass $\times$ specific heat ≈ 6.4

$$\text{Atomic mass} \approx \frac{6.4}{\text{specific heat}} = \frac{6.4}{0.836/4.2} = 32$$

10.2 For determination molecular mass :

Some of the most commonly used methods for determination of molecular mass are:

(i) Victor Meyer's Method

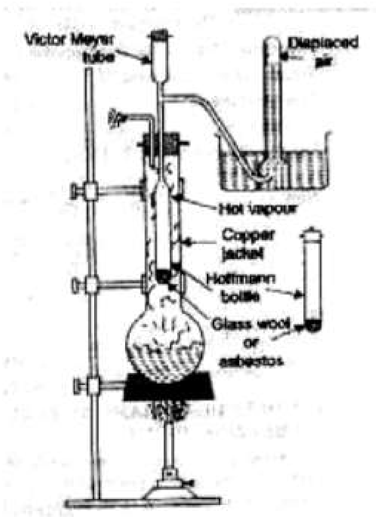
(ii) Silver Salt Method

(iii) Platinic chloride method

10.2.1 VICTOR MEYER'S METHOD

(Applicable for volatile substance)

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



Calculations involved

Let the mass of the substance taken be	= W g
Volume of moist vapours collected	= V cm^3
Room temperature	= T K
Barometric pressure	= P mm
Aqueous tension at T K	= p mm
Pressure of dry vapour	= (P - p) mm.

Calculation of molecular mass(M).

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

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

Applying PV = nRT for the dry vapour and using n = w/M

Vapour pressure of liquid

The pressure exerted by the vapours in equilibrium with its liquid state is called vapour pressure of liquid. In case of liquid water it is also known as aqueous tension.

It depends only on temperature of liquid and is independent of

(i) Amount of liquid

(ii) Surface area of liquid

(iii) Volume of container

Illustration

0.15 g of a substance displaced 58.9 cm^3 of air at 300 K and 746 mm pressure Calculate the molecular mass. (Aq. Tension at 300 K = 26.7 mm).

Sol. Mass of the substance = 0.15 g
Volume of air displaced (V) = 58.9 cm^3
Temperature (T) = 300 K
Pressure (P) = 746 - 26.7 = 719.3 mm

$$\text{Molecular mass} = \frac{719.3}{760} \times \frac{58.9}{1000} = \frac{0.15}{M} \times 0.821 \times 300$$

$\therefore$ Molecular mass = 66.27 g/mol

10.2.2 SILVER SALT METHOD

(Applicable to organic acids only).

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

$$\underset{\text{organic acid}}{HX} \xrightarrow{AgNO_3} \underset{\substack{\text{Silver salt} \\ (W\ g)}}{AgX} \xrightarrow{\text{Ignite}} \underset{\substack{\text{Silver} \\ (x\ g)}}{Ag}$$

Calculations involved

Let the mass of the silver salt formed = W g
The mass of Ag formed = x g
For polybasic acid of the type H_nX (n is basicity)

$$\underset{\text{Organic acid}}{H_nX} \xrightarrow{AgNO_3} \underset{\substack{\text{Silver salt} \\ (W\ g)}}{Ag_nX} \xrightarrow{\text{Ignite}} \underset{\substack{\text{silver} \\ (x\ g)}}{nAg}$$

Mass of silver that gives x g of Ag = Wg

Mass of silver that gives n g- atom (108 g) of $Ag = \frac{108nW}{x} g$

Molar Mass of salt $= \frac{108 \times nW}{x} g$

Molar mass of acid = (molar mass of salt) – n (atomic mass of silver) + n (atomic mass of H)

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

Illustration

0.41 g of the silver salt of a dibasic organic acid left a residue to 0.216 g of silver on ignition. Calculate the molecular mass of the acid

Sol. Molecular mass of the silver salt taken (W) = 0.41 g

Mass of Ag formed (x) = 0.216 g

$$H_2X \rightarrow \underset{w=0.41g}{Ag_2X} \rightarrow \underset{x=0.216\,g}{2\,Ag}$$

$$\text{Now molar mass of acid} = n\left(\frac{108W}{x} - 107\right)\text{g mol}^{-1}$$

$$= 2\left(\frac{108 \times 0.41}{0.216} - 107\right)\text{g mol}^{-1} = 196\text{gmol}^{-1}$$

10.2.3 PLATINIC CHLORIDE METHOD

(Applicable for finding the molecular masses of organic bases.)

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

If B represents the molecule of monoacidic organic base, then, the formula of platinic chloride salt is $B_2H_2PtCl_6$

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

Calculations involved

Let the mass of platinic chloride salt = Wg

The mass of platinum residue left = x g

It may be noted that salt formed with diacidic base would be $B_2(H_2PtCl_6)_2$: with triacidic base would be $B_2(H_2PtCl_6)_3$ and with polyacidic base would be $B_2(H_2PtCl_6)_n$

$$\text{Mass of salt which gives 195g (1 g- atom) of Pt} = \frac{W \times 195 \times n}{x}$$

$$\text{Molar mass of salt} = \frac{W \times 195 \times n}{x}\text{g mol}^{-1}$$

Now from the formula $B_2(H_2PtCl_6)_n$

Molar mass of salt = [2 × Molar mass of base] + n × [Molar mass of H_2PtCl_6]

Molar mass of base = $\frac{1}{2}(Molar\ mass\ of\ salt - Molar\ mass\ of\ H_2PtCl_6)$

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

Illustration

0.98 g of the chloroplatinate of some diacidic base when ignited left 0.39 g of platinum as residue. What is the molecular mass of the base? (At. Mass of Pt = 195)

Sol. Mass of the chloroplatinate salt (W) = 0.98 g

Mass of platinum (x) = 0.39 g

Acidity of the base (n) = 2

Now molar mass of the base $= \frac{n}{2}\left(\frac{W \times 195}{x} - 410\right) \text{gmol}^{-1}$

$$= \frac{2}{2}\left(\frac{0.98 \times 195}{0.39} - 410\right) \text{gmol}^{-1} = 80 \text{ gmol}^{-1}$$

11. EUDIOMETRY - GAS ANALYSIS

The study of gaseous reactions is done in a eudiometer tube with the help of Gay-Lussac's law and Avogadro's law. Eudiometer tube is a closed graduated tube open at one end. The other end is a closed one which is provided with platinum terminals for passing electricity for electric spark, through the known volume of mixture of gases and known volume of oxygen gas. Volume of CO_2 formed is determined by absorbing in KOH solution, O_2 is determined by dissolving unreacted O_2 in alkaline pyrogallol and water vapours formed are determined by noting contraction in volume caused due to cooling. Eudiometry helps :

(i) To study composition of gaseous mixture
(ii) To study volume – volume relationship
(iii) To determine molecular formula of gaseous hydrocarbons and
(iv) To determine molecular formula of gases

11.1 GAY LUSSAC LAW

According to Gay - Lussac's law, the volumes of gaseous reactants reacted and the volumes of gaseous products formed, all are measured at the same temperature and pressure, bear a simple ratio.

$$\underset{\substack{1\text{ mol}\\1\text{ vol}}}{N_2(g)} + \underset{\substack{3\text{ mol}\\3\text{ vol}}}{3H_2(g)} \longrightarrow \underset{\substack{2\text{ mol}\\2\text{ vol}}}{2NH_3(g)}$$

11.2 AVOGADRO'S LAW

In 1812, Amadeo Avogadro stated that samples of different gases which contain the same number of molecules (any complexity, size, shape) occupy the same volume at the same temperature and pressure.

For ideal gas at constant Temperature & Pressure, pressure is directely proportional to no. of moles

11.3 SOME ABSORBENTS OF GASES

The absorbent which is used for specific gas is listed below

Absorbent	**Gas or gases absorbed**
Turpentine oil	O_3
Alkaline pyrogallol	O_2
Ferrous sulphate solution	NO
Heated magnesium	N_2
Heated palladium	H_2
Ammonical coprous chloride	O_2, CO, C_2H_2 or $CH\equiv CH$
Copper sulphate solution	H_2S, PH_3, AsH_3
Conc. H_2SO_4	H_2O i.e., moisture, NH_3
NaOH or KOH solution	CO_2, NO_2, SO_2, X_2, all acidic oxides

11.4 VOLUME EXPANSION AND CONTRACTION IN THE EUDIOMETER TUBE

$$aA(g) + bB(g) \longrightarrow cC(g) + dD(g)$$

Δn_g = No. of gaseous products – No. of gaseous reactants = (c + d) – (a + b)

(a) If $\Delta n_g > 0$, then expansion will occur

(b) If $\Delta n_g = 0$, No contraction /expansion (volume remains constant)

(c) If $\Delta n_g < 0$, then contraction will occur

11.5 ASSUMPTIONS

1. All gases are assumed to be ideal.
2. Nitrogen gas formed during reaction will not react with any other gas.
3. The volume of solids and liquids are negligible in comparision to the volume of gas.

11.6 GENERAL REACTIONS FOR COMBUSTION OF ORGANIC COMPOUNDS

(i) When an organic compound is hydrocarbon :

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow xCO_2 + \frac{y}{2} H_2O$$

(ii) When an organic compound contain carbon, hydrogen and oxygen :

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right) O_2 \rightarrow xCO_2 + \frac{y}{2} H_2O$$

(iii) When an organic compound contain carbon, hydrogen and nitrogen :

$$C_xH_yN_z + \left(x + \frac{y}{4}\right) O_2 \rightarrow xCO_2 + \frac{y}{2} H_2O + \frac{z}{2} N_2$$

11.7 ANALYSIS OF GASEOUS MIXTURE

Illustration

10 ml of a mixture of CO, CH_4 and N_2, exploded with excess of oxygen, gave a contraction of 6.5 ml. There was a further contraction of 7 ml when the residual gas was treated with KOH. What is the composition of the original mixture ?

Sol. Let the volume of CO = a ml

CH_4 = b ml

∴ $N_2 = (10 - a - b)$ ml

The explosion reactions are

$$\underset{a}{CO} + \underset{a/2}{1/2\ O_2} \rightarrow \underset{a}{CO_2}$$

$$\underset{b}{CH_4} + \underset{2b}{2O_2} \rightarrow \underset{b}{CO_2} + 2H_2O\ (l)$$

contraction in volume = a + a/2 + b + 2b – a–b = 6.5

or, a + 4b = 13 ....(1)

CO_2 is absorbed by KOH solution

∴ a + b = 7 ....(2)

From equation (1) and (2) a = 5, b = 2

$$\therefore \begin{cases} \text{vol. of } CO = 5mL \\ \text{vol. of } CH_4 = 2mL \\ \text{vol. of } N_2 = 10 - 5 - 2 = 3mL \end{cases}$$

Exercise

A mixture of Cl_2 gas (2.8 L) and H_2 gas (3L) was exploded in a eudiometer tube. Calculate the composition by volume of the resulting mixture if all measurements are done under similar conditions of temperature and pressure.

Ans. Volume of H_2 gas left behind = 0.2 L , Volume of HCl gas formed = 5.6 L

11.8 VOLUME - VOLUME ANALYSIS

Illustration

1 litre of a mixture of CO and CO_2 is taken. This mixture is passed through a tube containing red hot charcoal. The volume now becomes 1.6 litres. The volumes are measured under the same condition. Find the composition of the mixture by volume.

Sol. Let the volume of CO_2 in the mixture be x litres

On passing through red hot charcoal, $CO_2 + C \longrightarrow 2CO$

x litre   2x litre

Now, total volume of CO = (1 – x) + 2x = 1.6 (given)

$\therefore$ x = 0.6 litre

$\therefore$ volume of CO_2 in the mixture = 0.6 litre

volume of CO in the mixture = 1 – 0.6 = 0.4 litre

Exercise

60 ml of a mixture of nitrous oxide and nitric oxide was exploded with excess of hydrogen. If 38 ml of N_2 was formed, calculate the volume of each gas in the mixture.

Ans. NO = 44 ml

N_2O = 16 ml **Ans.**

11.9 DETERMINATION OF MOLECULAR FORMULA OF GASEOUS HYDROCARBONS

Illustration

A gaseous hydrocarbon (V.D. = 15) having volume 10 ml was exploded with excess of O_2. On cooling, a contraction in volume by 25 ml was observed. Calculate the molecular formula of the hydrocarbon.

Sol. Let the molecular formula of hydrocarbon = C_xH_y

Reaction $$C_xH_y + \left(x+\frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$$

$$10\text{ ml} \qquad 10\left(x+\frac{y}{4}\right)\text{ ml} \qquad 10\,x\text{ ml}$$

From reaction contraction in volume is given as : $10 + 10\left(x+\frac{y}{4}\right) - 10x = 25$ (given)

$\therefore$ y = 6

Now, Formula of hydrocarbon = C_xH_6

Mol. wt. of $C_xH_6 = (12 \times x) + (6 \times 1) = 2 \times 15$

$\therefore$ x = 2

Hence, Molecular formula of hydrocarbon = C_2H_6

Exercise

500 ml of a hydrocarbon gas burnt in excess of oxygen yields 2500 ml of CO_2 and 3.0 litres of water vapours, all the volume being measured at the same temperature and pressure. What is the formula of hydrocarbon gas ?

Ans. C_5H_{12}

11.10 DETERMINATION OF MOLECULAR FORMULA OF GASES

Illustration

60 ml of a mixture of equal volumes of Cl_2 and an oxide of chlorine were heated and then cooled back to the original temperature. The resulting gas mixture was found to have a volume of 75 ml. On treatment with caustic soda, the volume contracted to 15 ml. Assuming that all measurements where made at the same temperature & pressure, deduce the simplest formula of the oxide of chlorine. (The oxide of chlorine on heating decomposes quantitatively to give O_2 & Cl_2)

Sol. Let Cl_xO_y be the oxide.

$$Cl_xO_y \rightarrow \frac{x}{2} Cl_2 + \frac{y}{2} O_2$$

$$1 \text{ Vol.} \qquad \frac{x}{2} \text{ Vol.} \qquad \frac{y}{2} \text{ Vol.}$$

$$30 \text{ ml} \qquad 15\,x \text{ ml} \qquad 15y \text{ ml}$$

Volume of Cl_xO_y = Vol. of Cl_2 initially = 30 ml
After cooling volume = 75 ml
This corresponds to volume of Cl_2 initially plus volume of Cl_2 produced & O_2 produced.

$$V(Cl_2) + V(Cl_2 \text{ produced}) + V(O_2) = 75 \text{ ml}$$

NaOH absorbs Cl_2 apart from CO_2. So after NaOH treatment, the residual volume corresponds to the volume of O_2 = 15 ml
and V (Cl_2 produced) = 75 – V (Cl_2) – V(O_2) = 75 – 30 – 15 = 30 ml
$15x = 30 \Rightarrow x = 2$
and $15y = 15 \Rightarrow y = 1$
Hence, formula of oxide of chloride is Cl_2O.

Exercise

50 ml of pure and dry oxygen was subjected to silent electric discharge and on cooling to the original temperature , the volume of ozonised oxygen was found to be 47 ml. The gas was then brought in contact with turpentine oil, the remaining gas occupied a volume of 41 ml. Find the molecular formula of ozone.

Ans. O_3

12. CONCENTRATION TERMS

A solution is a homogeneous mixture of two or more substances, the composition of which may vary within limits. "A solution is a special kind of mixture in which substances are intermixed so intimately that they can not be observed as separate components". The substance which is to be dissolved is called **solute** while the medium in which the solute is dissolved to get a homogeneous mixture is called the **solvent**. A solution is termed as binary and ternary if it consists of two and three components respectively.

12.1 METHODS OF EXPRESSING CONCENTRATION OF SOLUTION

Concentration of solution is the amount of solute dissolved in a known amount of the solvent or solution. The concentration of solution can be expressed in various ways as discussed below.

12.1.1 Percentage : It refers to the amount of the solute per 100 parts of the solution. It can also be called as parts per hundred (pph). It can be expressed by any of following four methods :

(i) Weight by weight percentage (%w/w) $= \dfrac{\text{Wt.}\,of\ solute\ (g)}{Wt.\ of\ solution\ (g)} \times 100$

e.g., 10% Na_2CO_3 solution w/w means 10g of Na_2CO_3 is dissolved in 100g of the solution. (It means 10g Na_2CO_3 is dissolved in 90 of solvent)

(ii) Weight by volume percent (% w/v) $= \dfrac{\text{Wt.}\,of\ solute(g)}{Volume\ of\ solution\ (cm^3)} \times 100$

e.g., 10% Na_2CO_3 (w/v) means 10g Na_2CO_3 is dissolved in 100 cm^3 of solution.

(iii) Volume by volume percent (% v/v) $= \dfrac{\text{Volume}\,of\ solute\ (cm^3)}{Volume\ of\ solution(cm^3)} \times 100$

e.g., 10% ethanol (v/v) means 10cm^3 of ethanol dissolved in 100 cm^3 of solution.

(iv) Volume by weight percent (%v/w) $= \dfrac{\text{Vol. of solute}}{\text{Wt. of solution}} \times 100$

e.g., 10% ethanol (v/w) means 10cm^3 of ethanol dissolved in 100g of solution.

Illustration

Concentrated nitric acid used as laboratory reagent is usually 69% by mass of nitric acid. Calculate the volume of the solution which contains 23 g nitric acid. The density of concentrated acid is 1.41 g cm^{-3}.

Sol. Given HNO_3 is 69% by mass;
density of HNO_3 = 1.41 g cm^{-3}.
Thus (i) 69 g HNO_3 is present in conc. HNO_3 = 100 g

23 g HNO_3 is present in conc. $HNO_3 = \frac{100}{69} \times 23 = 33.33$ g

(ii) Volume of solution required $= \frac{\text{Mass}}{\text{Density}} = \frac{33.33}{1.41}$ **= 23.64 mL**

Exercise

Calculate % w/w of NaOH in a solution containing 40% w/v NaOH . Density of solution is d (g/ml).

Ans. % by mass $= \frac{40}{d}\%$

12.1.2 Parts per million (ppm) and parts per billion (ppb) : When a solute is present in very small quantity, it is convenient to express the concentration in parts per million and parts per billion. It is the number of parts of solute per million (10^6) or per billion (10^9) parts of solution. It is independent of the temperature.

$$\text{ppm} = \frac{\text{Mass of solute component}}{\text{Total mass of solution}} \times 10^6$$

$$\text{ppb} = \frac{\text{Mass of solute component}}{\text{Total mass of solution}} \times 10^9$$

Illustration

Calculate the parts per million of SO_2 gas in 250 ml water (density 1 g cm^{-3}) containing 5×10^{-4} g of SO_2 gas.

Sol. Mass of SO_2 gas = 5×10^{-4} g;
Mass of H_2O = Volume × Density = 250 cm^3 × 1 g cm^{-3} = 250 g

$\therefore$ Parts per million of SO_2 gas $= \frac{5 \times 10^{-4}}{250\text{g}} \times 10^6$ **= 2**

Exercise

Units of parts per million (ppm) or per billion (ppb) are often used to describe the concentrations of solutes in very dilute solutions. The units are defined as the number of grams of solute per million or per billion grams of solvent. Bay of Bengal has 1.9 ppm of lithium ions. What is the molality of Li^+ in this water ?

Ans. 2.7×10^{-4}

12.1.3 Normality (N) : It is defined as the number of gram equivalents of a solute present per litre of the solution. Unit of normality is gram equivalents litre^{-1}. Normality changes with temperature since it involves volume. When a solution is diluted x times, its normality also decreases by x times. Concentration in terms of normality is generally expressed as,

N = Normal solution; 5N = Penta normal, 10N = Deca normal;

N/2 = semi normal; N/10 = Deci normal; N/5 = Penti normal

N/100 or 0.01 N = centinormal, N/1000 or 0.001 = millinormal.

Mathematically normality can be calculated by following formulas,

(i) Normality

$$N = \frac{\text{Number of gram equivalents of solute}}{\text{Volume of soltuion}(\ell)} = \frac{\text{Weight of solute in gram}}{\text{equivalent weight of solute} \times \text{Volume of solution}(\ell)}$$

$$= \frac{\text{wt. of solute}}{\text{eq. wt. of solute}} \times \frac{1000}{\text{wt. of solution (ml)}}$$

$$\text{Equivalent weight of solute} = \frac{\text{Gram molar mass}}{\text{Acidity/Basicity/Cation valency}}$$

Acidity = No. of replaceable OH^- in a molecule of a base

For example : Acidity of NaOH = 1

Basicity = No. of replaceable H^+ in a molecule of an acid

For example : Basicity of $H_2SO_4 = 2$

(ii) If volume V_1 and normality N_1 is so changed that new normality is N_2 and volume is V_2 then,

$$\boxed{N_1V_1 = N_2V_2}$$ (No. of equivalents remains same in mixing and dilution)

(iii) When two solutions of the same solute and solvent are mixed then normality of mixture (N) is

$$\boxed{N = \frac{N_1V_1 + N_2V_2}{V_1 + V_2}}$$

Illustration

Calculate normality of 7g /L H_2SO_4.

Sol. $N_{H_2SO_4} = \dfrac{g/L}{Eq.wt.} = \dfrac{7}{49} = \dfrac{1}{7} = 0.143 \text{ g eq } l^{-1}$

Exercise

How many grams of oxalic acid are to be dissolved in 250 ml water to prepare 0.1 N solution? (Eq. wt. of ox. acid = 63)

Ans. 1.575g

12.1.4 Molarity (M) : Molarity of a solution is the number of moles of the solute per litre of solution (or number of millimoles per ml of solution). Unit of molarity is mol/litre or mol/dm^3. For example, a molar (1M) solution of sugar means a solution containing 1 mole of sugar per litre of the solution. Solutions in terms of molarity is generally expressed as,

1M = One molar solution, 2M = Molarity is two, $\dfrac{M}{2}$ or 0.5M = Semimolar solution,

$\dfrac{M}{10}$ or 0.1M = Decimolar solution, $\dfrac{M}{100}$ or 0.01 M = Centimolar solution

$\dfrac{M}{1000}$ or 0.001 M = Millimolar solution

Mathematically, molarity can be calculated by following formulas :

(i) $M = \dfrac{\text{No. of moles of solute(n)}}{\text{Vol. of solution in litres}} = \dfrac{\text{wt. of solute (gm)}}{\text{gm mol.wt. of solute}} \times \dfrac{1000}{\text{wt. of solution (ml)}}$

(ii) If molarity and volume of the solution are changed from M_1, V_1 to M_2,V_2. Then,

$$M_1V_1 = M_2V_2$$

(iii) In balanced chemical equation, if n_1 moles of reactant-1 react with n_2 moles of reactant-2 . Then,

$$n_1A + n_2B \longrightarrow \text{Product}$$

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

(iv) If two solutions of the same solute are mixed then molarity (M) of resulting solution

$$M = \frac{M_1V_1 + M_2V_2}{(V_1 + V_2)}$$

Illustration

A bottle of commercial sulphuric acid (density 1.787 g ml^{-1}) is labelled as 86% by weight. What is the molarity of acid?

Sol. (i) Molarity of $H_2SO_4 = \dfrac{\text{Wt. of } H_2SO_4 \text{ in 1L solution}}{\text{mol. wt. of } H_2SO_4}$

But wt. of given H_2SO_4 per litre $= \dfrac{86}{100} \times 1.787 \times 1000 = 1536.82$ g.

Hence molarity of $H_2SO_4 = \dfrac{1536.82}{98} = 15.68 \text{ mol L}^{-1}$

Exercise

A sample contains I_2 and benzene. The mole fraction of $I_2 = 0.2$. Calculate molarity of solution if

(i) density of solution is d gm/ml (ii) density of I_2 & benzene are d_{I_2} & $d_{benzene}$

Ans. (i) M = 1.77 d (ii) $M = \dfrac{0.2}{\left(\dfrac{50.8}{d_{I_2}} + \dfrac{62.4}{d_{benzene}}\right)} \times 1000$

12.1.5 Formality (F) : Formality of solution may be defined as the number of gram formula units of the ionic solute dissolved per litre of the solution. It is represented by **F**. Commonly, the term formality is used to express the concentration of the ionic solids which do not exist as molecules but exist as network of ions. A solution containing one gram formula mass of solute per litre of the solution has formality equal to one and is called **Formal solution**. It may be mentioned here that the formality of a solution changes with change in temperature.

$$\text{Formality(F)} = \frac{\text{Number of gram formula units of solute}}{\text{Volume of solution in litres}}$$

$$= \frac{\text{Mass of ionic solute(g)}}{\text{gram formula unit mass of solute} \times \text{Volume of solution (l)}}$$

Illustration

What will be the formality of KNO_3 solution having strength equal to 2.02 g per litre ?

Sol. Strength of $KNO_3 = 2.02 \text{ gL}^{-1}$

and g formula weight of $KNO_3 = 101$ g

$\therefore$ Formality of $KNO_3 = \dfrac{\text{strength in } gl^{-1}}{\text{g.formula wt.of } KNO_3} = \dfrac{2.02}{101} = \mathbf{0.02\ F}$

Exercise

Calculate the formality of NaCl solution, 5.85 g of which have been dissolved to form 250 ml of the given solution

Ans. 0.4 F

12.1.6 Molality (m) : It is the number of moles of the solute per 1000g of the solvent. Unit of molality is mol/kg. For example, a 0.2 molal (0.2m) solution of glucose means a solution obtained by dissolving 0.2 mole of glucose in 1000 gm of water. Molality (m) does not depend on temperature since it involves measurement of weight of liquids.

Mathematically molality can be calculated by following formulas,

(i) $m = \dfrac{\text{Number of moles of solute}}{\text{Weight of solvent in kg}} = \dfrac{\text{Number of moles of solute}}{\text{Weight of solvent in gm}} \times 1000$

(ii) $= \dfrac{\text{Wt. of solute}}{\text{Mol. wt. of solute}} \times \dfrac{1000}{\text{Weight of solvent in gm}}$

Illustration

The density of a 3 M $Na_2S_2O_3$ solution is 1.25 g ml^{-1}. Calculate percentage by mass of $Na_2S_2O_3$ and molalities of Na^+ and $S_2O_3^{2-}$ ions.

Sol. (i) Total mass of $Na_2S_2O_3$ solution = Vol of solution × Density of solution

= 1000 ml × 1.25 g ml^{-1} = 1250 g

Wt. of 3M $Na_2S_2O_3$ in 1000 ml solution = 3 × Mol. wt of $Na_2S_2O_3$ (158) = 474 g

[∵ Mol. wt. of $Na_2S_2O_3$ = 158 g mol^{-1}]

$\therefore \% \text{ of } Na_2S_2O_3 = \dfrac{\text{Wt. of } Na_2S_2O_3}{\text{Total wt. of solution}} \times 100 = \dfrac{474}{1250} \times 100 = 37.92\%$

(ii) To find molality of Na^+ ions

∵ 3 M $Na_2S_2O_3$ contain 6 moles of Na^+ ions in one litre

$\therefore \text{Molality of } Na^+ \text{ ions} = 6 \times \dfrac{1000}{\text{wt. of solvent } (1250 - 474 = 776\text{g})} = 6 \times \dfrac{1000}{776} = 7.73 \text{ m}$

(iii) To find molality of $S_2O_3^{2-}$

∵ 3M $Na_2S_2O_3$ contain 3 moles of $S_2O_3^{2-}$ ions in one litre

$\text{Molality of } S_2O_3^{2-} = 3 \times \dfrac{1000}{\text{wt. of solvent} = 776} = 3.865 \text{ m}$

Exercise

Find molality of 40% by mass (w/w) NaOH.

Ans. $\frac{50}{3}$ m

12.1.7 Mole fraction (χ) : Mole fraction may be defined as the ratio of number of moles of one component to the total number of moles of all the components (solvent and solute) present in the solution. It is denoted by the letter χ. It may be noted that the mole fraction is independent of the temperature. Mole fraction is dimensionless. If a solution contains the components A and B and suppose that W_A gram of A and W_B gram of B are present in it.

Number of moles of A is given by, $n_A = \frac{W_A}{M_A}$ and the number of moles of B is given by, $n_B = \frac{W_B}{M_B}$

where M_A and M_B are molecular mass of A and B respectively.

Total number of moles of A and B = $n_A + n_B$

Mole fraction of A, $\chi_A = \frac{n_A}{n_A + n_B}$

Mole fraction of B, $\chi_B = \frac{n_B}{n_A + n_B}$

The sum of mole fractions of all the components in the solution is always one.

$$\chi_A + \chi_B = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = 1$$

$$\chi_A + \chi_B = 1$$

Thus, if we know the mole fraction of one component of a binary solution, the mole fraction of the other can be calculated.

Illustration

Find out the masses of acid and water required to prepare 1 mole of CH_3COOH solution of 0.3 mole fraction of CH_3COOH.

Sol. $\chi_{CH_3COOH} = 0.3$

$\chi_{H_2O} = 1 - 0.3 = 0.7$

Wt. of CH_3COOH = χ_{CH_3COOH} × mol. wt.(CH_3COOH) = 0.3 × 60 = **18 g**

Wt. of water = χ_{H_2O} × mol. wt. (H_2O) = 0.7 × 18 = **12.6 g**

Exercise

Mole fraction of a solute in benzene is 0.2. Find out the molality of the solution.

Ans. 3.2 mol kg^{-1}

12.1.8 Mass Fraction : Mass fractino of a component in a solution is the mass of the component divided by the total mass of the solution. For a solution containing w_A gm of A and w_B gm of B.

Mass fraction of A $= \frac{w_A}{w_A + w_B}$ Mass fraction of B $= \frac{w_B}{w_A + w_B}$

Note : It may be noted that molality, mole fraction, mass fraction etc. are preferred to molarity, normality, formality etc. Because the former involve the weights of the solute and solvent where as later involve volumes of solutions. Temperature has no effect on weights but it has significant effect on volumes.

12.2 MOLARITY OF IONIC COMPOUNDS

In ionic compounds, calculate the dissociated mole of each ion per mole of molecule considering the degree of dissociation.

Illustration

Find the molarity of various ions in 0.1 M $BeCl_2$ solution, considering degree of dissociation of $BeCl_2$ as 80%.

Sol. $BeCl_2 \xrightarrow{80\%} Be^{+2} + 2Cl^-$

0.1 0 0

0.1–0.08 0.08 0.16

Be^{+2} = 0.08M, Cl^- = 0.16 M

Exercise

Calculate 'm' of all the ions present in the solution of $Al_2(SO_4)_3$ for 1M solution.

Given $d_{solution}$ = 2.342 gm/ml.

Ans. Al^{3+} = 1m, SO_4^{2-} = 1.5m

12.3 MIXING OR DILUTION OF SOLUTIONS

Illustration

20 ml N/2 HCl, 60 ml N/10 H_2SO_4 and 150 ml N/5 HNO_3 are mixed together. Calculate the normality of the $[H^+]$ in final solution.

Sol. $N_1V_1 + N_2V_2 + N_3V_3 = NV$

$$\left(\frac{1}{2}\times 20\right) + \left(\frac{1}{10}\times 60\right) + \left(\frac{1}{5}\times 150\right) = N\,(230)$$

$10 + 6 + 30 = N\,(230)$

$46 = N\,(230)$

$N = 0.2$

Exercise

200 ml of 1M HCl solution is mixed with 800 ml of 2M HCl solution.

(a) Calculate the final molarity of the solution.

(b) If density of final solution is 1.2 gm/ml. Calculate molality 'm'

Ans (a) 1.8M, (b) 1.5 m

12.4 MIXING OF ACID & BASE SOLUTIONS

In case of mixing of acid and base, calculate equivalent or milliequivalent of acid and base separately, substract the lower value from higher value, which gives the number of equivalent in the final solution.

Illustration

50 ml N/2 HCl, 50 ml N/5 H_2SO_5 and 200 ml N/10 NaOH are mixed. What will be normality of $[H^+]$ ions ?

Sol. meq of acids $= \left(50\times\frac{1}{2}\right) + \left(50\times\frac{1}{5}\right) = 25 + 10 = 35$

meq of base $= 200 \times \frac{1}{10} = 20$

After mixing meq of acid $= 35 - 20 = 15$ $\therefore$ Normality of H^+ ion, $N = \frac{15}{300} = 0.05$ **Ans.**

Exercise

Calculate $[H^+]$ in a solution if 0.2 M 100 ml H_2SO_4 is mixed with 0.1 M 300 ml NaOH solution.

Ans. 0.025M

12.5 PROBLEM INVOLVING PRECIPITATION

In problems involving precipitation, complete reaction is assumed and the limiting reagent completely reacts. Ions in the precipitated product is not considered in finding concentration of that ions.

Illustration

10 ml of HCl solution gave 0.1435 g of AgCl when treated with excess of $AgNO_3$. Find the molarity of the acid solution (Ag = 108)

Sol. $HCl + AgNO_3 \rightarrow AgCl + HNO_3$

(1+35.5) (excess) (108 + 35.5)

= 36.5 g = 143.5 g

143.5 g of AgCl is obtained from HCl = 36.5 g

0.1435 g of AgCl is obtained from HCl = $\frac{36.5}{143.6} \times 0.1435g = 0.0365$

$\therefore$ Molarity of HCl solution $= \frac{0.0365}{36.5} \times \frac{1000}{10} = 0.1$ M

Exercise

If 200 ml of 0.1 NaCl in mixed with 100 ml of 0.2 M $AgNO_3$ solution. Calculate molarity of all the ions in the final solution.

Ans. $Na^+ = 0.067$ M, $NO_3^- = 0.067$ M

12.6 SOME TYPICAL CONCENTRATION TERMS

12.6.1 Strength of H_2O_2 solution :

The strength of H_2O_2 is aqeous solution is expressed in the following two ways :

(i) **Percentage strength :** The mass of H_2O_2 present in 100 ml of the aqueous solution is termed as percentage strength. For example, a 25% solution (w/v) of H_2O_2 means that 25 grams of H_2O_2 are present in 100 ml of the solution.

(ii) **Volume strength :** Strength of the sample of H_2O_2 is generally expressed in terms of the volume of oxygen at 0°C and 1 atm that one volume of the sample of hydrogen peroxide gives on heating. The commercial samples are marked as '10 volume'. '15 volume' or '20 volume'. 10 volume means that one volume of the sample of hydrogen peroxide gives 10 volumes of oxygen at 0°C and 1 atm. 1 ml of a 10 volume solution of H_2O_2 will liberate 10 ml of oxygen at 0°C and 1 atm.

Illustration

Find the volume strength of 1.6 M H_2O_2 solution.

Sol. Strength of the solution = Molarity × mol. mass = 1.6 × 34 = 54.4 gL^{-1}

$2H_2O_2 \rightarrow 2H_2O + O_2$

68 g 22.4 L

54.4 $\frac{22.4}{68} \times 54 = 19.92$ L

$\therefore$ Volume strength = **'19.92 V'**

Exercise

For '44.8 V' H_2O_2 solution having d = 1.136 g/ml calculate
(i) Molarity of H_2O_2 solution. (ii) Mole fraction of H_2O_2 solution.

Ans. (i) 4 M ; (ii) 0.06

12.6.2 Percentage labelling of oleum

Oleum is fuming sulphuric acid which contains extra SO_3 dissolved in H_2SO_4. To convert this extra SO_3 into H_2SO_4, water has to be added ($SO_3 + H_2O \rightarrow H_2SO_4$). The amount of sulphuric acid obtained when just sufficient water is added into 100 g of oleum so that all SO_3 present in it is converted into H_2SO_4 is called percentage labelling of oleum.

Illustration

An oleum is labelled as 109%. Calculate mass percent of free SO_3 and H_2SO_4

Sol. It means that water added = 9 g in 100 gm oleum

Let us calculate how much SO_3 can be converted into H_2SO_4 by 9 g of water

$$SO_3 + H_2O \rightarrow H_2SO_4$$
$$80\text{ g} \quad 18\text{ g} \quad 98\text{ g}$$

i.e., 9 g H_2O can dissolve 40 g SO_3 to form 49 g H_2SO_4

$\therefore$ Mass of SO_3 in 100 g oleum = 40 g

and % by mass of SO_3 = 40 %

and % by mass of H_2SO_4 = 60 %

Exercise

A mixture is prepared by mixing 10 gm H_2SO_4 and 40 gm SO_3 calculate,
(a) mole fraction of H_2SO_4 (b) % labelling of oleum

Ans. (a) 0.169; (b) 118 %

12.7 RELATIONSHIP BETWEEN DIFFERENT CONCENTRATION TERMS

1. $N = M \times n\text{ factor}$

2. $M = \dfrac{md}{1 + mM_2/1000}$

3. $m = \dfrac{1000 \times x_2}{x_1M_1}$

4. $M = \dfrac{1000dx_2}{x_1M_1 + x_1M_2}$

5. $d = M\left(\dfrac{1}{m} + \dfrac{M_2}{1000}\right)$

6. Volume strength of $H_2O_2 = 5.6 \times N = \dfrac{5.6 \times \text{Percentagestrength}}{\text{Eq.wt.of } H_2O_2(17)} \times 10$

7. Volume strength of $H_2O_2 = 11.2 \times M = \dfrac{11.2 \times \text{Percentagestrength} \times 10}{\text{Mol.wt.of } H_2O_2 (34)}$

8. In oleum labelled as $(100 + x)\%$

$$\% \text{ of free } SO_3 = \left(\frac{80 \times x}{18}\right) \text{ (w/w)}$$

where N = Normality

M = Molarity
d = density of solution
x_2 = Mole fraction of solute
M_1 = Molecular mass of solvent
m = molality
M_2 = Molecular mass of solute
x_1 = Mole fraction of solvent
d = Density of solution.

SOLVED EXAMPLES

Q.1 Naturally occurring chlorine is 75.53% Cl^{35} which has an atomic mass of 34.969 amu and 24.47% Cl^{37} which has a mass of 36.966 amu. Calculate the average atomic mass of chlorine-
(A) 35.5 amu (B) 36.5 amu (C) 71 amu (D) 72 amu

Ans. (A)

Sol. Average atomic mass $= \dfrac{\%\text{ of I isotope} \times \text{its atomic mass} + \%\text{ of II isotope} \times \text{its atomic mass}}{100}$

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

= **35.5 amu.**

Q.2 How many carbon atoms are present in 0.35 mol of $C_6H_{12}O_6$ -
(A) 6.023×10^{23} carbon atoms (B) 1.26×10^{23} carbon atoms
(C) 1.26×10^{24} carbon atoms (D) 6.023×10^{24} carbon atoms

Ans. (C)

Sol. $\therefore$ 1 mol of $C_6H_{12}O_6$ has = 6 N_A atoms of C
$\therefore$ 0.35 mol of $C_6H_{12}O_6$ has
= $6 \times 0.35\ N_A$ atoms of C
= $2.1\ N_A$ atoms
= $2.1 \times 6.022 \times 10^{23}$ = **1.26×10^{24} carbon atoms**

Q.3 Calculate the mass in gm of $2N_A$ molecules of CO_2 -
(A) 22 gm (B) 44 gm (C) 88 gm (D) None of these.

Ans. (C)

Sol. $\because$ N_A molecules of CO_2 has molecular mass = 44 gm
$\therefore$ $2N_A$ molecules of CO_2 has molecular mass = 44 × 2 = **88 gm.**

Q.4 How many years it would take to spend Avogadro's number of rupees at the rate of 1 million rupees in one second -
(A) 19.098×10^{19} years (B) 19.098 years
(C) 19.098×10^{9} years (D) None of these

Ans. (C)

Sol. $\because$ 10^6 rupees are spent in 1sec.

$\therefore$ 6.022×10^{23} rupees are spent in $= \dfrac{1 \times 6.022 \times 10^{23}}{10^6}$ sec

$= \dfrac{1 \times 6.023 \times 10^{23}}{10^6 \times 60 \times 60 \times 24 \times 365}$ years = **19.098×10^9 year**

Q.5 Calculate the number of Cl^- and Ca^{+2} ions in 222 g anhydrous $CaCl_2$.
(A) $2N_A$ ions of Ca^{+2} 4 N ions of Cl^- (B) $2N_A$ ions of Cl^- & 4N ions of Ca^{+2}
(C) $1N_A$ ions of Ca^{+2} & 1N ions of Cl^- (D) None of these.

Ans. (A)

Sol. $\because$ mol. wt. of $CaCl_2$ = 111 g
$\because$ 111 g $CaCl_2$ has = N_A ions of Ca^{+2}
$\therefore$ 222g of $CaCl_2$ has $\dfrac{N_A \times 222}{111}$ = $2N_A$ ions of Ca^{+2}

Also $\because$ 111 g $CaCl_2$ has = $2N_A$ ions of Cl^-

$\therefore$ 222 g $CaCl_2$ has = $\frac{2N_A \times 222}{111}$ ions of Cl^- = **$4N_A$ ions of Cl^- .**

Q.6 What is the molecular mass of a substance, each molecule of which contains 9 carbon atoms, 13 hydrogen atoms and 2.33×10^{-23} g of other component?

Ans. 135.04

Sol. The molecule has C, H and other component.

Mass of 9 C atoms = 12 × 9 = 108 amu

Mass of 13 H atoms = 13 × 1 = 13 amu

Mass of other component = $\frac{2.33 \times 10^{-23}}{1.66 \times 10^{-24}} = 14.04$amu

$\therefore$ Total mass of one molecule = 108 + 13 + 14.04 = 135.04 amu

$\therefore$ Mol. mass of substance = **135.04**

Q.7 The density of O_2 at 0ºC and 1 atm is 1.429g / litre. The molar volume of gas is -

(A) 22.4 lit. (B) 11.2 lit (C) 33.6 lit (D) 5.6 lit.

Ans. (A)

Sol. $\because$ 1.429 gm of O_2 gas occupies volume = 1 litre.

$\therefore$ 32 gm of O_2 gas occupies = $\frac{32}{1.429}$ **= 22.4 litre/mol.**

Q.8 How many molecules are in 5.23 gm of glucose ($C_6H_{12}O_6$) -

(A) 1.65×10^{22} (B) 1.75×10^{22} (C) 1.75×10^{21} (D) None of these

Ans. (B)

Sol. $\because$ 180 gm glucose has = N_A molecules

$\therefore$ 5.23 gm glucose has = $\frac{5.23 \times 6.022 \times 10^{23}}{180}$ **= 1.75×10^{22} molecules**

Q.9 How many g of S are required to produce 10 moles and 10g of H_2SO_4 respectively?

Ans. 320 g, 3.265 g

Sol. $\because$ 1 mole of H_2SO_4 has = 32g S

$\therefore$ 10 mole of H_2SO_4 has = 32 × 10 = **320 g S**

Also, 98g of H_2SO_4 has = 32 g S

$\therefore$ 10 g of H_2SO_4 has = (32 × 10)/98 = **3.265 g S**

Q.10 P and Q are two elements which form P_2Q_3 and PQ_2 molecules. If 0.15 mole of P_2Q_3 and PQ_2 weighs 15.9 g and 9.3g, respectively, what are atomic mass of P and Q?

Ans. P = 26, Q = 18

Sol. Let at. mass of P and Q be a and b respectively,

$\therefore$ Mol. mass of P_2Q_3 = 2a + 3b

and Mol. mass of PQ_2 = a + 2b

$\therefore$ (2a + 3b) × 0.15 = 15.9

and (a + 2b) × 0.15 = 9.3

a = 26, b = 18

atomic mass of **P = 26**

atomic mass of **Q = 18**

Q.11 A hydrate of iron (III) thiocyanate $Fe(SCN)_3$, was found to contain 19% H_2O. What is the formula of the hydrate?

Ans. $Fe(SCN)_3.3H_2O$

Sol. Let the hydrate be $Fe(SCN)_3.mH_2O$

Molecular mass of hydrate = 56 + 3 × (32 + 12 + 14) + 18m = 230 + 18m

$\therefore$ % of $H_2O = \frac{18m \times 100}{230 + 18m} = 19$ or $m = 2.99 \approx 3$

$\therefore$ Formula is **$Fe(SCN)_3.3H_2O$**

Q.12 The vapour density of a mixture containing NO_2 and N_2O_4 is 38.3 at 27ºC. Calculate the mole of NO_2 in 100 mole mixture.

Ans. 33.48

Sol. Mol. mass of mixture of NO_2 and N_2O_4 = 38.3 × 2 = 76.6

Let a mole of NO_2 be present in 100 mole mixture

= mass of NO_2 + mass of N_2O_4 = mass of mixture,

a × 46 + (100 – a) × 92 = 100 × 76.6

$\therefore$ a = **33.48 mole**

Q.13 What is the weight of 3.01×10^{23} molecules of ammonia -

(A) 17 gm (B) 8.5 gm (C) 34 gm (D) None of these

Ans. (B)

Sol. $\because$ 6.022×10^{23} molecules of NH_3 has weight = 17 gm

$\therefore$ 3.01×10^{23} molecules of NH_3 has weight $= \frac{17 \times 3.01 \times 10^{23}}{6.022 \times 10^{23}}$ = **8.50 gm**

Q.14 How many moles of potassium chlorate to be heated to produce 5.6 litre oxygen at 0ºC and 1 atm ?

Ans. 1/6

Sol.

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

Mole ratio for reaction: 2 mole, 2 mole, 3 mole

$\because$ 3 × 22.4 litre O_2 is formed by 2 mole $KClO_3$

5.6 litre O_2 is formed by $\frac{2 \times 5.6}{3 \times 22.4}$ = **1/6 mole $KClO_3$**

Q.15 How many molecules are present in 1mℓ of water vapours at 0ºC and 1 atm -

(A) 1.69×10^{19} (B) 2.69×10^{-19} (C) 1.69×10^{-19} (D) 2.69×10^{19}

Ans. (D)

Sol. $\because$ 22.4 litre water vapour at 0ºC and 1 atm has = 6.022×10^{23} molecules

$\therefore$ 1×10^{-3} litre water vapours has $= \frac{6.022 \times 10^{23}}{22.4} \times 10^{-3}$ = **2.69×10^{19}**

Q.16 Calculate the weight of lime (CaO) obtained by heating 200 kg of 95% pure lime stone ($CaCO_3$).

(A) 104.4 kg (B) 105.4 kg

(C) 212.8 kg (D) 106.4 kg

Ans. (D)

Sol. 100 kg impure sample has pure $CaCO_3$ = 95 kg

$\therefore$ 200 kg impure sample has pure $CaCO_3 = \frac{95 \times 200}{100}$ = 190 kg.

$CaCO_3 \rightarrow CaO + CO_2$

$\because$ 100 kg $CaCO_3$ gives CaO = 56 kg.

$\therefore$ 190 kg $CaCO_3$ gives CaO = $\frac{56 \times 190}{100}$ = **106.4 kg.**

Q.17 Zinc and hydrochloric acid react according to the reaction :

$$Zn(s) + 2HCl\,(aq.) \longrightarrow ZnCl_2(aq.) + H_2(g)$$

If 0.30 mole of Zn are added to hydrochloric acid containing 0.52 mole HCl, how many moles of H_2 are produced?

Ans. 0.26

Sol.

	Zn(s)	+ 2HCl(aq.) ⟶	$ZnCl_2$(aq.)	+ H_2(g)
Initial moles	0.30	0.52	0	0
Final moles	0.04	0	0.26	0.26

Moles of H_2 produced = **0.26**

Q.18 4 g of an impure sample of $CaCO_3$ on treatment with excess HCl produces 0.88 g CO_2. What is percent purity of $CaCO_3$ sample?

Ans. 50%

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

44g $CO_2 \equiv$ 100 g $CaCO_3$

0.88 g $CO_2 \equiv \frac{100 \times 0.88}{44}$ = 2.0 g $CaCO_3$

$\therefore$ Percentage purity = $\frac{2}{4} \times 100$ = **50%**

Q.19 A mixture of FeO and Fe_3O_4 when heated in air to constant weight gains 5% in its weight. Find out composition of mixture.

Ans. FeO = 20.28%,

Fe_3O_4 = 79.72%

Sol. Let weight of FeO and Fe_3O_4 be a and b g, respectively.

$$2FeO + \frac{1}{2}O_2 \longrightarrow Fe_2O_3$$

$$2Fe_3O_4 + \frac{1}{2}O_2 \longrightarrow 3Fe_2O_3$$

$\because$ 144 g FeO gives 160 g Fe_2O_3

$\therefore$ a g FeO gives 160 × a/144 g Fe_2O_3

Similarly, weight of Fe_2O_3 formed by $Fe_3O_4 = \frac{160 \times 3b}{464}$

Now if a + b = 100 ; then $\frac{160 \times a}{144} + \frac{160 \times 3b}{464} = 105$

Solving these two equations : a = 21.06 and b = 78.94

Percentage of **FeO ≈ 20.28%** and percentage of **Fe_3O_4 ≈ 79.72%**

Q.20 The reaction, $2C + O_2 \longrightarrow 2CO$ is carried out by taking 24 g of carbon and 96g O_2, find out:
(A) Which reactant is left in excess?
(B) How much of it is left
(C) How many mole of CO are formed?
(D) How many g of carbon should be taken so that nothing is left at the end of the reaction?

Sol.

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

(A) $\therefore$ O_2 is left in excess.
(B) 2 mole of O_2 or 64 g O_2 is left.
(C) 2 mole of CO or 56 g CO is formed.
(D) To use O_2 completely total 6 mole of carbon or 72 g carbon is needed.

Q.21 8g of sulphur are burnt to from SO_2, which is oxidised by Cl_2 water. The solution is treated with $BaCl_2$ solution. The amount of $BaSO_4$ precipitated is :
(A) 1.0 mole (B) 0.5 mole (C) 0.75 mole (D) 0.25 mole

Ans. (D)

Sol. $$S \xrightarrow{O_2} SO_2 \xrightarrow{Cl_2} SO_4^{2-} \xrightarrow{BaCl_2} BaSO_4$$

Mole of $BaSO_4$ formed = moles of sulphur $= \frac{8}{32} = \frac{1}{4}$

Q.22 8 litre of H_2 and 6 litre of Cl_2 are allowed to react to maximum possible extent. Find out the final volume of reaction mixture. Suppose P and T remains constant throughout the course of reaction-
(A) 7 litre (B) 14 litre (C) 2 litre (D) None of these.

Ans. (B)

Sol.

	H_2	+ Cl_2	$\rightarrow$ 2 HCl
Volume before reaction	8 lit	6 lit	0
Volume after reaction	2	0	12

$\therefore$ Volume after reaction = Volume of H_2 left + Volume of HCl formed
= 2 + 12 = **14 lit**

Q.23 When measured at the same temperature and pressure, hydrogen reacts with oxygen to form water in the volume ratio 2 : 1. Calculate the volume of O_2 gas measured at 137ºC and 760 mm pressure that will combine with 100 ml of H_2 at 0ºC and 200 mm pressure.

Ans. 19.76 ml

Sol. Reaction : $2H_2 + O_2 \rightarrow 2H_2O$
2Vol 1Vol

2 volume of H_2 required O_2 = 1 Vol

$\therefore$ 100 mL of H_2 required $O_2 = \frac{100}{2} = 50$ ml at 0ºC and 200 mm

$\therefore$ $P_1 = 200$ mm, $V_1 = 50$ mL, $T_1 = 0 + 273 = 273$ K, $P_2 = 760$ mm, $V_2 = ?$, $T_2 = 137 + 273 = 410$ K

But, $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$ (gas equation)

Hence, $V_2 = \frac{P_1V_1T_2}{P_2T_1}$

$\therefore$ $V_2 = \frac{200mm \times 50mL \times 410K}{760mm \times 273K}$ = **19.76 ml Ans.**

Q.24 A gaseous mixture containing 49.5 ml of hydrogen chloride and H_2 gases was kept in contact with Na/Hg. The volume of mixture decreased to 42 ml. If 99.5 ml of the same mixture is mixed 49.5 ml of gaseous ammonia and then exposed to water, calculate the final volume. All measurements of volume being done under same conditions of temperature and pressure.

Ans. 60.5 ml

Sol. Volume of H_2 gas + HCl (g) = 49.5 mL. When kept in contact with Na/Hg only HCl will react with Na as follows :

$$2Na + \underset{2Vol}{HCl} \longrightarrow 2NaCl + \underset{1Vol}{H_2}$$

Reduction in volume = 2 Vol – 1 Vol = 1 Vol for 2 Vol of HCl

Actual reduction in volume = 49.5 – 42 = 7.5 ml

$\therefore$ Volume of HCl present in 49.5 ml mixture = 7.5 × 2 = 15 ml

Volume of H_2 = 49.5 – 15 = 34.5 ml

$\therefore$ 99.5 mL of mixture would contain HCl(g) = $15 \times \frac{99.5}{49.5}$ = 30 ml

and H_2 = 99.5 – 30 = 69.5 ml

When mixed with NH_3, the reaction will be :

$$\underset{\substack{1Vol \\ 30\,ml}}{NH_3(g)} + \underset{\substack{1Vol \\ 30\,ml}}{HCl(g)} \longrightarrow NH_4Cl(s)$$

$\therefore$ Residual NH_3 = 49.5 – 30 = 19.5 ml

It will also dissolve in H_2O. So, only gas left behind is H_2 gas. Hence :

Residual H_2 = 99.5 – 30 = 69.5 mL or final volume = **69.5 ml**

Q.25 A mixture of ethyne (C_2H_2) and H_2 was mixed with 65 ml of O_2 and exploded in a eudiometer tube. On cooling, it was found to have undergone a contraction of 35 ml. When treated with a KOH solution, a further contraction of 34 ml took place and 15 ml of O_2 alone was left behind. Find the percentage composition of ethyne and H_2 in the mixture.

Ans. C_2H_2 = 53.2 %, H_2 = 46.8%

Sol. Let mixture contains H_2 = x ml and C_2H_2 = y ml

Reaction (i) $\underset{2\,Vol}{2H_2} + \underset{1\,Vol}{O_2} \longrightarrow \underset{2\,Vol}{2H_2O}$

or x ml $\quad \frac{x}{2}$ ml

(ii) $\underset{2\,Vol}{2C_2H_2} + \underset{5\,Vol}{5O_2} \longrightarrow \underset{4\,Vol}{4CO_2} + \underset{2\,Vol}{2H_2O}$

or y ml $\quad \frac{5y}{2}$ ml $\quad$ 2y ml

From question

$2y = 34 \Rightarrow y = 17$

and , $\frac{x}{2} + \frac{5y}{2} = 65 - 17$

$\therefore \quad x = 15$

$\therefore \quad x = 2 \times 7.5 = 15.0$ ml

Thus, volume of H_2 = 15.0 mL; volume of C_2H_2 = 17 ml

$\therefore \quad \%\text{ age of } H_2 = \frac{\text{Vol. of } H_2}{\text{Vol. of } H_2 + \text{Vol. of } C_2H_2} \times 100$

$= \frac{15}{15+17} \times 100 = 46.8$

$\therefore \quad \%\text{ age of } C_2H_2 = 100 - 46.88 = 53.2$

Q.26 0.9 g of a solid organic compound (molecular weight 90) containing carbon, hydrocarbon and oxygen, was heated with oxygen corresponding to a volume of 224 ml at S.T.P. After combustion, the total volume of the gases was 560 ml at S.T.P. On treatment with potassium hydroxide, the volume decreased to 112 ml. Determine the molecular formula of the compound.

Ans. $C_2H_2O_4$

Sol. Let the formula of organic compound containing C, H and oxygen = $C_xH_yO_z$,

On combustion, CO_2 and H_2O (zero volume at 0ºC) are formed

So, the residual gas will contain CO_2 and unused O_2,

Since CO_2 gas is absorbed by KOH, the volume of CO_2 formed = 560 – 12 = 448 ml

Volume of O_2 used = 224 – 112 = 112 ml

$\text{Mole of } CO_2 \equiv \frac{1}{22400} \times 448$

$\text{No. of mole of compound} = \frac{0.9}{90} = 0.01 \text{ mol}$

$\therefore$ 0.01 mole compound produced = 0.02 mole of CO_2

$1 \text{ mole compound produced } CO_2 = 0.2 \times \frac{1}{0.01} = 2\text{mol } CO_2$

$\therefore \quad 2 \text{ mol } CO_2 \equiv 2 \text{ mol C atoms}$

$\therefore$ Formula of compound = $C_2H_yO_z$

Mol. wt. of $C_2H_yO_z = (2 \times 12) + 1 \times y + 16 \times z = 24 + y + 16z$

Reaction $C_2H_yO_z + \frac{1}{2}O_2 \rightarrow 2CO_2 + \frac{y}{2} H_2O$

Atoms of oxygen involved in the above reaction are :

$$z + 1 = 4 + \frac{y}{2};\ z = 4 + \frac{y}{2} - 1 = 3 + \frac{y}{2}$$

$\therefore \quad z = 3 + \frac{y}{2}$

But mol. wt. $24 + y + 16z = 90$

Hence $24 + y + 16\left(3+\frac{y}{2}\right) = 90$

$y = 2$

Substituting the value of y = 2

$z = 3 + \frac{2}{2} = 4$

$\therefore$ Molecular formula of compound = $C_2H_yO_z = C_2H_2O_4$ Ans.

Q.27 At high temperatures, the compound S_4N_4 decomposes completely into N_2 and sulphur vapours. If all measurements are made under the same conditions of temperature and pressure, it is found that for each volume of S_4N_4 decomposed 2.5 volumes of gaseous products are formed. What is the molecular formula of sulphur ?

Ans. S_8

Sol. Reaction $N_4S_4 \xrightarrow{\text{High temp.}} 2N_2 + \text{sulphur vapours}$

1 Vol → 2.5 Vol (2 + 0.5)

1 molecule → 2.5 molecules

2.5 molecules of N_2 + sulphur vapours = 4 atoms of nitrogen + 0.5 molecule of sulphur vapour. Hence the formula S_4N_4 indicates that :

0.5 molecule of sulphur contains S-atoms = 4

1 molecule of sulphur contains S-atoms = $\frac{4}{0.5} = 8$

$\therefore$ Formula of sulphur = S_8

Q.28 10 ml of a gaseous organic compound containing C, H and O only was mixed with 100 ml of oxygen and exploded under conditions which allowed the water formed to condense. The volume of the gas after explosion was 90 ml. On treatment with potash solution, a further contraction in volume of 20 ml was observed. Given that the vapour density of the compound is 23, deduce the molecular formula. All volume measurements were carried out under the same conditions.

Ans. C_2H_6O

Sol. Let formula of organic compound = $C_xH_yO_z$

$$\text{Reaction } C_xH_yO_z + \left(x+\frac{y}{4}-\frac{z}{2}\right)O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$$

$$10\text{ ml} \quad 10\left(x+\frac{y}{4}-\frac{z}{2}\right) \quad 10x\text{ ml} \quad \frac{10\times y}{2} = 5y\text{ ml}$$

(a) Since potash solution (KOH) absorbs CO_2, so volume of CO_2 gas = 20 ml.

$10x = 20;\ x = 2$

(b) Contraction in volume after explosion and cooling as obtained from reaction

$$10 + 10\left(x+\frac{y}{4}-\frac{z}{2}\right) - 10x = 10 + 100 - 90 = 20\text{ ml (given)}$$

$$10 + 10\left(2+\frac{y}{4}-\frac{z}{2}\right) - (10\times 2) = 20$$

$$5y - 10z = 20 \qquad \text{........(1)}$$

But mol. wt. of $C_xH_yO_z$ or $C_2H_yO_z = (2 \times 12) + (y \times 1) + (16 \times z)$

$= 24 + y + 16z = 2 \times 23$ (given)

or $y + 16z = 46 - 24 = 22$ ....(2)

From (1) and (2) $z = 1$

$y = 6$

Since $x = 2$, $y = 6$ and $z = 1$, the molecular formula of $C_xH_yO_z = C_2H_6O$

Q.29 A mixture of formic acid and oxalic acid is heated with concentrated H_2SO_4. The gas produced is collected and on its treatment with KOH solution the volume of the gas decreased by one-sixth. Calculate the molar ratio of the two acids in the original mixture.

Ans. 4 : 1

Sol. Let moles of HCOOH and $H_2C_2O_4$ are a and b respectively

The decomposition of the acid takes place as follows

HCOOH	→	H_2O	+	CO		
a moles		a moles		a moles		

$H_2C_2O_4$	→	H_2O	+	CO	+	CO_2
b moles		b moles		b moles		b moles

H_2O is absorbed by H_2SO_4 and CO_2 is absorbed by KOH.

Thus as given, $\dfrac{\text{volume of } CO_2}{\text{total volume of } (CO + CO_2)} = \dfrac{b}{a+b+b} = \dfrac{1}{6}$

or $\dfrac{a}{b} = 4$

Molar ratio of HCOOH and $H_2C_2O = 4 : 1$

Q.30 9 volumes of a gaseous organic compound A and just sufficient amount of oxygen required for its complete combustion, yielded, 4 volume of CO_2, 6 volumes of water vapour and 2 volumes of N_2, all volumes measured at the same temperature and pressure. If the compound A contained only C, H and N, (i) how many volumes of oxygen are required for complete combustion, and (ii) what is the molecular formula of the compound A?

Ans. (i) 7 volume (ii) $C_2H_6N_2$

Sol. Suppose the compound A is $C_xH_yN_z$

(i)	$C_xH_yN_z$	+	O_2	→	CO_2	+	H_2O (vapour)	+	N_2
or	(9 – v) moles		v moles		4 moles		6 moles		2 moles

Applying POAC for O atoms,

$2 \times$ moles of $O_2 = 2 \times$ moles of $CO_2 + 1 \times$ moles of H_2O

$2v = 2 \times 4 + 1 \times 6 = 14; v = 7$ volumes

(ii) The reaction is

	$C_xH_yN_z$	+	O_2	→	CO_2	+	H_2O (vapour)	+	N_2
	2 vols.		7 vols.		4 vols.		6 vols.		2 vols.
or	2 moles		6 moles		4 moles		6 moles		2 moles

Applying POAC for C, H and N, we get respectively

$x \times$ moles of $C_xH_yN_z = 1 \times$ moles of CO_2

$x \times 2 = 1 \times 4; x = 2$

$y \times$ moles of $C_xH_yN_z = 2 \times$ moles of H_2O (vapour)

$y \times 2 = 2 \times 6; y = 6$

$z \times$ moles of $C_xH_yN_z = 2 \times$ moles of N_2

$z \times 2 = 2 \times 2; z = 2$

Hence the compound is $C_2H_6N_2$

Q.31 15 ml of gaseous hydrocarbon required for complete combustion 357 ml of air (21% of O_2 by volume) and the gaseous products occupted 327 ml (all volumes being measured at S.T.P.). What is the formula of hydrocarbon ?

Ans. C_3H_8

Sol. Let C_xH_y be the hydrocarbon

$$C_xH_y \quad + \left(x + \frac{y}{4}\right) O_2 \rightarrow \quad xCO_2 + \frac{y}{2} H_2O$$

$$1 \text{ Vol.} \quad \left(x + \frac{y}{4}\right) \text{Vol.} \quad x \text{ Vol.}$$

From equation, the contraction

$= 1 + (x + y/4) - (x + 0) = 1 + y/4$

for 15 ml gas, contraction =

$15 (1 + y/4) = (15 + 357) - (327) = 45$

$y = 8$

The gaseous products after contraction = 327

This includes vol. of CO_2 plus volume of N_2 in the air (O_2 is completely used up). So calculate the volume of N_2 in the air.

Vol. of $O_2 = 0.21 \times 357 = 75$ ml

Vol. of $N_2 = 357 - 75 = 282$ ml

Now, Vol. of N_2 + Vol. of $CO_2 = 327$ ml

Vol. of $CO_2 = 327 - 282 = 45$ ml

The volume of CO_2 produced = 15 x

$15\,x = 45$

$x = 3$

Hence the hydrocarbon is C_3H_8

Q.32 Calculate the molarity and molality of a solution of H_2SO_4 (sp. gr. = 1.98) containing 27% H_2SO_4 by mass.

Ans. 3.3 M, 3.77 M

Sol. Vol of 100 g of 27% $H_2SO_4 = \frac{\text{wt.}}{\text{d}} = \frac{100}{1.198}$ ml

$$M_{H_2SO_4} = \frac{\text{wt./mol.wt.}}{\text{vol. of solution (litre)}} = \frac{27 \times 1.198 \times 1000}{98 \times 100} = \mathbf{3.3\ mol}\ L^{-1}$$

$$m_{H_2SO_4} = \frac{\text{wt./mol.wt.}}{\text{wt. of solvent(kg)}} = \frac{27 \times 1000}{(100 - 27) \times 98} = \mathbf{3.77}\ \text{mol}\ Kg^{-1}$$

Q.33 How many milliliter of concentrated sulphuric acid of density 1.84 g ml^{-1} containing 98% H_2SO_4 by mass are required to make (a) 4 litre of 1 N solution and (b) 200 mL of 0.25 M solution.

Ans. (a) 108.7 (b) 2.72 ml

Sol. (a) Gram eq. wt. of $H_2SO_4 = \frac{98}{2} = 49$ g.

To find wt. of H_2SO_4 (W) required to prepare 4 L of 1N H_2SO_4, we have :

$$1 = \frac{\text{wt. of } H_2SO_4}{\text{g. eq. wt. of } H_2SO_4 \times 4(l)} = \frac{\text{wt. of } H_2SO_4}{49 \times 4(l)}$$

Or wt. of H_2SO_4 = 196 g.

Since acid is 98% thus amount of solution $= \frac{196 \times 100}{98} = 200$ g.

Thus, volume (mass/density) of 98% H_2SO_4 solution $= \frac{200}{1.84}$ **= 108.7 ml**

(b) $0.25 = \frac{\text{wt.of } H_2SO_4 \times 1000}{\text{g. mol. wt. of } H_2SO_4 \times \text{vol. of solution in ml}}$

$\therefore$ wt. of $H_2SO_4 = \frac{0.25 \times 98 \times 200}{1000} = 4.9$ g

$\therefore$ wt. of 98% H_2SO_4 solution $= \frac{4.9 \times 100}{98} = 5$ g

Volume of H_2SO_4 solution $= \frac{\text{Mass}}{\text{Density}} = \frac{5}{1.84}$ **= 2.72 ml**

Q.34 Derive the relation between molality (m) and mole fraction of solute, χ_2

Sol. Molality, m means, m mole of solute in 1000 g of solvent which is equal to 1000/M_1 mol where M_1 = molar mass of the solvent.

$$\therefore \quad \text{Mole fraction, } \chi_2 = \frac{\text{moles of solute}}{\text{Moles of solute + Moles of solvent}} = \frac{m}{m + \frac{1000}{M_1}} = \frac{mM_1}{mM_1 + 1000}$$

Hence $m = \frac{1000 \times \chi_2}{(1 - X_2)}$

Q.35 The molality and molarity of a solution of H_2SO_4 are 94.13 and 11.12 respectively. Calculate the density of the solution.

Ans. 1.2079 g/ml

Sol. $d = M\left(\frac{1}{m} + \frac{\text{mol.wt.}}{1000}\right) \quad = 11.12\left(\frac{1}{94.13} + \frac{98}{1000}\right)$ **= 1.2079 g/ml**

Q.36 Calculate the (a) molarity (b) normality of the phosphoric acid solution (sp. gravity 1.426 and containing 60% by weight of pure H_3PO_4. Atomic mass of P = 31)

Ans. (a) 8.73 M (b) 26.19 N

Sol. Weight of H_3PO_4 in 100 g solution = 60 g; Weight of water = 100 – 60 = 40 g

(a) Calculation of molarity

Molecular mass of H_3PO_4 = 98 g mol^{-1}

$$\text{Molarity} = \frac{60}{98} \times \frac{1.426 \times 1000}{100} = \mathbf{8.73\ M}$$

(b) Normality = Molarity × Basicity = 8.73 × 3 = **26.19 N**

Q.37 Upon heating a litre of $\frac{M}{2}$ HCl solution, 2.675 g hydrogen chloride is lost due to evaporation and the volume of the solution shrinks to 750 ml. Calculate
(i) the molarity of the resulting solution and
(ii) the number of milli moles of HCl in 100 ml of the final solution.

Ans. (i) 0.569 M (ii) 56.9

Sol. Mol. wt. of HCl = 36.5

Mass of HCl in 1L of $\frac{M}{2}$ HCl = $\frac{1}{2} \times 36.5 = 18.25$ g

Weight of HCl lost on heating = 2.675 g

Weight of HCl left in solution = 18.25 – 2.675 = 15.575 g

Number of moles in 15.575 g HCl = $\frac{15.575}{36.5} = 0.4267$

Volume of the solution left after heating = 750 ml = $\frac{750}{1000} = 0.75$ L

$$\therefore \quad \text{Molarity of solution} = \frac{\text{No. of gram moles}}{\text{Volume in litres}} = \frac{0.4267}{0.75} = 0.569\text{M}$$

Now number of milli moles = (volume in ml) × (Molarity)

= 100 × 0.569 = **56.9**

Q.38 Calculate the normality of a solution obtained by mixing 0.01 L of $\frac{N}{10}$ NaOH and 40 ml of seminormal KOH solution.

Ans. 0.42 N

Sol. Total volume (V) of mixed solution = $\left(0.01\text{L} \times \frac{1000\text{mL}}{1\text{L}}\right) + 40\text{ ml} = 50\text{ m}l$

Now $N_1V_1 + N_2V_2 = NV$

$$\frac{1}{10} \times 10 + \frac{1}{2} \times 40 = N \times 50$$

$$\therefore \quad N = \frac{21}{50} = \mathbf{0.42\ \ geq}\ L^{-1}$$

Q.39 30 ml Na_2CO_3 solution is mixed in 20 ml 0.8 N H_2SO_4. The resulting solution required 20 ml 0.7 N HCl for neutralization. Calculate the strength of Na_2CO_3 solution in g/L, Take Na_2CO_3 as anhydrous.

Ans. 53 g/L

Sol. meq of acids = (20 × 0.8) + (20 × 0.7) = 16 + 14 = 30

meq of Na_2CO_3 = 30

$$\text{Normality of } Na_2CO_3 = \frac{30}{30} = 1N$$

$$\text{Strength} = N \times \text{eq. wt} = \left(1 \times \frac{106}{2}\right) = \mathbf{53\ g/L}$$

Q.40 1 g sample of H_2O_2 solution containing x % of H_2O_2 by weight requires x ml $KMnO_4$ solution for complete oxidation under acidic conditions. Calculate the normality of $KMnO_4$ solution.

Ans. 0.588 N

Sol. 1 g of solution contains $\frac{1 \times x}{100} = 0.01\ x\ g\ H_2O_2$

17 g (eq. wt.) of H_2O_2 is present in 1000 ml 1N solution

$\therefore$ 0.01 x g (eq. wt.) of H_2O_2 is present in $\frac{1000 \times 0.01x}{17}$ ml 1N solution

$$\text{Now, } \frac{1000 \times 0.01x}{17} \times N = x \times N_{KMnO_4}$$

$$N_{KMnO_4} = \frac{1000 \times 0.01x \times N}{17 \times x} = \mathbf{0.588\ N}$$

EXERCISE-1 (Exercise for JEE Mains)

[SINGLE CORRECT CHOICE TYPE]

Q.1 Which is heaviest :
(A) 25 g of Hg (B) 2 mole of H_2O (C) 2 mole of CO_2 (D) 4 g-atom of O
[2020112299]

Q.2 16 g of SO_x occupies 5.6 litre at STP. Assuming ideal gas nature, The value of x is :
(A) 1 (B) 2 (C) 3 (D) None of these
[2020110849]

Q.3 The density of liquid (mol. wt. = 70) is 1.2 g mL^{-1}. If 2 mL of liquid contains 35 drops, the number of molecules of liquid in one drop are :
(A) $\frac{1.2}{3.5} \times N_A$ (B) $\frac{1}{35} \times N_A$ (C) $\frac{1.2}{35^2} \times N_A$ (D) 1.2 N_A
[2020110582]

Q.4 How many moles of magnesium phosphate $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms:
(A) 0.02 (B) 3.125×10^{-2} (C) 1.25×10^{-2} (D) 2.5×10^{-2}
[2020110100]

Q.5 Rearrange the following (I to IV) in the order of increasing masses.
(I) 0.5 mole of O_3 (II) 0.5 gm molecule of Nitrogen
(III) 3.011×10^{23} molecules of O_2 (IV) 11.35 L of CO_2 at STP.
(A) IV < III < II < I (B) II < III < IV < I (C) III < II < I < IV (D) I < II < III < IV
[2020110110]

Q.6 A mixture of gas "X" (mol. wt. 16) and gas Y (mol. wt. 28) in the mole ratio a : b has a mean molecular weight 20. What would be mean molecular weight if the gases are mixed in the ratio b : a under identical conditions (gases are non reacting).
(A) 24 (B) 20 (C) 26 (D) 40
[2020111599]

Q.7 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%
[2020111450]

Q.8 An iodized salt contains 0.5 % of NaI. A person consumes 3 gm of salt everyday. The number of iodide ions going into his body everyday is
(A) 10^{-4} (B) 6.02×10^{-4} (C) 6.02×10^{19} (D) 6.02×10^{23}
[2020111898]

Q.9 The number of carbon atoms present in a signature, if a signature written by carbon pencil weights 1.2×10^{-3} g is
(A) 12.04×10^{20} (B) 6.02×10^{19} (C) 3.01×10^{19} (D) 6.02×10^{20}
[2020110919]

Q.10 The average atomic mass of a mixture containing 79 mole % of ^{24}Mg and remaining 21 mole % of ^{25}Mg and ^{26}Mg, is 24.31. % mole of ^{26}Mg is
(A) 5 (B) 20 (C) 10 (D) 15
[2020111344]

Q.11 An unknown compound contains 8% sulphur by mass. Calculate
(a) Least molecular weight of the compound and
(b) Molecular weight if one molecule contains 4 atoms of "S"
(A) 200, 400 (B) 300, 400 (C) 400, 1600 (D) 400, 1200
[2020111598]

Q.12 The hydrated salt, $Na_2SO_4 .n\ H_2O$ 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
[2020110960]

Q.13 The haemoglobin from the red blood corpuscles of most mammals contains approximately 0.33% of iron by weight. The molecular weight of haemoglobin as 67,200. The number of iron atoms in each molecule of haemoglobin is (atomic weight of iron = 56) :
(A) 2 (B) 3 (C) 4 (D) 5
[2020112649]

Q.14 Insulin contains 3.4% sulphur. The minimum molecular weight of insulin is :
(A) 941.176 (B) 944 (C) 945.27 (D) None of these
[2020110197]

Q.15 2.76 g of silver carbonate on being strongly heated yields a residue weighting :
(A) 2.16 g (B) 2.48 g (C) 2.32 g (D) 2.64 g
[2020110497]

Q.16 The volume equivalent of CO_2 (at STP) in the reaction :
$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2 \text{ is :}$$
(A) 22.4 litre (B) 112 litre (C) 11.2 litre (D) 5.6 litre
[2020111199]

Q.17 What mass of HNO_3 is needed to convert 5 gm of iodine into iodic acid according to the reaction?
$$I_2 + HNO_3 \rightarrow HIO_3 + NO_2 + H_2O$$
(A) 12.4 g (B) 24.8 g (C) 0.248 g (D) 1.24 g
[2020111247]

Q.18 According to following reaction :
$$A + BO_3 \longrightarrow A_3O_4 + B_2O_3$$
The number of moles of A_3O_4 produced if 1 mole of A is mixed with 1 mole of $B\,O_3$.
(A) 3 (B) 1 (C) 1/3 (D) 2/3
[2020110196]

Q.19 How much ammonia will be formed from 2.95 g of acetamide at STP
$$CH_3CONH_2 + NaOH \rightarrow CH_3COONa + NH_3$$
(A) 1120 ml (B) 2240 ml (C) 4000 ml (D) 4200 ml
[2020111600]

Q.20 What is the maximum amount of nitrogen dioxide that can be produced by mixing 4.2 gm of NO(g) and 3.2 gm of O_2(g) ?
(A) 4.60 g (B) 2.30 g (C) 3.22 g (D) 6.44 g
[2020111249]

Q.21 How many gm pure $KMnO_4$ should be heated with H_2SO_4 to produce 48 gm O_2 ?
$$KMnO_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + O_2$$
(A) 189.6 g (B) 122.5 g (C) 158 g (D) 316 g
[2020111947]

Q.22 NX is produced by the following steps of reactions
$M + X_2 \rightarrow MX_2$
$MX_2 + X_2 \rightarrow M_3X_8$
$M_3X_8 + N_2CO_3 \rightarrow NX + CO_2 + M_3O_4$
How much M (Metal) is consumed to produce 206 gm of NX (Given at. wt. of M = 56, N = 23, X = 80)
(A) $\frac{7}{4}$ gm (B) $\frac{14}{3}$ (C) 56 (D) 42
[2020110538]

Q.23 Mass of sucrose $C_{12}H_{22}O_{11}$ produced by mixing 84 gm of carbon, 12 gm of hydrogen and 56 lit. O_2 at 1 atm & 273 K according to given reaction, is
$$C(s) + H_2(g) + O_2(g) \longrightarrow C_{12}H_{22}O_{11}(s)$$
(A) 138.5 (B) 155.5 (C) 172.5 (D) 199.5
[2020112296]

Q.24 The minimum mass of mixture of A_2 and B_4 required to produce at least 1 kg of each product is :
(Given At. mass of 'A' = 10 ; At. mass of 'B' = 120)
$$5A_2 + 2B_4 \longrightarrow 2AB_2 + 4A_2B$$
(A) 2120 g (B) 1060 g (C) 560 g (D) 1660 g
[2020112599]

Q.25 The mass of CO_2 produced from 620 gm mixture of $C_2H_4O_2$ & O_2, prepared to produce maximum energy is (Combustion reaction is exothermic)
(A) 413.33 g (B) 593.04 g (C) 440 g (D) 320 g
[2020111547]

Q.26 The mass of P_4O_{10} produced if 440 gm of P_4S_3 is mixed with 384 gm of O_2 is
$$P_4S_3 + O_2 \longrightarrow P_4O_{10} + SO_2$$
(A) 568 g (B) 426 g (C) 284 g (D) 396 g
[2020112249]

Q.27 The mass of Mg_3N_2 produced if 48 gm of Mg metal is reacted with 34 gm NH_3 gas is
$$Mg + NH_3 \longrightarrow Mg_3N_2 + H_2$$
(A) $\frac{200}{3}$ (B) $\frac{100}{3}$ (C) $\frac{400}{3}$ (D) $\frac{150}{3}$
[2020110548]

Q.28 In a compound C, H, N atoms are present in 9 : 1 : 3.5 by weight. Molecular weight of compound is 108. Its molecular formula is :
(A) $C_2H_6N_2$ s (B) C_3H_4N (C) $C_6H_8N_2$ (D) $C_9H_{12}N_3$
[2020110136]

Q.29 Two elements A (at. wt. 75) and B (at. wt. 16) combine to yield a compound. The % by weight of A in the compound was found to be 75.76. The formula of the compound is :
(A) A_2B (B) A_2B_3 (C) AB (D) AB_2
[2020110798]

Q.30 74 gm of a sample on complete combustion gives 132 gm CO_2 and 54 gm of H_2O. The molecular formula of the compound may be
(A) C_5H_{12} (B) $C_4H_{10}O$ (C) $C_3H_6O_2$ (D) $C_3H_7O_2$
[2020112948]

Q.31 In the quantitative determination of nitrogen, N_2 gas liberated from 0.42 gm of a sample of organic compound was collected over water. If the volume of N_2 gas collected was $\frac{100}{11}$ ml at total pressure 860 mm Hg at 250 K, % by mass of nitrogen in the organic compound is
[Aq. tension at 250 K is 24 mm Hg and R = 0.08 L atm mol^{-1} K^{-1}]
(A) $\frac{10}{3}$% (B) $\frac{5}{3}$% (C) $\frac{20}{3}$% (D) $\frac{100}{3}$%
[2020110600]

Q.32 One gram of the silver salt of an organic dibasic acid yields, on strong heating, 0.5934 g of silver. If the weight percentage of carbon in it 8 times the weight percentage of hydrogen and one-half the weight percentage of oxygen, determine the molecular formula of the acid. [Atomic weight of Ag = 108]
(A) $C_4H_6O_4$ (B) $C_4H_6O_6$ (C) $C_2H_6O_2$ (D) $C_5H_{10}O_5$
[2020111594]

Q.33 $C_6H_5OH\ (g) + O_2\ (g) \longrightarrow CO_2\ (g) + H_2O\ (l)$
Magnitude of volume change if 30 ml of C_6H_5OH (g) is burnt with excess amount of oxygen, is
(A) 30 ml (B) 60 ml (C) 20 ml (D) 10 ml
[2020211782]

Q.34 10 ml of a compound containing 'N' and 'O' is mixed with 30 ml of H_2 to produce H_2O (l) and 10 ml of N_2 (g). Molecular formula of compound if both reactants reacts completely, is
(A) N_2O (B) NO_2 (C) N_2O_3 (D) N_2O_5
[2020211825]

Q.35 200 ml of a gaseous mixture containing CO, CO_2 and N_2 on complete combustion in just sufficient amount of O_2 showed contraction of 40 ml. When the resulting gases were passed through KOH solution it reduces by 50 % then calculate the volume ratio of $V_{CO_2} : V_{CO} : V_{N_2}$ in original mixture.
(A) 4 : 1 : 5 (B) 2 : 3 : 5 (C) 1 : 4 : 5 (D) 1 : 3 : 5
[2020211810]

Q.36 When 20 ml of mixture of O_2 and O_3 is heated, the volume becomes 29 ml and disappears in alkaline pyragallol solution. What is the volume percent of O_2 in the original mixture?
(A) 90% (B) 10% (C) 18% (D) 2%
[2020213000]

Q.37 A mixture of C_2H_2 and C_3H_8 occupied a certain volume at 80 mm Hg. The mixture was completely burnt to CO_2 and $H_2O(l)$. When the pressure of CO_2 was found to be 230 mm Hg at the same temperature and volume, the fraction of C_2H_2 in mixture is
(A) 0.125 (B) 0.5 (C) 0.85 (D) 0.25
[2020212019]

Q.38 20 mL of a mixture of CO and H_2 were mixed with excess of O_2 and exploded & cooled. There was a volume contraction of 23 mL. All volume measurements corresponds to room temperature (27°C) and one atmospheric pressure. Determine the volume ratio $V_1 : V_2$ of CO and H_2 in the original mixture
(A) 6.5 : 13.5 (B) 5 : 15 (C) 9 : 11 (D) 7 : 13
[2020211878]

Q.39 The % by volume of C_4H_{10} in a gaseous mixture of C_4H_{10}, CH_4 and CO is 40. When 200 ml of the mixture is burnt in excess of O_2. Find volume (in ml) of CO_2 produced.
(A) 220 (B) 340 (C) 440 (D) 560
[2020212700]

Q.40 A definite amount of gaseous hydrocarbon was burnt with just sufficient amount of O_2. The volume of all reactants was 600 ml, after the explosion the volume of the products [$CO_2(g)$ and $H_2O(g)$] was found to be 700 ml under the similar conditions. The molecular formula of the compound is
(A) C_3H_8 (B) C_3H_6 (C) C_3H_4 (D) C_4H_{10}
[2020211751]

Q.41 How many gram of KCl would have to be dissolved in 60 g H_2O to give 20% by weight of solution?
(A) 15 g (B) 1.5 g (C) 11.5 g (D) 31.5 g
[2020212294]

Q.42 Density of 2.05 M solution of acetic acid in water is 1.02 g/mL. The molality of same solution is :
(A) 1.14 mol kg^{-1} (B) 3.28 mol kg^{-1} (C) 2.28 mol kg^{-1} (D) 0.44 mol kg^{-1}
[2020211591]

Q.43 Two solutions of a substance (non - electrolyte) are mixed in the following manner 480 mL of 1.5 M of irst solution with 520 mL of 1.2 M of second solution. The molarity of final solution is :
(A) 1.20 M (B) 1.50 M (C) 1.344 M (D) 2.70 M
[2020210563]

Q.44 Equal volumes of 10% (v/v) of HCl is mixed with 10% (v/v) NaOH solution. If density of pure NaOH is 1.5 times that of pure HCl then the resultant solution be.
(A) basic (B) neutral (C) acidic (D) can't be predicted.
[2020212245]

Q.45 One mole mixture of CH_4 & air (containing 80% N_2 20% O_2 by volume) of a composition such that when underwent combustion gave maximum heat (assume combustion of only CH_4). Then which of the statements are correct, regarding composition of initial mixture.(X presents mole fraction)

(A) $X_{CH_4} = \frac{1}{11}, X_{O_2} = \frac{2}{11}, X_{N_2} = \frac{8}{11}$ (B) $X_{CH_4} = \frac{3}{8}, X_{O_2} = \frac{1}{8}, X_{N_2} = \frac{1}{2}$

(C) $X_{CH_4} = \frac{1}{6}, X_{O_2} = \frac{1}{6}, X_{N_2} = \frac{2}{3}$ (D) Data insufficient

[2020210295]

Q.46 Assuming complete precipitation of AgCl, calculate the sum of the molar concentration of all the ions if 2 lit of 2M Ag_2SO_4 is mixed with 4 lit of 1 M NaCl solution is :

(A) 4M (B) 2M (C) 3 M (D) 2.5 M

[2020210850]

Q.47 100 mL of 30% (w/v) NaOH solution is mixed with 100 mL 90% (w/v) NaOH solution. Find the molarity of final solution.

(A) 1.3 (B) 13 (C) 1/5 (D) 15

[2020211847]

Q.48 12.5gm of fuming H_2SO_4 (labelled as 112%) is mixed with 100 lit water. Molar concentration of H^+ in resultant solution is :

[Note : Assume that H_2SO_4 dissociate completely and there is no change in volume on mixing]

(A) $\frac{2}{700}$ (B) $\frac{2}{350}$ (C) $\frac{3}{350}$ (D) $\frac{3}{700}$

[2020211200]

Q.49 If 50 gm oleum sample rated as 118% is mixed with 18 gm water, then the correct option is

(A) The resulting solution contains 18 gm of water and 118 gm H_2SO_4

(B) The resulting solution contains 9 gm water and 59 gm H_2SO_4

(C) The resulting solution contains only 118 gm pure H_2SO_4

(D) The resulting solution contains 68 gm of pure H_2SO_4

[2020210498]

Q.50 Similar to the % labelling of oleum, a mixture of H_3PO_4 and P_4O_{10} is labelled as (100 + x) % where x is the maximum mass of water which can react with P_4O_{10} present in 100 gm mixture of H_3PO_4 and P_4O_{10}. If such a mixture is labelled as 127 %. Mass of P_4O_{10} in 100 gm of mixture, is

(A) 71 gm (B) 47 gm (C) 83 gm (D) 35 gm

[2020210095]

EXERCISE-2 (Exercise for JEE Advanced)

[PARAGRAPH TYPE]

Paragraph for Question Nos. 1 to 2

$FeSO_4$ undergoes decomposition as

$$2FeSO_4 (s) \longrightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

At 1 atm & 273 K if (7.6gm) $FeSO_4$ is taken then [2020110028]

Q.1 The volume occupied by the gases at 1 atm & 273 K

(A) 22.4 lit (B) 11.2 lit (C) 1.12 lit (D) 2.24 lit

Q.2 The average molar mass of the gaseous mixture.

(A) 72 (B) 36 (C) 48 (D) 60

Paragraph for Question Nos. 3 to 5

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

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

$3FeBr_2 + Br_2 \longrightarrow Fe_3Br_8$ ....(ii) (not balanced)

$Fe_3Br_8 + Na_2CO_3 \longrightarrow 3NaBr + CO_2 + Fe_3O_4$ ....(iii) (not balanced)

[2020110049]

Q.3 Mass of iron required to produce 2.06×10^3 kg NaBr

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

Q.4 If the yield of (ii) is 60% & (iii) reaction is 70% then mass of iron required to produce 2.06×10^3 kg NaBr

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

Q.5 If yield of (iii) reaction is 90% then mole of CO_2 formed when 2.06×10^3 gm NaBr is formed

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

Paragraph for Question Nos. 6 to 9

A 10 ml mixture of N_2, a alkane & O_2 undergo combustion in Eudiometry tube. There was contraction of 2 ml, when residual gases are passed through KOH. To the remaining mixture comprising of only one gas excess H_2 was added & after combustion the gas produced is absorbed by water, causing a reduction in volume of 8 ml. [20202120210]

Q.6 Gas produced after introduction of H_2 in the mixture?

(A) H_2O (B) CH_4 (C) CO_2 (D) NH_3

Q.7 Volume of N_2 present in the mixture?

(A) 2 ml (B) 4 ml (C) 6 ml (D) 8 ml

Q.8 Volume of O_2 remained after the first combustion?

(A) 4 ml (B) 2 ml (C) 0 (D) 8 ml

Q.9 Identify the hydrocarbon.

(A) CH_4 (B) C_2H_6 (C) C_3H_8 (D) C_4H_{10}

Paragraph for Question Nos. 10 to 13

A gaseous mixture of Cl_2, ClO_P (P an integer) and NH_3 in the molar ratio 1 : 4 : 6 having a total volume 110 ml is taken and underwent sparking I, causing only decomposition of oxide of chlorine to Cl_2 (gas) and O_2 (gas) resulting a rise in volume by 20 ml. On sparking II only partial decomposition of NH_3 took place and the resulting mixture on passing through water showed a contraction by 20 ml. On sparking III of the resulting mixture some drops of water were formed with only one more product and the mixture when passed through KOH (absorbs Cl_2 only) showed no volume change. From this information calculate [202021210234]

Q.10 Formula of oxide of chlorine
(A) ClO_2 (B) Cl_2O (C) ClO (D) Cl_2O_7

Q.11 Percentage decomposition of NH_3 on sparking
(A) 66.67 (B) 33.33 (C) 50% (D) none of these

Q.12 Reactions which would have occurred on sparking III (one or more than one)
(A) $H_2 + Cl_2 \longrightarrow HCl$ (B) $3H_2 + N_2 \longrightarrow 2NH_3$
(C) $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O(l)$ (D) Data insufficient

Q.13 Volume change that would be observed when the mixture after III sparking is over is passed (through alkaline pyragallol).
(A) 25 (B) 10 (C) 45 (D) none of these

Paragraph for Question Nos. 14 to 15

2 litre of 9.8 % w/w H_2SO_4 (d = 1.5 gm/ml) solution is mixed with 3 litre of 1 M KOH solution. [2020211595]

Q.14 The number of moles H_2SO_4 added are
(A) 1 (B) 2 (C) 3 (D) 0.5

Q.15 The concentration of H^+ if solution is acidic or concentration of OH^- if solution is basic in the final solution is

(A) 0 (B) $\frac{3}{10}$ (C) $\frac{3}{5}$ (D) $\frac{2}{5}$

Paragraph for Question Nos. 16 to 17

A mixture is prepared by mixing 20 gm SO_3 in 30 gm H_2SO_4.
[2020211896]

Q.16 Find mole fraction of SO_3.
(A) 0.2 (B) 0.45 (C) 0.6 (D) 0.8

Q.17 Determine % labelling of oleum solution.
(A) 104.5 (B) 106 (C) 109 (D) 110

[REASONING TYPE]

These questions consists of two statements each, printed as Statement-I and Statement-II. While answering these Questions you are required to choose any one of the following four responses.

(A) If both Statement-I & Statement-II are True & the Statement-II is a correct explanation of the Statement-I.

(B) If both Statement-I & Statement-II are True but Statement-II is not a correct explanation of the Statement-I.

(C) If Statement-I is True but the Statement-II is False.

(D) If Statement-I is False but the Statement-II is True.

Q.18 **Statement-I** : During a chemical reaction total moles remains constant.
Statement-II : During a chemical reaction total mass remains constant. [2020110157]

Q.19 **Statement-I** : Approximate mass of 1 atom of O^{16} in gms is $(16 / N_A)$
Statement-II : 1 atom of O^{16} weighs 16 a.m.u & 1 a.m.u = $(1 / N_A)$ g. [2020110549]

Q.20 **Statement-I** : For the reaction producing Fe & CO_2 by the reaction of Fe_2O_3 and C the ratio of stoichiometric coefficients of Fe_2O_3 : Fe is 1 : 2.
Statement-II : During a chemical a reaction atoms can neither be created nor be destroyed.
[2020110176]

Q.21 **Statement-I** : Molality of pure ethanol is lesser than pure water.
Statement-II : As density of ethanol is lesser than density of water.
[Given : $d_{ethanol}$ = 0.789 gm/ml; d_{water} = 1 gm/ml] [2020210596]

Q.22 **Statement-I** : Mass of a solution of 1 litre of 2M H_2SO_4 [$d_{solution}$ = 1.5 gm/ml] is greater than the mass of solution containing 400 gm MgO which is labelled as 40% (w/w) MgO.
Statement-II : Mass of H_2SO_4 in 1 litre 2M H_2SO_4 [$d_{solution}$ = 1.5 gm/ml] is greater than the mass of MgO in 1 litre 40% (w/w) MgO [$d_{solution}$ =2 gm /ml] solution. [2020211194]

Q.23 **Statement-I :** A One molal solution prepared at 20°C will retain the same molality at 100°C , provided there is no loss of solute or solvent on heating.
Statement-II : Molality is independent of temperatures. **[2020210185]**

[MULTIPLE CORRECT CHOICE TYPE]

Q.24 One mole of CO_2 contains :
(A) 6.023×10^{23} g-atom of CO_2
(B) 12.04×10^{23} atom of oxygen
(C) 18.1×10^{3} molecule of CO_2
(D) 6.023×10^{23} atom of carbon
[2020110342]

Q.25 11.2 litre of a gas at STP weighs 14 g. The gases would be :
(A) N_2 (B) CO (C) N_2O (D) B_2H_6
[2020110223]

Q.26 Two gases A and B which react according to the equation

$$aA_{(g)} + bB_{(g)} \longrightarrow cC_{(g)} + dD_{(g)}$$

to give two gases C and D are taken (amount not known) in an Eudiometer tube (operating at a constant Pressure and temperature) to cause the above.
If on causing the reaction there is no volume change observed then which of the following statement is/are correct.
(A) (a + b) = (c + d)
(B) average molecular mass may increase or decrease if either of A or B is present in limited amount.
(C) Vapour Density of the mixture will remain same throughout the course of reaction.
(D) Total moles of all the component of mixture will change. [2020212050]

Q.27 A mixture of C_3H_8 (g) & O_2 having total volume 100 ml in an Eudiometry tube is sparked & it is observed that a contraction of 45 ml is observed what can be the composition of reacting mixture.
(A) 15 ml C_3H_8 & 85 ml O_2
(B) 25 ml C_3H_8 & 75 ml O_2
(C) 45 ml C_3H_8 & 55 ml O_2
(D) 55 ml C_3H_8 & 45 ml O_2 [2020210113]

Q.28 For the following reaction

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

Identify the compositions which will produce same amount of NH_3.
(A) 140 g N_2 & 35 g H_2
(B) 18 g H_2 & 52 g N_2
(C) Total 20 moles of mixture having N_2 & H_2 present in stoichiometric ratio (No limiting reagent)
(D) 136 gm of mixture having mass fraction of $H_2 = \frac{6}{34}$ [2020110886]

Q.29 An organic compound is burnt with excess of O_2 to produce CO_2(g) and $H_2O(l)$, which results in 25% volume contraction. Which of the following option(s) satisfy the given conditions.
(A) 10 ml C_3H_8 + 110 ml O_2
(B) 20 ml C_2H_6O + 80 ml O_2
(C) 10 ml $C_3H_6O_2$ + 50 ml O_2
(D) 40 ml $C_2H_2O_4$ + 60 ml O_2 **[20202120151]**

Q.30 Solution(s) containing 40 gm NaOH is/are
(A) 50 gm of 80% (w/w) NaOH
(B) 50 gm of 80% (w/v) NaOH [$d_{soln.}$ = 1.2 gm/ml]
(C) 50 gm of 20 M NaOH [$d_{soln.}$ = 1 gm/ml]
(D) 50 gm of 5m NaOH [2020210442]

Q.31 The **incorrect** statement(s) regarding 2M $MgCl_2$ aqueous solution is/are ($d_{solution}$ = 1.09 gm/ml)
(A) Molality of Cl^- is **4.44 m**
(B) Mole fraction of $MgCl_2$ is exactly **0.035**
(C) The conc. of $MgCl_2$ is **19% w/v**
(D) The conc. of $MgCl_2$ is **19×10^4 ppm** [2020210750]

Q.32 A sample of H_2O_2 solution labelled as 56 volume has density of 530 gm/L. Mark the correct option(s) representing concentration of same solution in other units. (Solution contains only H_2O and H_2O_2)
(A) $M_{H_2O_2} = 6$
(B) $\% \frac{w}{v} = 17$
(C) Mole fraction of $H_2O_2 = 0.25$
(D) $m_{H_2O_2} = \frac{1000}{72}$ [2020211238]

Q.33 100 mL of 0.8 M NaOH are used to neutralize 100 mL solution obtained by passing 2.70 g SO_2Cl_2 in water. Select the correct statement.
(A) The solution of SO_2Cl_2 has 0.2 M H_2SO_4 and 0.4 M HCl
(B) The volume ratio of NaOH used for H_2SO_4 and HCl is 1:1
(C) The volume ratio of NaOH used for H_2SO_4 and HCl is 1:2
(D) Molarity of SO_2Cl_2 solution is 0.1 M **[2020211100]**

[MATCH THE COLUMN]

Q.34 One type of artificial diamond (commonly called YAG for yttrium aluminium garnet) can be represented by the formula $Y_3Al_5O_{12}$.[Y = 89, Al = 27]

	Column I Element		Column II Weight percentage
(A)	Y	(P)	22.73%
(B)	Al	(Q)	32.32%
(C)	O	(R)	44.95%

[2020111551]

Q.35 The recommended daily dose is 17.6 milligrams of vitamin C (ascorbic acid) having formula $C_6H_8O_6$. Match the following. Given : $N_A = 6 \times 10^{23}$

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

[2020111630]

Q.36 Match the column:

	Column I		Column II
(A)	16 g of CH_4	(P)	½ mole molecule
(B)	1 g of H_2	(Q)	$6.023 \times 10^{23} \times 5$ atoms
(C)	22 g of CO_2	(R)	11.2 litre
(D)	9 g of H_2O	(S)	1.806×10^{23} atoms

[2020111509]

Q.37 Match the column:

	Column I (Reaction)		Column II (Yield of product)
(A)	$N_2 + 3H_2 \rightarrow 2NH_3$ 1g 1g	(P)	1.125 g
(B)	$CaCO_3 \rightarrow CaO + CO_2$ 1g	(Q)	1.214 g
(C)	$2H_2 + O_2 \rightarrow 2H_2O$ 1g 1g	(R)	0.56 g CaO
(D)	$C + 2H_2 \rightarrow CH_4$ 1g 1g	(S)	0.44 g CaO
		(T)	1.333 g

[2020111726]

Q.38 Match the column:

	Column I		Column II
(A)	20 V H_2O_2	(P)	1.78 M
(B)	17.45 % w/v H_2SO_4 (d = 1.1745 g/ml)	(Q)	1.78 m
(C)	Pure water	(R)	1.5 M
(D)	5 % w/w NaOH (d=1.2 gm/ml)	(S)	55.5 M

[2020210400]

Q.39 Match the column:

	Column I		Column II
(A)	10 M MgO ($d_{solution}$ = 1.20 gm/ml) Solute : MgO Solvent: H_2O	(P)	$W_{solvent}$ = 120 gm per 100 ml of solution
(B)	40% w/v NaOH ($d_{solution}$ = 1.6 gm/ml) Solute : NaOH Solvent: H_2O	(Q)	$W_{solution}$ = 150 gm per 100 gm solvent
(C)	8 m $CaCO_3$ Solute : $CaCO_3$ Solvent: H_2O	(R)	W_{solute} = 120 gm per 100 gm of solvent
(D)	0.6 mol fraction of 'X' (molecular mass = 20) in 'Y' (molecular mass 25) Solute : X Solvent : Y	(S)	$W_{solvent}$ = 125 gm per 100 gm of solute

[2020211899]

Q.40 Match the column

	Column-I		Column-II
(A)	20% by volume aqueous C_2H_5OH solution by volume, having density of 0.96 g cm^{-3}	(P)	236.8 M
(B)	5V H_2O_2 solution.	(Q)	2.55 M
(C)	18 M aq H_2SO_4 solution, having density of 1.84 g cm^{-3}	(R)	3.47 M
(D)	20 % aq. H_2SO_4 solution by weight, having density of 1.25 g cm^{-3}	(S)	0.44 M

[2020114009]

EXERCISE-3 (Miscellaneous Exercise)

Q.1 Find the number of g-molecules of oxygen in 6.023×10^{24} CO molecules. **[2020112647]**

Q.2 On heating 1.763 g of hydrated barium chloride $[BaCl_2.x\ H_2O]$ to dryness, 1.505 g of anhydrous salt remained. Find the value of x. **[2020110598]**

Q.3 The abundance of three isotopes of oxygen are as follows
% of O^{16} = 90%
% of O^{17} + % of O^{18} = 10%
Assume at. mass same as mass no. Find out % of O^{17} and O^{18}, if the isotopic mass is 16.12. **[2020111246]**

Q.4 1.44 gram of Titanium (Ti) reacted with excess of O_2 and produced x gram of non-stoichiometric compound $Ti_{1.44}O$. Calculate The value of x be **[2020110146]**

Q.5 How many g of HCl is needed for complete reaction with 69.6 g MnO_2 ?
$$HCl + MnO_2 \longrightarrow MnCl_2 + H_2O + Cl_2$$ **[2020111201]**

Q.6 Flourine reacts with uranium to produce uranium hexafluoride, UF_6, as represented by this equation
$$U(s) + 3F_2(g) \rightarrow UF_6(g)$$
How many fluorine molecules are required to produce 2.0 mg of uranium hexafluoride, UF_6, from an excess of uranium ? The molar mass of UF_6 is 352 gm/mol. **[2020111576]**

Q.7 What total volume, in litre at 600°C and 1 atm, could be formed by the decomposition of 16 gm of NH_4NO_3 ? Reaction : $2\ NH_4NO_3 \rightarrow 2N_2 + O_2 + 4H_2O_{(g)}$. **[2020110801]**

Q.8 Calculate mass of phosphoric acid required to obtain 53.4g pyrophosphoric acid. **[2020110500]**

Q.9 Calculate the amount of H_2SO_4 produced (in g) when 40 ml H_2O (d = 0.9 gm/ml) reacts with 50 l SO_3 at 1 atm. and 300 K, according to the following reaction ?
$$H_2O + SO_3 \rightarrow H_2SO_4$$ **[2020111926]**

Q.10 In one process for waterproofing, a fabric is exposed to $(CH_3)_2SiCl_2$ vapour. The vapour reacts with hydroxyl groups on the surface of the fabric or with traces of water to form the waterproofing film $[(CH_3)_2SiO]_n$, by the reaction
$$n(CH_3)_2SiCl_2 + 2nOH^- \longrightarrow 2nCl^- + nH_2O + [(CH_3)_2SiO]_n$$
where n stands for a large integer. The waterproofing film is deposited on the fabric layer upon layer. Each layer is 6.0 Å thick [the thickness of the $(CH_3)_2SiO$ group]. How much $(CH_3)_2\ SiCl_2$ is needed to waterproof one side of a piece of fabric, 1.00 m by 3.00 m, with a film 300 layers thick ? The density of the film is 1.0 g/cm^3. **[2020111550]**

Q.11 Titanium, which is used to make air plane engines and frames, can be obtained from titanium tetrachloride, which in turn is obtained from titanium oxide by the following process :

$$3\,TiO_2(s) + 4C\,(s) + 6Cl_2\,(g) \longrightarrow 3TiCl_4(g) + 2CO_2(g) + 2CO\,(g)$$

A vessel contains 4.32 g TiO_2, 5.76 g C and; 6.82 g Cl_2, suppose the reaction goes to completion as written, how many gram of $TiCl_4$ can be produced ? (Ti = 48)

[2020110899]

Q.12 A chemist wants to prepare diborane by the reaction

$$6\,LiH + 8BF_3 \longrightarrow 6Li\,BF_4 + B_2H_6$$

If he starts with 2.0 moles each of LiH & BF_3. How many moles of B_2H_6 can be prepared.

[2020111736]

Q.13 $$P_4S_3 + 8O_2 \longrightarrow P_4O_{10} + 3SO_2$$

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

[2020111228]

Q.14 39 gm of an alloy of aluminium and magnesium when heated with excess of dil. HCl forms magnesium chloride, aluminium chloride and hydrogen. The evolved hydrogen collected at 0°C has a volume of 44.8 litres at 1 atm pressure. Calculate the composition of the alloy by moles. [2020110547]

Q.15 A sample containing only $CaCO_3$ and $MgCO_3$ is ignited to CaO and MgO. The mixture of oxides produced weight exactly half as much as the original sample. Calculate the mass percentages of $CaCO_3$ and $MgCO_3$ in the sample. [2020111197]

Q.16 Determine the percentage composition of a mixture (by mass) of anhydrous sodium carbonate and sodium bicarbonate from the following data:
wt. of the mixture taken = 2g
Loss in weight on heating = 0.11 gm. [2020110846]

Q.17 A sample of mixture of $CaCl_2$ and NaCl weighing 4.22 gm was treated to precipitate all the Ca as $CaCO_3$ which was then heated and quantitatively converted to 0.959 gm of CaO. Calculate the mass percentage of $CaCl_2$ in the mixture. [2020111498]

Q.18 A power company burns approximately 474 tons of coal per day to produce electricity. If the sulphur content of the coal is 1.30 % by weight, how many tons SO_2 are dumped into the atmosphere each day? [2020112549]

Q.19 Calculate the percent loss in weight after complete decomposition of a pure sample of potassium chlorate.

$$KClO_3(s) \longrightarrow KCl(s) + O_2(g)$$

[2020112899]

Q.20 Cyclohexanol is dehydrated to cyclohexene on heating with conc. H_2SO_4. If the yield of this reaction is 75%, how much cyclohexene will be obtained from 100 g of cyclohexanol ?

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

[2020110643]

Q.21 How many grams of 90% pure Na_2SO_4 can be produced from 250 gm of 95% pure NaCl ?

[2020110250]

Q.22 A mixture of Ferric oxide (Fe_2O_3) and Al is used as a solid rocket fuel which reacts to give Al_2O_3 and Fe. No other reactants and products are involved. On complete reaction of 1 mole of Fe_2O_3, 200 units of energy is released.

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

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

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

[2020110093]

Q.23 If the yield of chloroform obtainable from acetone and bleaching powder is 75%. What is the weight of acetone required for producing 30 gm of chloroform ?

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

[2020110799]

Q.24 A mixture of nitrogen and hydrogen. In the ratio of one mole of nitrogen to three moles of hydrogen, was partially converted into NH_3 so that the final product was a mixture of all these three gases. The mixture was to have a density of 0.497 g per litre at 25°C and 1.00 atm. What would be the mass of gas in 22.4 litres at 1 atm and 273 K? Calculate the % composition of this gaseous mixture by volume.

[2020110547]

Q.25

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

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

According to the above sequence of reactions, how much H_2SO_4 will 1146 gm of PbS produce?

[2020110089]

Q.26 Potassium superoxide, KO_2, is utilised in closed system breathing apparatus. Exhaled air contains CO_2 and H_2O, both of which are removed and the removal of water generates oxygen for breathing by the reaction

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

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

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

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

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

[2020110193]

Q.27 0.80 g of the chloroplatinate of a mono acid base on ignition gave 0.262g of Pt. Calculate the mol. wt of the base. [2020111589]

Q.28 Equal weights of mercury and iodine are allowed to react completely to form a mixture of mercurous and mercuric iodide leaving none of the reactants. Calculate the ratio by weight of Hg_2I_2 and HgI_2 formed (Hg = 200 , I = 127) [2020111149]

Q.29 Two substance P_4 & O_2 are allowed to react completely to form mixture of P_4O_6 & P_4O_{10} leaving none of the reactants. Using this information calculate the composition of final mixture when mentioned amount of P_4 & O_2 are taken.

$$P_4 + 3O_2 \longrightarrow P_4O_6$$
$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

(i) If 1 mole P_4 & 4 mole of O_2
(ii) If 3 mole P_4 & 11 mole of O_2
(iii) If 3 mole P_4 & 13 mole of O_2 [2020111699]

Q.30 1 gm sample of $KClO_3$ was heated under such conditions that a part of it decomposed according to the equation (1) $2KClO_3 \longrightarrow 2\,KCl + 3O_2$
and remaining underwent change according to the equation.
(2) $4KClO_3 \longrightarrow 3\,KClO_4 + KCl$
If the amount of O_2 evolved was 112 ml at 1 atm and 273 K., calculate the % by weight of $KClO_4$ in the residue. [2020110940]

Q.31 When 100 ml of a $O_2 - O_3$ mixture was passed through turpentine, there was reduction of volume by 20 ml. If 100 ml of such a mixture is heated, what will be the increase in volume? [2020212900]

Q.32 60 ml of a mixture of nitrous oxide and nitric oxide was exploded with excess of hydrogen. If 38 ml of N_2 was formed, calculate the volume of each gas in the mixture. [2020212598]

Q.33 20 ml of a mixture of C_2H_2 and CO was exploded with 30 ml of oxygen. The gases after the reaction had a volume of 34 ml. On treatment with KOH, 8 ml of oxygen remained. Calculate the composition of the mixture. [2020212500]

Q.34 10 ml of a mixture of CH_4, C_2H_4 and CO_2 were exploded with excess of air. After explosion, there was contraction on cooling of 17 ml and after treatment with KOH, there was further reduction of 14 ml. What is the composition of the mixture? [2020211449]

Q.35 40 ml of a mixture of C_2H_2 and CO is mixed with 100 ml of O_2 gas and the mixture is exploded. The residual gases occupied 104 ml and when these are passed through KOH solution, the volume becomes 48 ml. All the volume are at same the temperature and pressure. Determine the composition of original mixture. [2020210048]

Q.36 A mixture of three gases an alkane (general formula C_nH_{2n+2}), an alkene (general formula C_xH_{2x}) and O_2 was subjected to sparking to cause combustion of both the hydrocarbon at 127°C. After the reaction three gases were present and none of the hydrocarbon remained. On passing the gases through KOH (absorb CO_2), an increment in mass of KOH solution by 132 gm was observed. The remaining gases were passed over white anhydrous $CuSO_4$ and the weight of blue hydrated $CuSO_4$ crystals was found to be 72 gm more than that of white anhydrous $CuSO_4$. Given that initially total 10 moles of the three gases were taken and **moles of alkane and alkene were equal** and if *molecular mass of alkene – molecular mass of alkane=12 i.e.* ($M_{alkene} - M_{alkane} = 12$), then answer the following questions. (Show calculations)

(a) Which three gases are remained after the combustion reactions
(b) What are the number of moles of product gases.
(c) What is the molecular formula of the two hydrocarbon.
(d) What is the number of moles of each of the two hydrocarbons and O_2 gas taken initially.
[2020211548]

Q.37 A mixture of H_2 and butyne (C_4H_8) was collected in a Eudiometer tube. Then, 80 ml of oxygen were also introduced. The resulting mixture of all the gases was exploded. **After** cooling **resulting gaseous mixture passes through** KOH solution which caused a contraction of 32 ml and 16 ml of oxygen alone were left behind.
(a) Calculate total volume of initial mixture.
(b) Calculate percentage volume of butyne in original gas mixture.
(c) Calculate contraction in volume (after explosion and cooling of resulting mixture).
[2020210449]

Q.38 A gaseous mixture of C_2H_4, CH_4, CO and N_2 at 400 K & 1 atm was added with excess of O_2 & subjected to sparking in a rigid container (volume constant). If pressure of CO_2 obtained at 400 K in same volume is 0.9 atm and that of H_2O vapour is 0.8 atm. If moles of C_2H_4 and CH_4 are equal then calculate the pressure of each gas in the original mixture.
[2020210201]

Q.39 10 ml of ammonia were enclosed in an eudiometer and subjected to electric sparks. The sparks were continued till there was no further increase in volume. The volume after sparking measured 20 ml. Now 30 ml of O_2 were added and sparking was continued again. The new volume then measured 27.5 ml. All volumes were measured under identical conditions of temperature and pressure. Calculate the molecular formula of ammonia. Nitrogen and Hydrogen are diatomic. [2020211549]

Q.40 The density of a solution containing 40% by mass of HCl is 1.2 g/mL. Calculate the molarity of the solution.
[2020211213]

Q.41 15 g of methyl alcohol is present in 100 mL of solution. If density of solution is 0.90 g mL^{-1}. Calculate the mass percentage of methyl alcohol in solution [2020210869]

Q.42 A 6.90 M solution of KOH in water contains 30% by mass of KOH. What is density of solution in gm/ml. [2020210523]

Q.43 The average concentration of Na^+ ion in human body is 3 to 4 gm per litre. The molarity of Na^+ ion is about. [2020210184]

Q.44 What is the concentration of chloride ion, in molarity, in a solution containing 10.56 gm $BaCl_2.8H_2O$ per litre of solution ? (Ba = 137)
[2020210854]

Q.45 The mole fraction of solute in aqueous urea solution is 0.2. Calculate the mass percent of solute ?
[2020210216]

Q.46 The concentration of $Ca(HCO_3)_2$ in a sample of hard water is 500 ppm. The density of water sample is 1.0 gm/ml. Calculate the molarity of solution ?
[2020210828]

Q.47 How much $BaCl_2$ would be needed to make 250 ml of a solution having the same concentration of Cl^- as one containing 3.78 gm NaCl per 100 ml ? (Ba = 137)

[2020211034]

Q.48 Calculate **molality (m)** of each ion present in the aqueous solution of **2M NH_4Cl** assuming 100% dissociation according to reaction.

$$NH_4Cl\ (aq) \longrightarrow NH_4^+\ (aq) + Cl^-\ (aq)$$

Given : Density of solution = 3.107 gm / ml. **[2020210986]**

Q.49 Find out the volume of 98% w/w H_2SO_4 (density = 1.8 gm/ ml), must be diluted to prepare 12.5 litres of 2.5 M sulphuric acid solution. **[2020210528]**

Q.50 500 ml of 2 M NaCl solution was mixed with 200 ml of 2 M NaCl solution. Calculate the final volume and molarity of NaCl in final solution if final solution has density 1.5 gm/ml. **[2020210082]**

Q.51 Calculate the amount of the water which must be added to a given solution of concentration of 40 mg silver nitrate per ml, to yield a solution of concentration of 16 mg silver nitrate per ml ?

[2020210178]

Q.52 500 gm of urea solution of mole fraction 0.2 is diluted to 1500 gm. Calculate the mole fraction of solute in the diluted solution ? **[2020210002]**

Q.53 What volume of 0.8 M $AlCl_3$ solution should be mixed with 50 ml of 0.2M $CaCl_2$ solution to get solution of chloride ion concentration equal to 0.6 M ? **[2020210367]**

Q.54 What volume of 0.2 M NaOH (in ml) solution should be mixed to 500 ml of 0.5 M NaOH solution so that 300 ml of final solution is completely neutralised by 20 ml of 2 M H_3PO_4 solution.
[Assuming 100% dissociation]

[2020210127]

Q.55 An oleum sample is labelled as 118 %, Calculate
(i) Mass of H_2SO_4 in 100 gm oleum sample.
(ii) Maximum mass of H_2SO_4 that can be obtained if 30 gm sample is taken.
(iii) Composition of mixture (mass of components) if 40 gm water is added to 30 gm given oleum sample. **[2020210170]**

Q.56 500 ml of a H_2O_2 solution on complete decomposition produces 2 moles of H_2O. Calculate the volume strength of H_2O_2 solution? **[Given : Volume of O_2 is measured at 1atm and 273 K]**

[2020210320]

Q.57 How much minimum volume of 0.1 M aluminium sulphate solution should be added to excess calcium nitrate to obtain atleast 1 gm of each salt in the reaction.

$$Al_2(SO_4)_3 + 3Ca(NO_3)_2 \longrightarrow 2Al(NO_3)_3 + 3CaSO_4$$

[2020210568]

Q.58 $H_2O_2 + 2KI \xrightarrow{40\% \text{ yield}} I_2 + 2KOH$

$H_2O_2 + 2KMnO_4 + 3H_2SO_4 \xrightarrow{50\% \text{ yield}} K_2SO_4 + 2MnSO_4 + 3O_2 + 4H_2O$

100 ml of H_2O_2 sample was divided into two parts. First part was treated with KI. And KOH formed required 200 ml of M/2 H_2SO_4 for complete neutralisation. Other part was treated with just sufficient $KMnO_4$ yielding 6.74 lit. of O_2 at 1 atm & 273 K. Calculate

(a) Moles of KOH produced
(b) Moles of $KMnO_4$ used
(c) Total moles of H_2O_2 used in both reaction
(d) Volume strength of H_2O_2 used. [2020210649]

Q.59 If 0.5 M methanol undergo self dissociation like $CH_3OH \rightleftharpoons CH_3O^- + H^+$ & if concentration of H^+ is 2.5×10^{-4} M then calculate % dissociation of methanol. [2020210695]

Q.60 Fill in the blanks in the following table.

Compound	Grams Compd	Grams Water	Molality of Compd	Mole Fraction of Compd
Na_2CO_3	______	250	0.0125	______
CH_3OH	13.5	150	______	______
KNO_3	______	555	______	0.0934

[2020212597]

EXERCISE-4

SECTION-A
(IIT JEE Previous Year's Questions)

Q.1 Which has the maximum number of atoms : **[IIT-JEE 2003]**
(A) 24 g C (12) (B) 56 g Fe (56) (C) 27 g Al (27) (D) 108 g Ag (108)
[2020110647]

Q.2 Calculate the molarity of pure water using its density to be 1000 kg m^{-3}. **[JEE'2003]**
[2020211198]

Q.3 One gm of charcoal absorbs 100 ml 0.5 M CH_3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = 3.01×10^2 m^2/gm. **[JEE'2003]**
[2020212244]

Q.4 Calculate the amount of calcium oxide required when it reacts with 852 g of P_4O_{10}.
[IIT-JEE 2005]
[2020111000]

Q.5 20% surface sites have adsorbed N_2. On heating N_2 gas evolved from sites and were collected at 0.001 atm and 298 K in a container of volume is 2.46 cm^3. Density of surface sites is 6.023×10^{14}/cm^2 and surface area is 1000 cm^2, find out the no. of surface sites occupied per molecule of N_2.
[JEE 2005]
[2020212593]

Q.6 Dissolving 120 g of urea (mol. wt. 60) in 1000 g of water gave a solution of density 1.15 g/mL. The molarity of the solution is **[JEE 2011]**
(A) 1.78 M (B) 2.00 M (C) 2.05 M (D) 2.22 M
[2020210589]

Q.7 The volume (in ml) of 0.1 M $AgNO_3$ required for complete precipitation of chloride ions present in 30 ml of 0.01 M solution of $[Cr(H_2O)_5Cl]Cl_2$, as silver chloride is close to **[JEE 2011]**
[2020210539]

SECTION-B
(AIEEE Previous Year's Questions)

Q.8 A solution containing 2.675 g of $CoCl_3.6\,NH_3$ (molar mass = 267.5 g mol^{-1}) is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of $AgNO_3$ to give 4.78 g of AgCl (molar mass = 143.5 g mol^{-1}). The formula of the complex is
(At. mass of Ag = 108 u) **[AIEEE-2010]**
(A) $[CoCl_3(NH_3)_3]$ (B) $[CoCl(NH_3)_5]Cl_2$ (C) $[Co(NH_3)_6Cl_3$ (D) $[CoCl_2(NH_3)_4]Cl$
[2020114017]

Q.9 29.5 mg of an organic compound containing nitrogen was digested according to Kjeldahl's method and the evolved ammonia was absorbed in 20 mL of 0.1 M HCl solution. The excess of the acid required 15 mL of 0.1 M NaOH solution for complete neutralization. The percentage of nitrogen in the compound is:
(A) 23.7 (B) 29.5 (C) 59.0 (D) 47.4
[AIEEE-2011]
[2020113966]

Q.10 A 5.2 molal aqueous solution of methyl alcohol, CH_3OH, is supplied. What is the mole fraction of methyl alcohol in the solution ? **[AIEEE-2011]**
(A) 0.100 (B) 0.190 (C) 0.086 (D) 0.050
[2020113915]

Q.11 The molarity of a solution obtained by mixing 750 mL of 0.5 (M) HCl with 250 mL of 2 (M) HCl will be:
(A) 1.00 M (B) 1.75 M (C) 0.975 M (D) 0.875 M
[JEE MAIN-2013]
[2020114119]

Q.12 A gaseous hydrocarbon gives upon combustion 0.72 g of water and 3.08 g of CO_2. The empirical formula of the hydrocarbon is:
(A) C_3H_4 (B) C_6H_5 (C) C_7H_8 (D) C_2H_4
[JEE MAIN-2013]
[2020114170]

ANSWER KEY

EXERCISE-1

Q.1 (C)	**Q.2** (B)	**Q.3** (C)	**Q.4** (B)
Q.5 (B)	**Q.6** (A)	**Q.7** (A)	**Q.8** (C)
Q.9 (B)	**Q.10** (C)	**Q.11** (C)	**Q.12** (D)
Q.13 (C)	**Q.14** (A)	**Q.15** (A)	**Q.16** (A)
Q.17 (A)	**Q.18** (C)	**Q.19** (A)	**Q.20** (D)
Q.21 (A)	**Q.22** (D)	**Q.23** (B)	**Q.24** (A)
Q.25 (C)	**Q.26** (B)	**Q.27** (A)	**Q.28** (C)
Q.29 (B)	**Q.30** (C)	**Q.31** (A)	**Q.32** (B)
Q.33 (B)	**Q.34** (C)	**Q.35** (C)	**Q.36** (B)
Q.37 (A)	**Q.38** (D)	**Q.39** (C)	**Q.40** (A)
Q.41 (A)	**Q.42** (C)	**Q.43** (C)	**Q.44** (A)
Q.45 (A)	**Q.46** (B)	**Q.47** (D)	**Q.48** (A)
Q.49 (B)	**Q.50** (A)		

EXERCISE-2

Q.1 (C)	**Q.2** (A)	**Q.3** (B)	**Q.4** (C)
Q.5 (B)	**Q.6** (D)	**Q.7** (B)	**Q.8** (C)
Q.9 (A)	**Q.10** (A)	**Q.11** (A)	**Q.12** (A), (C)
Q.13 (A)	**Q.14** (C)	**Q.15** (C)	**Q.16** (B)
Q.17 (C)	**Q.18** (D)	**Q.19** (A)	**Q.20** (A)
Q.21 (B)	**Q.22** (D)	**Q.23** (A)	**Q.24** (B), (D)
Q.25 (A), (B), (D)	**Q.26** (A), (C)	**Q.27** (A), (B)	**Q.28** (A), (C)
Q.29 (A), (C)	**Q.30** (A), (C)	**Q.31** (B), (D)	**Q.32** (B), (D)

Q.33 (A), (C)
Q.34 [(A) R, (B) P, (C) Q]
Q.35 [(A) R, (B) Q, (C) P]
Q.36 [A-Q ; B-P, R ; C-P,R; D-P]
Q.37 [A-Q, B-R, C-P, D-T]
Q.38 [(A) P; (B) P,Q ; (C) S; (D) R]
Q.39 [(A) Q; (B) P; (C) S; (D) R]
Q.40 [(A) –R, (B) – S, (C) – P, (D)–Q]

EXERCISE-3

Q.1 [5 g-mole] **Q.2** [2] **Q.3** [16.12] **Q.4** [1.77 g]
Q.5 [116.8 g] **Q.6** [1.0×10^{19}] **Q.7** [50.14 litre] **Q.8** [58.8 g]
Q.9 [0196] **Q.10** [0.9413 g] **Q.11** [9.12] **Q.12** [0.25 mole]
Q.13 [1.1458 g] **Q.14** [Al = 66.6%] **Q.15** [$CaCO_3$ = 28.4%; $MgCO_3$ = 71.6%]
Q.16 [$NaHCO_3$ = 14.9 %; Na_2CO_3 = 85.1 %] **Q.17** [45%]
Q.18 [12.3] **Q.19** [39.18] **Q.20** [61.5 g] **Q.21** [320.3 g]
Q.22 [(i) $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$; (ii) 80 : 27; (iii)10,000 units]
Q.23 [19.4 g] **Q.24** [12.15g, N_2 = 14.28 % H_2 = 42.86%, NH_3 = 42.86 %]
Q.25 [470.4 g] **Q.26** [(a)59.17 g (b) 61.97 g] **Q.27** [92.70 g/mol]
Q.28 [0.532 : 1.00] **Q.29** [.(i) 0.5 , 0.5 ; (ii) 2, 1 (iii) 1, 2] **Q.30** [59.72%]

Q.31 [10 ml]
Q.32 [NO = 44 ml; N_2O = 16 ml]
Q.33 [C_2H_2 = 6 ml, CO = 14 ml]
Q.34 [CH_4 = 4.5 ml, CO_2 = 1.5 ml]
Q.35 [C_2H_2 = 16 ml, CO = 24 ml]
Q.36 [(a) CO_2, H_2O and O_2 ; (b) $n_{CO_2} = 3$, $n_{H_2O} = 4$; (c) C_2H_4 and CH_4 are the H.C; (d) $n_{O_2} = 8$]
Q.37 [(a) 40 ml, (b) 20%, (c) 72 ml]
Q.38 [0.2,0.2,0.3,0.3]
Q.39 [NH_3]
Q.40 [13.15]
Q.41 [16.67%]
Q.42 [1.288]
Q.43 [0.15 M]
Q.44 [0.06 M]
Q.45 [45.45%]
Q.46 [3×10^{-3} M]
Q.47 [16.8 g]
Q.48 [0.6667, 0.6667]
Q.49 [1.736 litre]
Q.50 [2 M]
Q.51 [1.5 ml]
Q.52 [0.05]
Q.53 [5.56 ml]
Q.54 [250]
Q.55 [(i) 20 gm H_2SO_4 ; (ii) 35.4 gm H_2SO_4; (iii) H_2SO_4= 35.4 gm, H_2O = 34.6gm]
Q.56 [44.8 V]
Q.57 [24.51 ml]
Q.58 [(a) 0.2; (b) 0.4 moles; (c) 0.45; (d) 50.4 'V']
Q.59 [0.05]
Q.60 [0.331g, 2.25×10^{-4}, 2.81, 0.0482, 321, 5.72]

EXERCISE-4

SECTION-A

Q.1 (A)
Q.2 [55.5 mol L^{-1}]
Q.3 [5×10^{-19} m^2]
Q.4 [1008 g]
Q.5 [2]
Q.6 (C)
Q.7 [6]

SECTION-B

Q.8 (C)
Q.9 (A)
Q.10 (C)
Q.11 (D)
Q.12 (C)

HINTS / SOLUTION

EXERCISE-1

Q.1 (a) wt of Hg = 25 g
(b) wt. of $H_2O = 2 \times 18 = 36$ g
(c) wt of $CO_2 = 2 \times 44 = 88$ g
(d) wt. of O = $4 \times 16 = 64$ g

Q.2 One mole of a gas occupies 22.4 litre at STP
gram mol wt. of $SO_x = 32 + 16x$ g

gram mol wt. of $SO_x = \frac{16 \times 22.4}{5.6} = 32 + 16x$ g

$x = 2$

Q.3 wt. of one drop of liquid = $\frac{1.2 \times 2}{35}$ gram

70 gram of liquid contain N_A molecules

$\frac{1.2 \times 2}{35}$ gram of liquid contain $\frac{N_A}{70} \times \frac{1.2 \times 2}{35} = \frac{1.2}{(35)^2} \times N_A$

Q.4 Moles of $Mg_3(PO_4)_2 = \frac{1}{8} \times 0.25 = 3.125 \times 10^{-2}$

Q.5 Convert all the value in mass and the increasing order is (II < III < IV < I)

Q.6 $\frac{a \times 16 + b \times 28}{a + b} = 20$

$16a + 28b = 20a + 20b$

$4a = 8b \Rightarrow a = 2b \Rightarrow a/b = 2$

Now $\frac{16b + 28a}{b + a} = \frac{16 + 28a/b}{1 + a/b} = \frac{16 + 28 \times 2}{1 + 2} = 24$

Q.7 $M_{avg} = \frac{x.M_{NO_2} + (100 - x)M_{NO}}{100}$

$34 = \frac{x \times 46 + (100 - x)30}{100}$

$x = 25\%$

Q.8 Moles of I^- = moles of NaI

$= \frac{\text{wt. of NaI}}{\text{Mol. mass of NaI}} = \left(\frac{0.5 \times 3}{100}\right) \times \frac{1}{150}$

$= 10^{-4}$ moles

No. of Iodine ions = moles of I^- × N_A

$$= 6.02 \times 10^{19}$$

Q.9 No. of carbon atoms = $\frac{1.2\times10^{-3}}{12} \times N_A = 6.02 \times 10^{19}$

Q.10 $M_{avg} = 24.31 = \frac{79\times24+(21-x)\times25+x\times26}{100}$

$x = 10$

Q.11 (a) 8 g sulphur is present in 100 g of the compound
(For minimum molecular mass, one mole of compound should contain at least one mole of sulphur)

Hence 32 g S (1 mole) will be present $= \frac{100}{8}\times32 = 400$ g

So minimum molecular weight = 400

(b) Molecular weight when four atoms are present $= \frac{400}{8}\times4$

$= 1600$

Q.12 $\frac{18n}{142+18n} \times 100 = 55.9$

$n = 10$

Q.13 Wt of iron $= \frac{0.33}{100} \times 67200 = 222.76$ amu.

Atoms of iron $= \frac{222.76}{56} = 3.98 \approx 4$

Q.14 Atomic wt. of S = 32 amu

Minimum molecular weight of insulin $= \frac{100\times32}{3.4} = 914.176$

Q.15 $Ag_2CO_3 \xrightarrow{\Delta} 2Ag + CO_2 + 1/2\ O_2$

276 g   216g

wt. of Ag $= \frac{216}{276}\times2.76 = 2.16$ g

Q.16 $NaHCO_3 + HCl \longrightarrow NaCl + CO_2 + H_2O$

1 1 1 1 1

Vol. = 22.4 litre at STP

Q.17 $I_2 + 10\,HNO_3 \rightarrow 2\,HIO_3 + 10NO_2 + 4H_2O$

Moles of iodine $= \frac{5}{254}$

Moles of $HNO_3 = \frac{5}{254} \times 10$

Mass of $HNO_3 = \frac{5 \times 10}{254} \times 63 = 12.4$ g

Q.18 $3A + 8/3\ BO_3 \rightarrow A_3O_4 + 4/3\ B_2O_3$

1 1

A is limiting reagent

Moles of A_3O_4 produced $= \frac{1}{3} \times 1 = 1/3$

Q.19 Moles of $CH_3CONH_2 = \frac{2.95}{59} = 0.05$

Moles of $NH_3 = 0.05$

Vol. of ammonia $= 22400 \times 0.05 = 1120$ ml

Q.20

	2 NO	+	O_2	$\rightarrow$	$2NO_2$
Moles	$\frac{4.2}{30}$		$\frac{3.2}{32}$		
	0.14		0.1		

NO is limiting reagent

Moles of NO_2 produced $= \frac{2}{2} \times 0.14 = 0.14$

Mass of $NO_2 = 0.14 \times 46 = 6.44$ g

Q.21 $2\,KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5/2\ O_2$

2.5 Moles of O_2 is produced by 2 moles of $KMnO_4$

1.5 Moles of O_2 is produced by $= \frac{2}{2.5} \times 1.5 = 1.2$

Mass of $KMnO_4 = 1.2 \times 158 = 189.6$ g

Q.22 Balance the three eq.

$M + X_2 \longrightarrow M\,X_2$

a a

$3M\,X_2 + X_2 \rightarrow M_3\,X_8$

a a/3

$M_3\,X_8 + 4N_2CO_3 \rightarrow 8\,NX + 4CO_2 + M_3O_4$

a/3 8a/3

$$\frac{8a}{3} = \frac{206}{103} = 2\,,\ a = \frac{3}{4}\text{ moles}$$

$$\text{Mass of M} = 56\text{ a} = \frac{3}{4} \times 56 = 42\text{ g/mol}$$

Q.23 Mole of C $= \frac{84}{12} = 7$

Mole of $H_2 = \frac{12}{2} = 6$

Mole of $O_2 = \frac{56}{22.4}$

$$12\text{ C (s)} + 11\text{ H}_2\text{ (g)} + \frac{11}{2}\text{ O}_2\text{ (g)} \rightarrow C_{12}H_{22}O_{11}\text{ (s)}$$

moles of $C_{12}H_{22}O_{11}$ (s) $= \frac{56}{22.4} \times \frac{2}{11}$ (O_2 is Limiting reagent)

mass of $C_{12}H_{22}O_{11}$ (s) $= \frac{56}{22.4} \times \frac{2}{11} \times 342 = 155.5$ g

Q.24

$5A_2$	+	$2B_4$	$\rightarrow$	$2AB_2$	+	$3A_2B$	
5		2		2		4	(By mole)
100		960		500		560	(By mass)

AB_2 will determine the least amount of mixture

$$= \frac{(100+960)}{500} \times 1\text{ kg}$$

$$= 2.12\text{ kg} = 2120\text{ g}$$

Q.25 For max. energy from a given mass of mixture, the reactant should be in stochiometric ratio.

$C_2H_4O_2 + $	$2O_2 \rightarrow$	$2CO_2$	$+ \ 2H_2O$
1	2	2	(moles)
60	64	$44 \times 2 = 88$	(mass)

mass of CO_2 produced $= \frac{88 \times 620}{(60+64)}$

$= 440$ g

Q.26

P_4S_3	+	$8O_2$	$\rightarrow$	P_4O_{10}	+	$3SO_2$	
440 g		384 g					(mass)
$\frac{440}{220} = 2$		12					(mole)

O_2 is limiting reagent

so moles of P_4O_{10} produced $= \frac{12}{8}$

mass of P_4O_{10} produced $= \frac{12}{8} \times 284 = 426$ g

Q.27

$3Mg$	+	$2NH_3$	$\rightarrow$	$Mg_3N_2 + 3H_2$	
48		34			(mass)
2		2			(mole)

Mg is limiting reagent

So moles of $Mg_3N_2 = \frac{2}{3}$

mass of $Mg_3N_2 = \frac{2}{3} \times 100 = \frac{200}{3}$

Q.28 Relative no. of atoms C : H : O

$$\frac{9}{12} : \frac{1}{1} : 0.25$$

$$3 \quad 4 \quad 1$$

Empirical formula mass = 36 + 4 + 16 = 56

$$n = \frac{108}{50} = 2$$

Molecules formula = 2 (Empirical formula)

$= 2\ (C_3H_4N) = C_6H_8N_2$

Q.29 Percentage of A in $A_2O_3 = \frac{150}{198} \times 100 = 75.76$

Q.30

$C_xH_yO_z$	+	O_2	$\rightarrow$	xCO_2	+	$\frac{y}{2}\ H_2O$
		(excess)				
1				x		$\frac{y}{2}$ Mole
				132/44 = 3		54/18 = 3

Emperical formula C_2H_6Oz

$3 \times 12 + 6 \times 1 + z \times 16 = 74$

$z = 2$

So possible molecular formula is $C_3H_6O_2$

Q.31 Moles of N_2, $n_{N_2} = \frac{PV}{RT} = \frac{(860-24) \times 100 \times 10^{-3}}{760 \times 11 \times 0.0821 \times 250}$

$= 4.87 \times 10^{-4}$ moles

$m_{N_2} = 0.01559$ g

$$\% N_2 = \frac{0.01559 \times 100}{0.42} = \frac{10}{3}\%$$

Q.32 Mol. mass of acid $= n\left[108\frac{w}{x} - 107\right]$

$$= 2\left[\frac{108 \times 1}{0.5934} - 107\right]$$

$= 150$

Molecule formula $= C_4H_6O_6$

Q.33 $C_6H_5{-}OH + 7\,O_2 \rightarrow 6CO_2 + 3H_2O$

30   $30 \times 7 = 210$ $30 \times 6 = 180$

$\Delta V = 210 + 30 - 180 = 60$

Q.34 $N_xO_y + yH_2 \rightarrow \frac{x}{2}N_2 + yH_2O$

$\frac{x}{2} = 10 \Rightarrow x = 20 \Rightarrow y = 30 \Rightarrow N_2O_3$

Q.35 $CO + CO_2 + N_2 = 200$

$a + b + c = 200$

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

$a \quad \frac{a}{2} \quad a$

$\frac{a}{2} = 40$

$CO_2 = 100$ mL

$a + b = 100$

$b = 20$

$c = 100$

$a : b : c$

$4 : 1 : 5$

Q.36 $2O_3 \rightarrow 3O_2$

$2 \quad 3$

$x \quad \frac{3}{2}x$

$\frac{3}{2}x - x = 9$ $[29 - 20 = 9]$

$x = 18$

$x = 90\%\ [O_3]$

$O_2 = 10\%$

Q.37 $C_2H_2 + C_3H_8$
$a + b = 80$

$C_2H_2 + \frac{5}{2} O_2 \rightarrow 2CO_2 + H_2O$

$a \quad \frac{5}{2}a \quad 2a$

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
$b \quad 5b \quad 3b$

$2a + 3b = 230$
$a + b = 80$
$b = 70, a = 10$

Fraction of $C_2H_2 = \frac{10}{80} = 0.125$

Q.38 $a + b = 20$ ....(1)

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

$a \quad \frac{a}{2} \quad a$

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

$b \quad \frac{b}{2}$

$\frac{a}{2} + b + \frac{b}{2} = 23$ ....(2)
$b = 13$
$a = 7$

Q.39 $C_4H_{10} = 80$
CO_2 = Produced by C_4H_{10}
$= 80 \times 4 = 320$

$CH_4 + CO \Rightarrow 2CO_2$

[120 ml (CH_4 + CO) produce = 120 ml of CO_2]
[Same no. of carbon atoms]

Total $CO_2 = 320 + 120 = 440$

Q.40 $C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow x\,CO_2 + \frac{y}{2} H_2O$

a $\quad a\left(x + \frac{y}{4}\right) \quad xa \quad \frac{ay}{a}$

$a + a\left(x + \frac{y}{4}\right) = 600$ ....(1)

$xa + \frac{ay}{2} - a + a\left(x + \frac{y}{4}\right) = 100$ ....(2)

Determine value of x and y

Q.41 20 g KCl present in 100–20 = 80 g of H_2O

Wt. of KCl in 60 g water = $\frac{20}{80} \times 60 = 15$ gram

Q.42 2.05 moles present in 1000 mL of solution

$m = \frac{2.05}{(1020 - 123)} \times 1000 = 2.28 \text{ mol kg}^{-1}$

Q.43 $(480 \times 1.5) + (520 \times 1.2) = M \times 1000$
$M = 1.344$

Q.44 Let Wg of HCl present in 10 ml of HCl
mass of HCl = 10 d
No. of moles of HCl = 10d/36.5
Mass of NaOH = 10 × 2d

Moles of NaOH = $\frac{10 \times 2 \times d}{40} = \frac{d}{2}$

Moles of HCl < NaOH
So solution is basic

Q.45 $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
1 $\quad$ 2
x $\quad$ 2x

$x + 2x + 8x = 1$
$11x = 1$

$x = \frac{1}{11}$

$CH_4 = \frac{1}{11}$, $X_{O_2} = \frac{2}{11}$, $x_{N_2} = \frac{8}{11}$

Q.46 Moles of $Ag_2SO_4 = 4$
Moles of NaCl = 4

$Ag_2SO_4 + 2\,NaCl \rightarrow 2AgCl + Na_2SO_4$
4 4
2 L.R. 2
Ag^{+1} ion = 4, $SO_4^{-2} = 2$
Na^{+1} ion = 4, $SO_4^{-2} = 2$
Total moles = 4 + 4 + 2 + 2 = 12

$$M = \frac{12}{2+4} = 2$$

Q.47 Total wt. of NaOH = 30 + 90 = 120
Total vol. of solution = 100 + 100 = 200

$$M = \frac{120}{40} \times \frac{1000}{200} = 15$$

Q.48 H_2SO_4 obtained $= \frac{112}{100} \times 12.5 = 14$ gram $= \frac{14}{98}$ moles

$$H^{+} = \frac{14 \times 2}{98 \times 100} = \frac{2}{700}$$

Q.49 In 100 g
$H_2SO_4 = 20$, $SO_3 = 80$ g
In 50 g
$H_2SO_4 = 10$g, $SO_3 = 40$ g
Mixed with 18 g H_2O

$SO_3 + H_2O \rightarrow H_2SO_4$
40 9g 49 g

Total $H_2SO_4 = 10 + 49 = 59$
Remaining $H_2O = 18 – 9 = 9$ gram

Q.50 $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
284 g $6 \times 18 = 108$ g

$$\text{mass of } P_4O_{10} = \frac{(127-100)}{108} \times 284 = 71 \text{ g}$$

EXERCISE-2

Paragraph for Question Nos. 1 to 2

Sol. **(1)** Volume of gases at STP = 22.4 (mole of $(SO_2 + SO_3)$)

$$= 22.4 \times \text{mole of } FeSO_4 = 22.4 \times \frac{7.6}{152} = 1.12 \text{ lit}$$

(2) $$M_{avg} = \frac{M_{SO_2} + M_{SO_3}}{1+1} = \frac{64+80}{2} = 72$$

Paragraph for Question Nos. 6 to 9

Sol. (1) Gas absorbed by water = NH_3

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

a 3a 2a

2a = 8

a = 4

(3) Only N_2 left

$O_2 = 0$

(4) Alkane + O_2 = 6 mL

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

2 : 4

Paragraph for Question Nos. 10 to 13

Sol. $Cl_2 + ClO_P + NH_3$

a + b + c = 110

1 : 4 : 6

$$Cl_2 = \frac{1}{11}\times 110 = 10 \text{ ml}$$

$$ClO_P = \frac{4}{11}\times 110 = 40 \text{ ml}$$

$$NH_3 = 60 \text{ ml}$$

$$ClO_P + \frac{1}{2}Cl_2 \rightarrow \frac{P}{2}O_2$$

$$40 \qquad 20 \qquad \frac{P}{2}\times 40 = 20P$$

20P + 20 – 40 = 20

20 P = 40

P = 2

(i) ClO_2

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

60–2x – x – 3x = 20

40 = 6x

$$x = \frac{40}{6} = 6.67$$

2x = 6.67 × 2 = 13.3

(iv) Percentage decomposition of

$$NH_3 = \frac{40}{60}\times 100 = 66.67\ \%$$

Q.14 $n = \frac{9.8 \times 1.5}{100 \times 98} \times 2000 = 3$

Q.15 $n_{H+} = 3 \times 2 = 6$

$n_{OH^-} = 3$

H^+ remaining $= 3/5$

Q.16 $x = \frac{20/80}{\frac{20}{80} + \frac{30}{98}} = \frac{0.25}{0.25 + 0.31} = \frac{0.25}{0.56} = 0.45$

Q.17 Mass of H_2O added

= moles of SO_3 in (100g) $\times$ 18

$= 2 \times \frac{20}{80} \times 18 = 4.5 \times 2 = 9$

Labelling = 100 + 9 = 109%

Q.18 During a chemical reaction moles may not e remains constant.

For example : $N_2 + 3H_2 \rightarrow 2\,NH_3$

Q.20 $2\,Fe_2O_3 + 3C \rightarrow 4\,Fe + 3CO_2$

Ratio of Fe_2O_3 and Fe is 2 : 4

1 : 2

Q.21 Let 1 kg of C_2H_5OH and H_2O each taken $= \frac{1000}{46}$

molality of C_2H_5OH is less than H_2O

Q.22 **Statement-I**

Mass of solution

$1000 \times 1.5 = 1500$ g

40% w/w

40 g in 100 g of solution

$400\text{ g} = \frac{100}{40} \times 400 = 1000$ g

Statement-II

Mass of $H_2SO_4 = 2 \times 98 = 196$ g

Mass of MgO $= \frac{40}{100} \times 2000 = 800$ g

Q.24 One mole of CO_2 contains = one mole of carbon

$= 6.02 \times 10^{33}$ atoms of carbon

One mole of CO_2 contains = 2 moles of oxygen atoms

$= 2 \times 6.02 \times 10^{23}$ moles of oxygen atoms

$= 12.04 \times 10^{23}$ atoms of oxygen

Q.25 $PV = \frac{W}{M}RT$

$$M = \frac{WRT}{PV} = \frac{14 \times 0.0821 \times 273}{1 \times 11.2} = 28 \text{ g mol}^{-1}$$

N_2, CO, B_2H_6

Q.26 No. change in vol. means no. of moles remains constant.

Q.27 (a) If limiting reagent is C_3H_8

$C_3H_8 + 5O_2 \rightarrow 3\ CO_2 + 4H_2O$

a 5a 3a

$a + b = 100$

$6a - 3a = 3a$

$3a = 45$

$a = 15$

$b = 85$

(b) If O_2 is limiting reagent

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$\frac{a}{5}$ a $\frac{3}{5}a$

$$\frac{a}{5} + a - \frac{3a}{5} = 45$$

$a = 75$

$b = 25$

Q.28 Convert all the wt. in mole and use limiting reagent concept find out the mole produced of NH_3.

In (A) & (C) it comes equal to 10 moles

Q.29 (i) $C_xH_y + \left(\frac{x+y}{4}\right) O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$$\text{Vol. contraction} = \frac{30}{120} = 25\%$$

(ii) $C_3H_6O_2 + \frac{7}{2}O_2 \rightarrow 3CO_2 + 3H_2O$

10 35 30

$$\text{Vol. contraction} = \frac{15}{60} \times 100 = 25\%$$

Q.30 (A) $\frac{80}{100}\times 50 = 40$ g

(B) $\frac{80}{100\times 1.2}\times 50 = \frac{40}{1.2}$

(C) $\frac{20\times 40}{1000}\times 50 = 40$

(D) $\frac{5}{1000+(40\times 5)}\times 50 = \frac{25}{120}$

Q.31 Molality of $Cl^- = \frac{2\times 1000\times 2}{(1000\times 1.09)-190} = 4.44$

Q.32 (A) $V = 11.2 \times M$

$M = \frac{5.6}{11.2} = 5$

(B) 1000 ml of solution contains 5×34 g of H_2O_2

100 ml of solution contains $= \frac{5\times 34}{1000}\times 100 = 17$

Q.33 Use neutralisation concept

Q.34 % of Y $= \frac{89\times 3}{(89\times 3)+(5\times 27)+(12\times 16)} \times 100$

$= \frac{267\times 100}{594} = 44.95\%$

% Al $= \frac{5\times 27}{594}\times 100 = 22.73$

% O $= \frac{12\times 16}{594}\times 100 = 32.32\%$

Q.35 O-atoms present $= 6 \times \left(\frac{17.6\times 10^{-3}}{176}\right) \times N_A = 3.6 \times 10^{20}$

Moles of vitamin C ($C_6H_8O_6$) in 1 gm $\frac{1}{176} = 5.68 \times 10^{-3}$ moles

Moles of vitamin C in 17.6 milligram (daily does)

$= \frac{1.76\times 10^{-3}}{176} = 10^{-4}$ moles

A – R, B–Q, C–P

Q.36 16 g CH_4 = 1 mole of CH_4 = 5 mole of atoms
$= 5N_A = 6.023 \times 10^{23} \times 5$
= 22.4 lit (At STP)

1 g H_2 = 1/2 mole of H_2 = 1 mole of atoms
$= 6.023 \times 10^{23}$ atoms = 11.2 lit

22 g CO_2 = 1/2 mole of CO_2 = 3/2 mole of atoms
$= 1/2 \times 6.023 \times 10^{23}$ atom
= 11.2 lit (At STP)

9 g H_2O = 1/2 mole H_2O = 3/2 mole of atoms
$= 3/2 \times 60.03 \times 10^{23}$ atoms

Q.37 (A)

N_2	+	$3H_2$	$\rightarrow$	$2NH_3$	
1		1			(mass)
(1/28)		(1/2)			(mole)

Mass of $NH_3 = \left(2 \times \frac{1}{28}\right) \times 17 = 1.214$ g

(B)

$CaCO_3$	$\rightarrow$	CaO	+	CO_2
1g				
10^{-2} mole		10^{-2} mole		10^{-2} mole

mass of CaO = $10^{-2} \times 56 = 0.56$ g

(C)

$2H_2$	+	O_2	$\rightarrow$	$2H_2O$	
1g		1g			
1/2		1/32		2/32	mole

mass of $H_2O = \frac{2}{32} \times 18 = 1.125$ g

(D)

C	+	$2H_2$	$\rightarrow$	CH_4	
1g		1g			
1/12		1/2		1/12	mole

mass of CH_4 = 1.33 g

Q.38 (A) $V = 11.2 \times M$
$20 = 11.2 \times M$
$M = 1.785$

(B) 17.45 g in 100 mL of solution
17.45 g in 117.45 g of solution

$$M = \frac{17.45 \times 1000}{98 \times 100}$$
= 1.78

$$m = \frac{17.45 \times 1000}{98 \times (117.45 - 17.45)}$$

$$m = \frac{17450}{98 \times (100)} = 1.78$$

(C) $m = \frac{1000}{18} = 55.5$

(D) 5 g in 100 g of solution

$$M = \frac{5}{40} \times \frac{1.2 \times 1000}{100} = 1.5$$

Q.39 (A) 10 mole present in 1000 mL of solution
400 g in [1000 × 1.2]
400 g in 1200 g
solvent = 1200 - 400 = 8000\

1200 solution ⇒ 800 g solved
800 solution ⇒ 1200

$$100 \text{ solution} = \frac{1200}{800} \times 100 = 150 \text{ gram}$$

(B) 40 g in 100 mL of solution
40 in 160 g of solution
40 g in 160–40 = 120 g solution

(C) 8 × 100 in 1000 g of solvent
800 g in 1000 g of solvent

$$100\text{g solvent} = \frac{1000}{800} \times 100 = 125$$

(D) Moles of x = 0.6
Moles of y = 0.4
Mass of x = 0.6 × 20 = 12
Mass of y = 0.4 × 25 = 10

12x g ⇒ y ⇒ 10 g
120x g ⇒ y ⇒ = 100 g

Q.40

(A) 20 cm^3 of C_2H_5OH is present in 100 cm^3 of solution.
Vol. of solution = 100 cm^3
Mass of solution = $V_{solution}$ × density of solution
= 100 × 0.96 = 96 g

$V_{solute} = 20\ cm^3$; $V_{H_2O} = 80\ cm^3$; $W_{H_2O} = 80 \times 1$ g
[∴ Density of $H_2O = 1\ g\ cm^{-3}$]
$W_{solute} = 96 - 80 = 16$ g

$$\text{molarity (M)} = \frac{\text{moles of solute}}{\text{Vol. of solution (in litre)}}$$

$$= \frac{16}{46 \times \left(\frac{100}{1000}\right) L} = \frac{16 \times 1000}{46 \times 100} = 3.47 \text{ M } \textbf{Ans.}$$

(B) 5V H_2O_2 solution means 5 litre of O_2 is evolved from 1 litre of H_2O_2 solution

$2H_2O_2 \rightarrow 2H_2O + O_2$

1 L sol. 5 L

$$\text{no. of moles of } O_2 \text{ evolved} = \frac{5}{22.4}$$

$$\text{no. of moles of } H_2O_2 \text{ present} = \frac{5}{22.4} \times 2 = \frac{10}{22.4}$$

$$\text{Molarity of } H_2O_2 = \frac{10}{22.4} = 0.44 \text{ M} \quad \textbf{Ans.}$$

(C) 18 M aq. H_2SO_4 solution means 18 moles of H_2SO_4 in 1 litre of solution.

Wt. of solvent = $W_{solution} - W_{solute}$

$= (V_{solution} \times density_{solution}) - W_{solute}$

$= (1000 \times 1.84) - (18 \times 98)$

$= 1840 - 1764 = 76$ g

$$\text{molarity} = \frac{\text{no. of moles of solute}}{\text{weight of solvent(in kg)}}$$

$$= \frac{18}{76/100} = 236.8\text{M} \quad \textbf{Ans.}$$

(D) 20% aq. H_2SO_4 solution by weight

20 g of H_2SO_4 in 100 g of solution

$$V_{sol.} = \frac{\text{wt. of solution}}{\text{Density of solution}}$$

$$= \frac{100}{1.25} \text{cm}^3$$

$$M = \frac{20 \times 1000}{98 \times \frac{100}{1.25}} = 2.55\text{M} \quad \textbf{Ans.}$$

EXERCISE-3

Q.1 Moles of CO = $\frac{6.023 \times 10^{24}}{6.023 \times 10^{23}} = 10$

gram molecules of O_2 = Moles of O_2 molecules = $\frac{1}{2}$ moles of CO = $\frac{10}{2} = 5$

Q.2 Mole of hydrated Barium chloride = mole of anhydrous salt

$$\frac{1.763}{(137+18x)} = \frac{1.505}{137}$$

$x = 2$

Q.3 Let $^{17}O = x_1$

$^{18}O = x_2$

$x_1 + x_2 = 10$

$x_1 = 10 - x_2$

$$16.12 = \frac{(90\times16)+17(10-x_2)+18x_2}{100}$$

$x_2 = 2$

$x_1 = 8$

% of $x_1 = 8\%$

% of $x_2 = 2\%$

Q.4 $1.44\ Ti + O_2 \rightarrow Ti_{1.44}O$

Moles of Ti $= \frac{1.44}{48} = 0.03$ [Atomic mass of Ti = 48]

Moles of $Ti_{1.44}O$ produced $= \frac{1}{1.44} \times 0.03$

Mass of $Ti_{1.44}O = \frac{0.03}{1.44} \times 85.12$ [Molecular mass of $Ti_{1.44}O = 85.12$]

$= 1.77$ g

Q.5 $4HCl + MnO_2 \rightarrow MnCl_2 + 2H_2O + Cl_2,$

Grams of HCl required $= \frac{4\times36.5}{87} \times 69.6 = 116.8$ g

Q.6 Moles of F_2 required $= \frac{3}{352} \times 2 \times 10^{-3} = 17 \times 10^{-6}$ moles

No. of F_2 molecules $= 17 \times 10^{-6} \times 6.023 \times 10^{23} = 102.391 \times 10^{17} \approx 1 \times 10^{19}$

Q.7 Mol wt. of $NH_4NO_3 = 80\ g\ mol^{-1}$

Moles of $NH_4NO_3 = \frac{16}{80} = 0.2$

Total moles produced $= \frac{7}{2} \times 0.2 = 0.7$

$PV = nRT$

$$V = \frac{nRT}{P} = \frac{0.7 \times 0.0821 \times 873}{1} = 50.14 \text{ litre}$$

Q.8 $2H_3PO_4 \rightarrow H_4P_2O_7 + H_2O$

gram mol. wt. of $H_3PO_4 = 98 \text{ g mol}^{-1}$

gram mol. wt. of $H_4P_2O_7 = 178 \text{ g mol}^{-1}$

$$\text{Mass of phosphoric acid} = \frac{2 \times 98}{178} \times 53.4 = 58.8 \text{ gram}$$

Q.9 $$\text{Mole of } H_2O(l) = \frac{(40 \times 0.9)g}{18} = 2 \text{ moles}$$

$$\text{Moles of } SO_3(g) = \frac{50}{22.4} \times \frac{273}{300} = 2.03 \text{ mole}$$

L.R. is H_2O & corresponding moles of H_2SO_4 is 2

Mass of $H_2SO_4 = 2 \times 98 = 196$ g

Q.10 Volume of water proof fabric $= 1 \times 3 \times (300 \times 6 \times 10^{-10})\ m^3$

$v = 0.54\ cm^3$

mass of v.d. $= 0.54 \times 1 = 0.54$ g

$$\text{mass of } (CH_3)_2 SiCl_2 = \frac{0.54}{M_{[(CH_2)_2 SiO]_n}}\ n \times M_{(CH_3)_2 SiCl_2}$$

$$= \frac{0.54 \times n \times 129}{n \times 74} = 0.9413 \text{ g}$$

Q.11 $$\text{Moles of C} = \frac{5.76}{12} = 0.48$$

$$\text{Moles of } Cl_2 = \frac{6.82}{71} = 0.096$$

Cl_2 is limiting reagent

$$\text{Moles of } TiCl_4 \text{ produced} = \frac{1}{2} \times 0.096 = 0.048$$

Grams of $TiCl_4$ formed $= 0.048 \times 190 = 9.12$ g

Q.12 BF_3 is limiting reagent

$$\text{Moles of } B_2H_6 \text{ produced} = \frac{1}{8} \times 2 = 0.25$$

Q.13 To ensure at least one gram each, the minimum amount produced of the P_4O_{10} & SO_2 should be one gram

$P_4S_3 + 8O_2$		$\rightarrow$	$P_4O_{10} + 3SO_2$		
1	8		1	3	(mole)
220	256		284	192	(mass in g)

so amount of $P_4S_3 = \frac{220}{192} = 1.1458$ g

Q.14 $Al + 3\,HCl \rightarrow AlCl_3 + 3/2\,H_2$
$Mg + 2HCl \rightarrow MgCl_2 + H_2$
Let Al = x g,
$\therefore$ Mg = 39 – x

Total moles of H_2 produced $= \frac{3x}{2 \times 27} + \frac{39 - x}{24}$

Total no. of moles of H_2 given $= \frac{PV}{RT} = \frac{1 \times 44.8}{0.0821 \times 273} = 2$

$$\frac{3x}{54} + \frac{39 - x}{24} = 2$$

or x = 27g (wt of Al)

Moles of Al $= \frac{27}{27} = 1$

wt. of Mg = 39 – 27 = 12 g

Moles of Mg $= \frac{12}{24} = 0.5$

% Moles of Al $= \frac{1}{1.5} \times 100 = 66.6\%$

Q.15 Let wt. of mix = 100 g
Let wt. $CaCO_3$ = x g
$\therefore$ wt. of $MgCO_3 = (100 - x)$ g
$CaCO_3 \rightarrow CaO + CO_2$

wt. of CaO produced $= \frac{56}{100} \times x$

$MgCO_3 \rightarrow MgO$

wt. of MgO produced $= \frac{40}{84} \times (100 - x)$

Total mass of oxides $= \frac{56x}{100} + \frac{40}{84}(100 - x) = 50$ [Half of mixture]

x = 28.4 %
y = 71.6 %

Q.16 Anhydrous sodium carbonate + sodium bicarbonate

	Na_2CO_3	+	$NaHCO_3$	
(Mole)	x		y	
(Mass)	106x	+	84 y = 2	.... (1)

On heating

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

(mole) y y/2 y/2 y/2

$$\text{Loss of weight} = \frac{y}{2}\left(M_{H_2O} + M_{CO_2}\right)$$

$$= 31\ y = 0.11 \qquad \text{.................(2)}$$

mole of $NaHCO_3$ = $y = 3.55 \times 10^{-3}$ moles

Mass of $NaHCO_3$ = 0.298 g

% of $NaHCO_3$ = 14.9 %

% of Na_2CO_3 = (100–14.9) = 85.1 %

Q.17 $CaCl_2 \rightarrow CaCO_3 \rightarrow CaO$

Moles of $CaCl_2$ = moles $CaCO_3$ = moles of CaO = moles of Ca

$$\frac{\text{mass of } CaCl_2}{\text{Molecular mass of } CaCl_2} = \frac{\text{mass of CaO}}{\text{Molecular mass of CaO}}$$

$$\text{Mass of } CaCl_2 = \frac{111 \times 0.959}{56} = 1.9\text{ g}$$

$$\text{Mass \% of } CaCl_2 = \frac{1.9 \times 100}{4.22} = 45\%$$

Q.18 474 tons coal will contain $S = \frac{1.3}{100} \times 474$ tons

$$= \frac{1.3 \times 474}{100} \times 10^6\ \text{g}$$

$$\text{moles of S} = \frac{1.3 \times 474}{100 \times 32} \times 10^6$$

1 moles 1 mole

$S + O_2 \rightarrow SO_2$

Moles of SO_2 = mole of S

$$\text{Moles of } SO_2 = \frac{1.3 \times 474}{100 \times 32} \times 64 \times 10^6\ \text{g} = 12.3\text{ tons}$$

Q.19 $KClO_3(s) \rightarrow KCl(s) + 3/2\ O_2\ (g)$

1 mole (122.5 g) 3/2 mole (48g)

$$\%\ \text{loss} = \frac{48}{122.5} \times 100 = 39\%$$

Q.20 Moles of cyclohexene = moles of ($C_6H_{12}O$) × (% Yield)

$$= \frac{100}{100} \times \frac{75}{100} = 0.75 \text{ mole}$$

mass of $C_6H_{10} = 0.75 \times 82 = 61.5$ g

Q.21

	2NaCl	→	Na_2SO_4
Moles	$\frac{250 \times 0.95}{58.5} = 4.06$		$\left(\frac{4.06}{2}\right)$

moles of impure Na_2SO_4 (90%) $= \frac{4.06 \times 142}{2 \times 0.90} = 320.3$ g

Q.22 (i) $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$

(ii) For maximum energy, ratio of moles of Fe_2O_3 and Al should be

1 : 2

By mass 160 : 54

80 : 27

(iii) Limiting reagent is Al

54 gram of Al produces 200 unit energy

2700 gram of Al produce $\frac{200}{50} \times 2700 = 10000$ Units

Q.23 2 × 119.5 g of $CHCl_3$ required = 58 × 2 g of $CH_3\,COCH_3$

30 g of $CHCl_3$ required $= \frac{58 \times 2}{2 \times 119.5} \times 30 \times \frac{100}{75}$ (% yield is 75)

$= 19.4$ g

Q.24

$$\overset{1}{N_2} + \overset{3}{3H_2} \rightleftharpoons 2NH_3$$

$1-\alpha \qquad 3(1-\alpha) \qquad 2\alpha$

Total moles $= 4-2\alpha$

$$P = \frac{dRT}{M_{Avg}} \Rightarrow M_{Avg} = \frac{dRT}{P} = \frac{0.497 \times 0.0821 \times 298}{1} = 12.15$$

$$M_{Avg} = \frac{\text{Total mass}}{\text{Total mole}}$$

$$12.15 = \frac{1 \times 28 + 3 \times 2}{4 - 2\alpha}$$

$4 - 2\alpha = 2.8$

$\alpha = 0.6$

$$\% N_2 = \left(\frac{1-\alpha}{4-2\alpha}\right) \times 100 = 14.28\%$$

$$\% H_2 = \frac{3(1-\alpha)}{4-2\alpha} \times 100 = 42.86\%$$

$$\% NH_3 = \frac{2\alpha}{4-2\alpha} \times 100 = 42.86\ \%$$

Q.25 Moles of PbS = $\frac{1146}{239}$ = moles of SO_2 = moles of H_2SO_4

mass of H_2SO_4 = $\frac{1146}{239} \times 98 = 470$ g

Q.26 (a) 32×3 g of O_2 produced by 71×4 g of KO_2

20 g of O_2 produced by = $\frac{71 \times 4}{32 \times 3} \times 20 = 59.17$

(b) $4\ KO_2 = 4\ CO_2$

71×4 g = 4×44 g

100 g = $\frac{4 \times 44}{71 \times 4} \times 100 = 61.97$ g

Q.27 Mol. wt of Base = $\frac{n}{2}\left[\frac{w \times 195}{x} - 410\right] = \frac{1}{2}\left[\frac{0.8 \times 195 - 410}{0.262}\right] = 92.70$

Q.28

Hg	+	I_2	$\rightarrow$	HgI_2
x		x		x
2Hg	+	I_2	$\rightarrow$	Hg_2I_2
2y		y		y

x & y are moles

Total wt. of Hg = $(x + 2y) \times 200$

Total wt. of $I_2 = (x + y) \times 254$

$(x + 2y) \times 200 = (x + y) \times 254$

$1 + 2y/x = (1 + y/x) \times 254/200$

$1 + 2y/x = 1.27 + 1.27\ (y/x)$

$0.73\ y/x = 0.27$

$y / x = 0.37$

Mass ratio of $\frac{Hg_2I_2}{HgI_2} = \frac{654}{454} \times 0.37 = 0.532$

Q.29 (i)

$$P_4 + 3O_2 \rightarrow P_4O_6$$
$$x \quad\quad 3x \quad\quad x$$

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$
$$y \quad\quad 5y \quad\quad y$$

$x + y = 1;\ 3x + 5y = 4$
$y = 0.5$
$x = 0.5$
$P_4O_6 : P_4O_{10} = 0.5 : 0.5$

(ii) $x + y = 3$
$3x + 5y = 11$
$y = 1$
$x = 2$

$P_4O_6 : P_4O_{10} = 2 : 1$

(iii) $x + y = 3$
$3x + 5y = 13$
$y = 2$
$x = 1$

$P_4O_6 : P_4O_{10} = 1:2$

Q.30 Mole of $O_2 = \frac{112}{22400} = 5 \times 10^{-3}$

Corresponding mole of $KClO_3 = \frac{2}{3} \times 5 \times 10^{-3}$

$= 3.33 \times 10^{-3}$

Mole of $KClO_3$ used for $KClO_4$

$$= \left(\frac{1}{122.5} - 3.33\times10^{-3}\right)$$

$= 4.83 \times 10^{-3}$

Mole of $KClO_4 = \frac{3}{4} \times 4.83 \times 10^{-3} = 3.6225 \times 10^{-3}$

Mass of $KClO_4 = 138.5 \times 3.6225 \times 10^{-3} = 0.5$ g

Mass lost = Mass of O_2

$= 5 \times 10^{-3} \times 32 = 0.16$ g

Mass of residue = $1 - 0.16 = 0.84$ g

% of $KCO_4 = \frac{0.5}{0.84} \times 100 = 59.7\%$

Q.31 $O_2 = 80$
$O_3 = 20$
$2O_3 \rightarrow 3O_2$
20 30
Increase in vol. = 110 – 100 = 10

Q.32 $N_2O + H_2 \rightarrow N_2 + H_2O$
a a

$2NO + H_2 \rightarrow \frac{1}{2} N_2 + H_2O$

b $\frac{b}{2}$

$a + \frac{b}{2} = 38$
$a + b = 60$
$a = 16, b = 44$

Q.33 $C_2H_2 + CO$
$a + b = 20$ ....(1)

$C_2H_2 + \frac{5}{2}O_2 \rightarrow 2\ CO_2 + H_2O$

a $\frac{5}{2}a$ 2a

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

b b/2 b

$\frac{5a}{2} + \frac{b}{2} = 30 - 8 - 22$ ....(2)

$a = b, b = 14$

Q.34 $CH_4 + C_2H_4 + CO_2$
$a + b + c = 10$ ....(1)
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
a 2a a

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
b 3b 2b

$a + 2b + c = 14$ ....(2)
$2a + 2b = 17$ ....(3)
$a = 4.5, b = 4$
$c = 1.5$

Q.35 $C_2H_2 + CO$

$a + b = 40$ ....(1)

$$C_2H_2 + \frac{5}{2}O_2 \rightarrow 2CO_2 + H_2O$$

$$a \qquad \frac{5}{2}a \qquad 2a$$

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

$$b \qquad \frac{b}{2} \qquad b$$

$$2a + b + 100 - \frac{5a}{2} - \frac{b}{2} = 104$$

$4a + 2b + 2CO - 5a - b = 208$

$a = 16$

$b = 24$

Q.36 $CO_2 = 3$

$H_2O = 4$

$C = 3$

$H = 8$

$C_nH_{2n+2} \leftrightarrow C_xH_{2x}$

$CH_4 \qquad C_2H_4$

$CH_4 + C_2H_4 = 2$ mole

Moles of $O_2 = 10 - 2 = 8$

Q.37 (a) $H_2 + C_4H_8$

$a \qquad b$

O_2 used $= 80 - 16 = 64$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O(l)$$

$$a \qquad \frac{a}{2} \qquad a$$

$C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O\ (l)$

$b \qquad 2b \qquad 4b$

$4b = 32$

$b = 8$ ....(1)

$\frac{a}{2} + 6b = 64$ ....(2)

$a = 32$
$b = 8$
$a + b = 32 + 8 = 40$ ml

(b) $\frac{8}{40} \times 100 = 20\%$

(c) $40 + 64 - 32 = 72$ ml

Q.38 $C_2H_4 + CH_4 + CO + N_2$
a + b + c + d

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
a 3b 2a 2a

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

$CO + \frac{1}{2}O_2 \rightarrow CO_2$
c c/2 c

$2a + b + c = 0.9$ ....(1)
$2a + 2b = 0.8$ ....(2)

$a = b$ ....(3)
$a = 0.2$
$b = 0.2$
$c = 0.3$
$d = 1 - 0.2 - 0.2 - 0.2 = 0.3$

Q.39 $N_x H_y \rightarrow$ $x/2\, N_2$ + $y/2\, H_2$
10 5x 5y
$5x + 5y = 20$ ....(i)
$H_2 + 1/2\, O_2 \rightarrow H_2O$
$5y$ $\frac{5y}{2}$ $5y$

Vol. left $= 275 = 30 - \frac{5y}{2} + 5x$ ....(ii)

$x = 1, y = 3$

Q.40 $M = \frac{40}{36.5} \times \frac{1.2}{100} \times 1000 = \frac{40 \times 120}{365} = 13.15$

Q.41 $W_{CH_3OH} = 15g$

$W_{so\ln} = 100 \times 0.9 = 90$
$W_{solvent} = 90 - 15 = 75$

% of solute $= \frac{15}{90} \times 100 = \frac{100}{6} = \frac{50}{3} = 16.67$

Q.42 30 g of solute in 100 g of solution
6.9 mole of KOH ⇒ 1000 mL of solution
6.9×56 g ⇒ 1000 mL of solution

$30 \text{ g} = \frac{1000}{6.9 \times 56} \times 6.9 \times 56$

$= 23 \times 56 \times 10^{-3} \qquad = 1.288 \text{ g ml}^{-1}$

Q.43 $M_1 = \frac{3}{21} = \frac{1}{7} = 0.12$

$M_2 = \frac{4}{21} = 0.19$

Avg. $= \left(\frac{M_1 + M_2}{2}\right) = 0.15$

Q.44

$BaCl_2$	$\rightarrow$	Ba^{+2}	+	$2Cl^-$
1M		1 M		2M

$M_{Cl^-} = \frac{2 \times 10.56 \times 1000}{(137 + 71 + 144) \times 1000} = \frac{21.12}{352} = 0.06$

Q.45 0.2 mole solute $= 0.2 \times 60 = 12$ g
0.8 mole solvent $= 0.8 \times 18 = 14.4$

Mass percentage $= \frac{12}{12 + 14.4} \times 100$

$= 45.45$ %

Q.46 $M = \frac{500}{162} \times \frac{1 \times 10^3}{10^6} = 3 \times 10^{-3}$

Q.47 M of NaCl = 0.646

M of $BaCl_2 = \frac{0.646}{2}$

Wt of $BaCl_2 = 16.8$ g

Q.48 2M = 2

$M = \frac{2 \times 1000}{1000 \times 3.107 - 2(53.5)} = \frac{2000}{3107.0 - 107} = \frac{2000}{3000} = \frac{2}{3} = 0.667$

Q.49 $M_1V_1 = M_2V_2$

$\frac{98\times1.8}{98\times100}\times1000\ V = 2.5 \times 12.5$

$1 \times 18 \times V = 2.5 \times 12.5$

$V = 1.736$

Q.50 $M_1V_1 + M_2V_2 = MV$

$500 \times 2 + 2 \times 200 = M\ (700)$

$1000 + 400 = M\ (700)$

$\frac{1400}{700} = M$

$M= 2$

Q.51 $V = \frac{40}{16} = 2.5$

Vol added $= 2.5 - 1 = 1.5$

$40 \times 10 = 16 \times V$

$V = 2.5$

Vol. of water added $= 2.5 - 1 = 1.5$

Q.52 $n_{urea} = 0.2$

mass of urea $= 0.2 \times 60 = 12$

$n_{H_2O} = 0.8$

mass of H_2O $= .8 \times 18 = 14.4$ g

Total mass of solution $= 26.4$

26.4 g solution $\Rightarrow$ urea $= 12$

500 g solution $= \frac{12}{26.4} \times 500$

$= 227.27$ g urea

water $= 500 - 227.27 = 272.73$

Total water $= 1000 + 272.73 = 1272.73$

mole fraciton of solute $= \frac{227.27/60}{\frac{227.27}{60}+\frac{1272.73}{18}} = \frac{3.8}{3.8+70.7} = \frac{3.8}{74.5} = 0.05$

Q.53 Molarity of Cl^- in $AlCl_3 = 2.4$

Molarity of Cl^- in $CaCl_2 = 0.2 \times 2 = 0.4$

$(2.4 \times V) + (0.4 \times 50) = 0.6 \times (50 + V)$

$(2.4\ V + 20) = 0.6\ (50 + V)$

$2.4\ V + 20 = 30 + 0.6\ V$

$1.8\ V = 10$

$V = \frac{10}{1.8} = 5.56$

Q.54 $M_1V_1 = M_2V_2$

$M_1 \times 300 = 2 \times 3 \times 20$

$M_1 = \frac{120}{300} = 0.4$

$(V \times 0.2) + (500 \times 0.5) = 0.4 \times (500 + V)$

$0.2V + 250 = 200 + 0.4\ V$

$50 = 0.2\ V$

$V = 250$ mL

Q.55 118% Oleum means 100g g Oleum + 18 g H_2O

Frce $SO_3 \Rightarrow 80$ g

(i) Mass of $H_2SO_4 = 100–80 = 20$

(ii) $100\text{ g} \Rightarrow 118$

$30\text{ g} \Rightarrow \frac{118}{100} \times 30 = 35.4$

(iii) In $100\text{ g} \Rightarrow SO_3$ is 80 gram

$30\text{ g} \Rightarrow \frac{80}{100} \times 30 = 24$ gram

$H_2SO_4 = 30 - 24 = 6$ gram

$H_2O + SO_3 \rightarrow H_2SO_4$

$\frac{24}{80}$

0.3 0.3 0.3

$H_2SO_4 \Rightarrow 6 + [98 \times 0.3] = 35.4$

$H_2O = 40\ [0.3 \times 18]$

$= 40 - 5.4$

$= 34.6$ g

Q.56 $H_2O_2 \rightarrow H_2O + 1/2\ O_2$

2 mole 2 mole

$M = \frac{2}{500} \times 1000 = 4$

$V = 11.2 \times 4 = 44.8$

Q.57 Molecular mass of $Al_2(SO_4)_3$

$= 342$

Molecular mass of $Al(NO_3)_3 = 213$

Molecular mass of $CaCO_4 = 136$

Moles of $Al(NO_3)_3$ produced $= 1/213$

Moles of $Al_2(SO_4)_3$ required $= \frac{1}{213 \times 2}$

Moles of $CaSO_4 = \frac{1}{136}$

Moles of $Al_2(SO_4)_3 = \frac{1}{3} \times \frac{1}{136}$

Vol. required is more for $CaSO_4$, So

$$0.1 = \frac{1}{3 \times 136} \times \frac{1000}{V}$$

$$V = \frac{1000}{3 \times 136 \times 0.1} = 24.5$$

Q.58 $2KOH + H_2SO_4 \rightarrow K_2SO_4$

200 millimoles (KOH), 100 millimoles (H_2SO_4)

(a) KOH moles of required = 200×10^{-3}
= 0.2

(b) Moles of $KMnO_4$ used

$$= \frac{2}{3} \times \frac{6.74}{22.4} \times \frac{100}{50} = 0.4 \text{ mole}$$

(c) In first reaction moles of $H_2O_2 = \frac{1}{2} \times 0.2 \times \frac{100}{40}$

= 0.25

In second reaction moles of $H_2O_2 = \frac{1}{2} \times 0.4 = 0.2$

Total moles of H_2O_2 used $= 0.25 + 0.2 = 0.45$

(d) Moles of H_2O_2 = 0.45

$$M = \frac{0.45}{100} \times 1000 = 4.5$$

$V = 11.2 \times 4.5 = 50.4$

Q.59 $[H^+]$ = $[CH_3OH]$ dissociated

Moles of CH_3OH

dissociated = 2.5×10^{-4}

$$\% \text{ dissociation} = \frac{2.5 \times 10^{-4}}{0.5} \times 100 = 5 \times 10^{-2} = 0.05$$

Q.60 (a) $0.0125 = \frac{W \times 1000}{106 \times 250}$

W = 0.0331 g

(b) $$\frac{0.331/106}{\frac{0.0331}{106} + \frac{250}{18}} = 2.25 \times 10^{-4}$$

(c) $m = \frac{13.5}{32} \times \frac{1000}{150}$

$= 2.81$

(d) $x = \frac{\frac{13.5}{32}}{\frac{13.5}{32} + \frac{150}{18}} = \frac{0.422}{0.422 + 8.33}$

$= \frac{0.422}{8.752} = 0.0482$

(e) $n_{KNO_3} = 0.0934$

$nH_2O = 1 - 0.0934 = 0.9066$

wt. of $KNO_3 = \frac{0.0934 \times 101}{0.9066 \times 18} \times 555 = 321$ g

(f) $m = \frac{0.0934 \times 1000}{0.9066 \times 10}$

$= 5.72$

EXERCISE-4

Q.1 No. of moles (A) $\frac{24}{12} = 12$ (B) $\frac{56}{56} = 1$

(C) $\frac{27}{27} = 1$ (D) $\frac{108}{108} = 1$

Q.2 $M = \frac{1000}{18} = 55.5$

Q.3 Millimoles of CH_3COOH
Adsorbed on charcoal
$= 50 - 49 = 01$
$= 6.023 \times 10^{20}$ molecules

Surface area absorbed by each molecule $= \frac{3.01 \times 10^2}{6.023 \times 10^2} = 0.5 \times 10^{-18} = 5 \times 10^{-19}$

Q.4 $6\ CaO + P_4O_{10} \rightarrow 2\ Ca_3\ (PO_4)_2$

Moles of $P_4O_{10} = \frac{852}{284} = 3$

Moles of CaO $= \frac{6}{1} \times 3 = 18g$

Mass of CaO = 18 × 56 = 1008 g

Q.5 No. of sites $\frac{6.023}{1} \times 10^{14} \times 1000 = 6.023 \times 10^{17}$

Only 20% sites used = $\frac{20}{100} \times 6.023 \times 10^{17} = 120.46 \times 10^{15}$

$$n = \frac{PV}{RT} = \frac{0.001 \times 2.46}{1000 \times 0.0821 \times 298} = 10^{-7}$$

Molecules = 6.023×10^{16}

$$\frac{120.46 \times 10^{15}}{6.023 \times 10^{16}} \Rightarrow \frac{12.046 \times 10^{16}}{6 \times 10^{16}} = \mathbf{2}$$

Q.6 $M = \frac{120 \times 1.15}{60 \times 1120} \times 1000 = 2.05$

Q.7 Millimoles of $Cl^- = 0.01 \times 30 \times 2 = 0.6$
Millimoles of $AgNO_3 = 0.6$

$$0.1 = \frac{0.6}{V} \Rightarrow V = \frac{0.6}{0.1} = 6 \text{ ml}$$

Q.8 $CoCl_3.6NH_3 \longrightarrow x\,Cl^- \xrightarrow{AgNO_3} x\,AgCl^-$
$n(AgCl) = x \times n\,(CoCl_3.6NH_3)$

$\frac{4.78}{143.5} = x \times \frac{2.675}{267.5}$ $\quad \therefore x = 3 \Rightarrow$ complex is $[Co(NH_3)_6]Cl_3$

Q.9 Moles of HCl reacting with Ammonia
= moles of HCl absorbed – moles of NaOH solution required
= $20 \times 0.1 \times 10^{-3} - (15 \times 0.1 \times 10^{-3})$ = moles of NH_3 evolved
= moles of 'N' in organic compound.
$\therefore$ wt of nitrogen in organic compound = $0.5 \times 10^{-3} \times 14 = 7 \times 10^{-3}$ gm

$$\% \text{ wt} = \frac{7 \times 10^{-3}}{29.5 \times 10^{-3}} = 23.7\ \%$$

Q.10 Moles fraction of solute (x_2) in aq solution = $\frac{m}{m + \frac{1000}{18}} = \frac{5.2}{5.2 + \frac{1000}{18}} \simeq 0.086$

Q.11 0.5 M HCl   HCl 2 M
750 ml   250 ml

$$M = \frac{0.5 \times 750 + 2 \times 250}{1000} = 0.875 \text{ M}$$

Q.12 $C_xH_y + O_2 \longrightarrow 7CO_2 + 4H_2O$
C_7H_8 3.08 g   0.72 g
0.07 mole   0.04 mole