JEE Companion

For JEE MAINS and ADVANCED

CHEMISTRY

Mole Concept

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1

MOLE CONCEPT

1. SIGNIFICANT FIGURES

Significant figures are equal to the number of digits in numbers with last digit uncertain and rest all are certain digits i.e. all the digits of datum including the uncertain one, are called significant figures.

Rules for determination significant figure :

(i) All non zero digits are significant.
Example : 3.14 has three significant figures

(ii) The zeros to the right of the decimal point are significant.
Example : 3.0 has two significant figures.

(iii) The zeros to the left of the first non zero digit in a number are not significant.
Example : 0.02 has one significant figure.

(iv) The zeros between two non zero digits are also significant.
Example : 6.01 has three significant figures.

(v) **Exponential form :** $N \times 10^n$. Where N show the significant figure.
Example : 1.86×10^4 has three significant figure.

2. ROUNDING OFF THE UNCERTAIN DIGIT

(a) If the left most digit to be rounded off is more than 5, the preceding number is increased by one.
Example : 2.16 is rounded to 2.2

(b) If the left most digit to be rounded off is less than 5 , the preceding number is retained.
Example : 2.14 is rounded off to 2.1

(c) If the left most digit to be rounded off is equal to 5 , the preceding number is not changed if it is even and increased by one if it is odd.
Example : 3.25 is rounded off to 3.2
2.35 is round off to 2.4

3. CLASSIFICATION OF MATTER

MATTER
- Homogenous (Composition uniform)
  - Elements (only one type of atoms)
  - Compounds
    * only one type of molecules
    * Different type of atoms but composition is uniform
- Heterogeneous (Composition nonuniform)
  - Mixture
    *Different type molecules of composition of them is not fixed and can be sometimes separated

Physical Classification :

It is based on physical state under ordinary conditions of temperature and pressure, matter is classified into the following three types :
(a) Solid
(b) Liquid
(c) Gas

(a) Solid :
A substance is said to be solid if it possesses a definite volume and a definite shape
e.g. sugar, iron, gold, wood etc.

(b) Liquid :
A substance is said to be liquid if it possesses a definite volume but not definite shape. They take up the shape of the vessel in which they are put.
e.g. water, milk, oil, mercury, alcohol etc.

(c) Gas :
A substance is said to be gas if it neither possesses a definite volume nor a definite shape. This is because they fill up the whole vessel in which they are put.
e.g. hydrogen(H_2), oxygen(O_2), carbon dioxide(CO_2), etc.'

Chemical Classification :

- 2 Types
  (A) Pure Substance
  (B) Mixture

(A) Pure Substance :

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

e.g. :

Element = Na, Mg, Ca…..... etc.

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

- 2 types

(a) Element

(b) Compound

(a) Element : The pure substance containing only one kind of atoms. **3 types (**depend on physical and chemical property)

(a′) Metal

(b′) Non-metal

(c′) Metalloids

(b) Compound :

It is defined as pure substance containing more than one kind of atoms which are combined together in a fixed ratio by weight and which can be decomposed into simpler substance by the suitable chemical method. The properties of a compound are differnt from those of its components.

e.g. : H_2O, HCl, HNO_3 .... etc.

2:16

1:8 **by wt.**

(B) Mixture :

A material which contain more than one type of substances and which is mixed any ratio by wt.is called as mixture.

u The property of the mixture is the property of its components

u The mixture is seperated by simple physical method.

Types of Mixture

2.1 Heterogenous mixture

A mixture in which the different constituents are not distributed uniformly is known as heterogenous mixture.

e.g. : Water + Sand, Water + Oil,

2.2 Homogenous mixture

A mixture in which the different constituents are uniformly distributed is known as homogenous mixture.

eg. $O_2 + N_2$, Water + Salt, Water + Sugar, Water + alcohol, etc.

Dalton's Atomic Theory :

1. Matter is made up of very small undivisible particle called atoms.

2. All the atoms of a given element is identical in all respect i.e. mass, shape, size, etc.

3. Atoms cannot be created nor destroyed by any chemical process.

4. Atoms of different elements are different in nature.

4. LAWS OF CHEMICAL COMBINATION

4.1 Law of conservation of mass-[Lavoisier, 1744]

(a) According to this law , matter is neither created nor destroyed in the course of chemical reaction although it may change from one form to other

(b) This law contradicts nuclear reactions where Einstein equation is applicable

(c) According to this law , sum of the masses of product formed is always equal to the sum of the masses of the reactant undergone change

Example : $H_2 + Cl_2 \rightarrow 2HCl$

$\underbrace{2gm \quad 71\ gm} \quad 2\,[1 + 35.5]$

$\Rightarrow$ 73 gm ≡ 73 gm

4.2 Law of definite proportion [Proust, 1799]

(a) According to the law, the composition of a compound always remains a constant i.e. the ratio of weights of different elements in a compound ; no matter by whatever method , it is prepared or obtained from different sources, remains always a constant

Example :

In H_2O ratio of weight = 1 : 8

In CO_2 ratio of weight = 3 : 8

4.3 Law of multiple proportion [John Dalton, 1804]

According to this law, when two elements A and B combine to form more than one chemical compound then different weights of A , which combine with a fixed weight of B, are in a proportion of simple whole number

Example : CO & CO_2

12 : 16 & 12 : 32

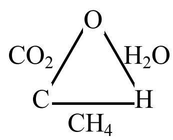
ratio = 16 : 32

= 1 : 2

4.4 Law of reciprocal proportions
[Ritcher, 1792-94]

When two elements combines separately with third element and form different types of molecules, their combining ratio is directly reciprocated if they combine directly

Example :



C with H form methane and with O form CO_2. In CH_4, 12 grams of C reacts with 4 grams of H whereas in CO_2 12 gram of C reacts with 32 grams of O. Therefore when H combines with O they should combine in the ratio of 4 : 32 (i.e. = 1 : 8) or in simple multiple of it. The same is found to be true in H_2O molecule. The ratio of weights of H and O in Water is 1 : 8

4.5 Gay-Lussac's [1808] law of combining volumes :

This law states that under similar conditions of pressure and temperature, volume ratio of gases is always in terms of simple integers.

Ex.

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

vol. ratio 1 : 3 : 2

5. AVOGADRO'S HYPOTHESIS

According to this under similar conditions of pressure and temperature , equal volumes of gases contain equal number of molecules.

5.1 Salient features of Avogadro's hypothesis

(1) It has removed the anomaly between Dalton's atomic theory and Gay Lussac's law of volume by making a clear distinction in between atoms and molecules.

(2) It reveals that common elementary gases like hydrogen , nitrogen , oxygen etc. are diatomic.

(3) It provides a method to determine the atomic weights of gaseous elements.

(4) It provides a relationship between vapour density and molecular weight of substances

Vapour density =

$$\frac{\text{Volume of definite amount of Gas}}{\text{Volume of same amount of Hydrogen}}$$

or Vapour density =

$$\frac{\text{Weight of n molecules of Gas}}{\text{Weight of n molecules of Hydrogen}}$$

or Vapour density =

$$\frac{\text{Weight of one molecule of Gas}}{\text{Weight of one atom of hydrogen} \times 2}$$

or Vapour density = $\frac{\text{Molecular weight}}{2}$

(5) It helps to determine molar volume

Molecular weight of the gas

= 2 × vapour density

$= 2 \times \frac{\text{Weight of 1 litre of the Gas at S.T.P}}{\text{Weight of 1 litre of Hydrogen at S.T.P}}$

$= 2 \times \frac{\text{Weight of 1 litre of the Gas at S.T.P}}{0.089 \text{ gm}}$

$= \frac{2}{0.089} \times$ Weight of 1 litre of the gas at S.T.P.

= 22.4 × Weight of 1 litre of gas at S.T.P.

= Weight of 22.4 litre of the gas at S.T.P

Example-1

How many years it would take to spend Avogadro's number of rupees at the rate of 10 lac rupees per second?

Solution :

Total rupees to be expanded = 6.023×10^{23}

Rupees spent per second = 10^6

Rupees spent per year = $10^6 \times 60 \times 60 \times 24 \times 365$

$\because$ $10^6 \times 60 \times 60 \times 24 \times 365$ Rupees are spent in 1 year

$\therefore$ 6.023×10^{23} " " $= \frac{6.023 \times 10^{23}}{10^6 \times 60 \times 60 \times 24 \times 365}$

= **1.9099×10^{10} year**

6. DENSITY

- **Density :**
  (a) Absolute density
  (b) Relative density

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

Relative density = $\frac{\text{density of substance}}{\text{density of standard substance}}$

Specific gravity = $\frac{\text{density of substance}}{\text{density of } H_2O \text{ at } 4°C}$

Vapour density : It is defined only for gas.

It is a density of gas with respect to H_2 gas at same temp & press

$$V.D = \frac{d\,gas}{d\,H_2} = \frac{PM_{gas}/RT}{PM_{H_2}/RT} = \frac{M_{gas}}{M_{H_2}} = \frac{M}{2}$$

$$V.D = \frac{M}{2}$$

$$V.D = \frac{\text{Molecular wt of gas}}{\text{Molecular wt of } H_2 \text{ gas}}$$

- Density of Cl_2 gas with respect to O_2 gas
$$= \frac{\text{Molecular wt of } Cl_2 \text{ gas}}{\text{Molecular wt of } O_2 \text{ gas}}$$

7. ATOM, MOLECULES

Atom : It is the smallest particle of an element that takes part in a chemical reaction and not capable of independent existence.

Molecule : It is the smallest particle of matter which is capable of independent existence. A molecule is generally an assembly of two or more tightly bonded atoms.

Homoatomic molecules : Molecules of an element contain one type of atoms. eg. O_2, Cl_2 etc.

Heteroatomic molecules : Molecules of compounds contain more that one type of atom.
eg. H_2O, HCl etc

7.1 Atomic mass scale

(A) Oxygen as standard : The standard reference for atomic weight may be oxygen with an assigned value of 16.

Atomic weight of an element =
$$\frac{\text{Weight of 1 atom of element}}{1/16 \times \text{Weight of 1 atom of oxygen}}$$

(B) Carbon as standard : The modern reference standard for atomic weight is carbon isotope of mass number 12.

Atomic weight of an element =
$$\frac{\text{Weight of 1 atom of the element}}{1/12 \times \text{Weight of 1 atom of C} - 12}$$

Important Points :

(1) Atomic weight is not a weight but a number.
(2) Atomic weight is not absolute but relative to the weight of the standard reference element C-12

7.2 Molecular weight

It is the number of times a molecule is heavier than $1/12^{th}$ of an atom of C – 12.

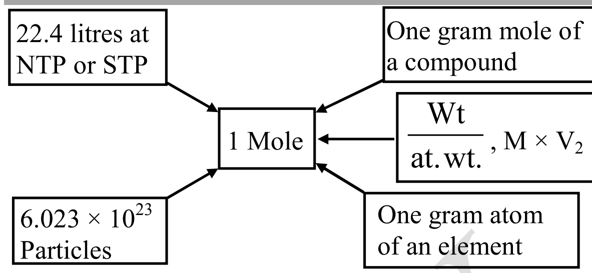
Molecular weight = $\frac{\text{Weight of 1 molecule}}{1/12 \times \text{Weight of one C} - 12}$

Important Points :

1. Molecular weight is not a weight but a number
2. Molecular weight is relative and not absolute
3. Molecular weight expressed in grams is called gram molecular weight
4. Molecular weight is calculated by adding all the atomic weights of all the atoms in a molecule

Example : $CO_2 = 12 + 2 \times 16 = 44$

8. MOLE CONCEPT



Important Points :

⇒ 1 mole = 6.023×10^{23} particles
⇒ 1 mole atoms = 6.023×10^{23} atoms
⇒ One mole molecule = 6.023×10^{23} molecules
⇒ Mass of one mole of atoms
= Gram atomic mass
⇒ Mass of one mole of molecules
= Gram molecular mass
⇒ Moles of a compound = Mass of compound
⇒ Volume occupied by 1 mole of a gas at N.T.P = 22.4 litres.

Example-2

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

Solution :

∵ 6.023×10^{23} molecules of CO_2 = 44 g

10^{21} molecules of $CO_2 = \frac{44 \times 10^{21}}{6.023 \times 10^{23}}$
$= 7.31 \times 10^{-2}$ g
= 73.1 mg

∴ CO_2 left = 200 – 73.1 = **126.9 mg**

Also mole of CO_2 left $= \frac{\text{wt.}}{\text{m.wt.}} = \frac{126.9 \times 10^{-3}}{44}$
$= \mathbf{2.88 \times 10^{-3}}$

Example-3

8 gm of methane is burnt with 4.48L of O_2 at STP. Find out the volume of CO_2 gas produced at STP and also the weight of CO_2 gas.

Solution :

The balanced chemical equation is

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$
1 mol 2 mol 1 mol
16 gm 2 × 22.4 L 22.4 L 44 gm

No. of moles of $CH_4 = \frac{8}{16} = 0.5$mol

No. of moles of $O_2 = \frac{4.48\text{L}}{22.4\text{L}} = 0.2$mol

Now since 1 mole of CH_4 requires 2 mol (i.e. 44.8 L) of O_2 for complete combustion. But the given moles of O_2 is only 0.2 mol. So, O_2 is the limiting reagent.
Again, since 2 moles of O_2 reacts with 1 mol of CH_4 to give 22.4 L of CO_2 at STP.
So 0.2 mole of O_2 will react with 0.1 mol of CH_4 to give 2.24 L of CO_2.
Wt. of CO_2 produced = 0.1 mol × 44
= 4.4 gms of CO_2

Example-4

If 0.5 mole of $BaCl_2$ is mixed with 0.2 mole of Na_3PO_4 the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is

(a) 0.7 **(b) 0.5**
(c) 0.3 **(d) 0.1**

Solution:

$3BaCl_2 + 2Na_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 6NaO$

From the molar ratio we see

$BaCl_2 : Na_3PO_4 : Ba_3(PO_4)_2 : NaCl$
3 : 2 : 1 : 6

$\therefore$ **(d)**

Example-5

The reaction between aluminum metal and dilute hydrochloric acid produces $H_{2(g)}$ and Al^{3+} ions. The molar ratio of aluminum used to hydrogen produced is

(a) 1:2 **(b) 2:1**
(c) 2:3 **(d) 3:2**

Solution:

$$Al_{(s)} + \underset{\text{From HCl}}{3H^+_{(ag)}} \longrightarrow \frac{3}{2} H_{2(g)} + Al^{3+}(aq.)$$

The molar ratio of $Al_{s)}$ used to H_2 produced is 1: $\frac{3}{2}$ or 2:3.

$\therefore$ **(c)**

Example-6

A mixture of magnesium chloride and magnesium sulphate is known to contain 0.6 moles of chloride ions and 0.2 moles of sulphate ions. The number of moles of magnesium ions present is

(a) 0.4 **(b) 0.5**
(c) 0.8 **(d) 1.0**

Solution:

In $MgCl_2$, the ratio of moles of Mg^{+2} to Cl^- is 1:2. Therefore, 0.6 moles of chloride combine with 0.3 moles of magnesium. In $MgSO_4$, 0.2 moles of sulphate combine with 0.2 moles of magnesium. Therefore, the number of moles of magnesium ion present is 0.3 + 0.2 = 0.5.

$\therefore$ **(b)**

9. CHEMICAL FORMULA

It is of two types -

[A] Molecular formulae : Chemical formulae that indicate the actual numbers and type of atoms in a molecule are called molecular formulae

[B] Empirical formulae : The chemical formulae that give only the relative number of atoms of each type in a molecule are called empirical formulae

9.1 Determination of chemical formulae

[A] Determination of empirical formulae :

Step – I : Determination of percentage
Step – II : Determination of mole ratio
Step – III : Making it whole number ratio
Step – IV : Removal of fractions from mole ratio

[B] Determination of molecular formulae

(i) First of all find empirical formulae
(ii) Molecular formulae = (Empirical formulae) n

$$\text{where } n = \frac{\text{Molecular weight}}{\text{Empirical formula weight}}$$

Example-7

Calculate the empirical formula for a compound that contains 26.6% potassium, 35.4% chromium and 38.1% oxygen.

[Given K = 39.1; Cr = 52, O = 16]

Solution:

Element	%	Atomic Mass	Relative number of atoms	Simplest ratio	Simplest whole number ratio
Potassium	26.6	39.1	$\frac{26.6}{39.1}$ = 0.68	$\frac{0.68}{0.68}$ =1	1 × 2= 2
Chromium	35.4	52.0	$\frac{35.4}{52}$ = 0.68	$\frac{0.68}{0.68}$ =1	1 × 2 =2
Oxygen	38.1	16.0	$\frac{38.1}{16}$ = 2.38	$\frac{2.38}{0.68}$ =3.5	3.5×2=7

Therefore, empirical formula is $K_2Cr_2O_7$

Example-8

A compound contains 34.8% oxygen, 52.2% carbon and 13.0% hydrogen. What is the empirical formula mass of the compound?

Solution:

Element	Percentage	Atomic Mass	Relative number of atoms	Simplest ratio
Oxygen	34.8	16	$\frac{34.8}{16}$ = 2.175	$\frac{2.175}{2.175}$ = 1
Carbon	52.2	12	$\frac{52.2}{12}$ = 4.35	$\frac{4.35}{2.175}$ = 2
Hydrogen	13.0	1	$\frac{13.0}{1}$ = 13.0	$\frac{13.0}{2.175}$ = 6

The empirical formula is C_2H_6O

Empirical formula mass = $(2 \times 12) + (6 \times 1) + 16 = 46$

10. CHEMICAL EQUATION

Representation of the chemical change in terms of symbol and formulae of the reactants & products is called a chemical equation.

10.1 Information conveyed by a chemical equation

(1) Qualitatively, a chemical equation tells us the names of the various reactants

(2) Quantitatively, it express

(a) The relative no. of molecules of reactants and products

(b) The relative no. of moles of reactant and products

(c) The relative masses of reactants and products

(d) The relative volumes of gaseous reactants and products

Significance of chemical Equations

Let us consider a balanced chemical equations

Example - 1: $PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$

This equation will provide us various quantitative informations :

1. The molar ratio of reactants, i.e., PbS and H_2O_2 in which they react together is 1:4.

2. The molar ratio of the two products i.e., $PbSO_4$ and H_2O being formed in the reaction is also 1:4.

3. The initial moles of PbS and H_2O_2 for the reaction to take place not necessarily be 1 and 4 respectively or also should not be in the molar ratio of 1:4.

4. One can start the reaction with PbS and H_2O_2 in any molar ratio, but the ratio of PbS and H_2O_2 which are reacting will always be in the ratio of 1:4.

5. One mole of $PbSO_4$ and 4 moles of H_2O will be formed for each mole of PbS being consumed.

The stoichiometric coefficients of a balanced chemical equation is the molar ratio and not the weight ratio.

One can use the balanced chemical equation for quantitative (gravimetrically or volumetrically) estimation of reactants and products. But if one does not have the balanced equation, it is very difficult to calculate the amounts of reactants consumed or products being formed.

Example – 2 : $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Above balanced chemical equation gives idea that 1 mole of N_2 (28 g) reacts with 3 mole of H_2 (6 g) to give 2 mole of NH_3

Example - 3 : $2N_2O_5 \longrightarrow 4NO_2 + O_2$

Above balanced equation indicates that 2 mole of N_2O_5 (2 ×108 g) will decompose to give 4 mole of NO_2 (4 × 46 g) and 1 mole of O_2 (32 g).

10.2 Limitations of chemical equations

(1) The physical state of the reactants and products

(2) The dilution of solution of reactants and products are in soluble state

(3) The energy changes during chemical reaction

(4) The conditions of P, T etc at which reaction occurs.

(5) The rate of chemical reaction

11. LIMITING REAGENT

It may be defined as the reactant which is completely consumed during the reaction is called limiting reagent-

Example : $2H_2(g) + O_2(g) \rightarrow 2H_2O$

Here H_2 is known as limiting reagent.

Calculation of limiting reagent :

(a) By calculating the required amount by the equation and comparing it with given amount.
[Useful when only two reactant are there]

(b) 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.

(c) 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]

Example-9

How many gram of ammonia will form by the combination of 3 gm hydrogen and 7 gm nitrogen?

Solution:

$N_2 + 3H_2 \longrightarrow 2NH_3$

1 mole 3 mole 2 mole

= 28 gm = 3 × 2 gm = 2 × 17 gm

$\because$ 28 gm N_2 requires 3 × 2 gm H_2 for complete reaction

$\therefore$ 7 gm N_2 requires $\frac{3\times2}{28}\times7 = 1.5$ gm < 3.0 gm

Hence, nitrogen is the limiting regent.

Now, $\because$ 28 gm N_2 will produce 2 × 17 gm NH_3

$\therefore$ 7 gm N_2 will produce $\frac{2\times17}{28}\times7 =$ **8.5 gm NH_3**

Example-10

What volume of chorine gas will liberate at STP, when 2.61 gm MnO_2 is reacted with 2.92 gm HCl ?

Solution :

$MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$

1 mole 4 mole 1 mole

= 87 gm = 4 × 36.5 gm = 22.4 *l*

$\because$ 87 gm MnO_2 requires 4 × 36.5 gm HCl for complete reaction

$\therefore$ 2.61 gm MnO_2 requires $\frac{4\times36.5}{87}\times2.61$ gm

= 4.38 > 2.92 gm

Hence, HCl is the limiting reagent.

Now, $\because$ 4 × 36.5 gm HCl will produce 22.4 *l* Cl_2 at STP

$\therefore$ 2.92 gm HCl will produce $\frac{22.4}{4\times36.5}\times2.92$ = **0.448 *l* Cl_2 at STP**

Example-11

If 170 gm of H_2S reacts with 256 gm of SO_2 and produces only 'S' produced is

$SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$

Solution :

No. of moles of $SO_2 = \frac{256}{64} = 4$

No. of moles of $H_2S = \frac{170}{34} = 5$?

From the given equation 1 mole of SO_2 reacts with 2 moles of H_2S. So for 5 moles of H_2S SO_2 needed is 2.5 moles of 1.5 moles of SO_2 is left unreacted

      1   2   3   4

R.R. $SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$

      4   5

        (LR)

      2.5   5   7.5

    (4–2.5)

$\Rightarrow$ 1.5 moles

  (excess)

Maximum weight of S obtained $\Rightarrow 7.5 \times 32 \Rightarrow 2$

12. DETERMINATION OF % OF ELEMENTS IN A GIVEN COMPOUND

$$\text{\% of element} = \left(\frac{\text{weight of that element}}{\text{mol. mass of compound}}\right)\times 100$$

Example-12

Calculate % of Ca, C, and O in $CaCO_3$,

Solution :

Mol. mass = 40 + 12 + 48 = 100

% of Ca = $\frac{40}{100}\times 100 = 40\%$

% of C = $\frac{12}{100}\times 100 = 12\%$

% of O = $\frac{48}{100}\times 100 = 48\%$

Example-13

Calculate the mass of 90% pure MnO_2 to produce 35.5g of Cl_2 according to the following reaction.

$MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$

Solution:

$MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$

87g   71g

$\because$ 71g Cl_2 is produced by 87g of MnO_2

$\therefore$ 35.5g Cl_2 is produced = $\frac{87\times37.5}{712} = 43.5$g

90g pure MnO_2 is present in 100g sample

$\therefore$ 43.5g pure $MnO_2 = \frac{100\times43.5}{90} = 48.3$g

Example-14

The percent loss in weight after heating a pure sample of potassium chlorate (Molecular weight = 122.5) will be

(a) 12.25 **(b) 24.50**

(c) 39.18 **(d) 49**

Solution:

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

245 g $KClO_3$ on heating shows a weight loss of 96 gm

$\therefore$ 100g $KClO_3$ on heating shows a weight loss of

$= \frac{96 \times 100}{245} = 39.18\%$

$\therefore$ **(c)**

13. PRINCIPLE OF ATOMIC CONSERVATION (POAC)

It is base upon law of conservation of mass.

(a) POAC is applicable only on the atom which is completely consumed during the course of reaction.

(b) It is used for solving the proble which we are not able to balance.

For example $CO_2 \longrightarrow (C_6H_{10}O_5)_n$

Applying POAC on C–atom

$1 \times n_{CO_2} = 6n \times n(C_6H_{10}O_5)_n$

$2.5 = 6\text{ n} \times \frac{W}{162n}$

$W = \frac{405}{6} = 67.5$ g of starch

Example-15

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

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

Solution :

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

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

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

($\because$ 1 mole of K_2CO_3 contains 1 moles of C)

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

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

Example-16

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

Solution :

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

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

Let wt. of Na_2CO_3 in the mixture be x g

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

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

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

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

(3.0 – x) (2.752 – x)

Applying POAC for Na atom

1 × moles of $NaHCO_3$ = 2 × moles of Na_2CO_3

$\Rightarrow \frac{(3-x)}{84} = 2x\frac{(2.752-x)}{106}$

$\therefore$ x = 2.3244 g

$\therefore$ % of $Na_2CO_3 = \frac{2.3244}{3} \times 100 = 77.48$ %

14. PERCENTAGE COMPOSITION OF SAMPLE

This topic applicable for sample containing at least two substances of same nature.

Example-17

8 moles of a mixture of KOH and $Ca(OH)_2$ required 5 moles of H_2SO_4 for complete neutralisation. Find % composition of mixture.

Solution:

$2KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O$

x x/2

$Ca(OH)_2 + H_2SO_4 \longrightarrow CaSO_4 + 2H_2O$

8 – x 8 – x

$\frac{x}{2} + 8 - x = 5$

x = 6

i.e. % of KOH = $\frac{6}{8} \times 100 = 75\%$

15. FOR DETERMINATION OF ATOMIC MASS

Dulong's and Petit's Law :

Atomic weight × specific heat (cal/gm°C) $\propto \cong 6.4$

Gives approximate atomic weight and is applicable for metals only. Take care of units of specific heat.

This law is valid for metals only. According to this law :

Atomic mass × specific heat (in cal/g) ≈ 6.4;

Note :

1. B, Si and diamond show exceptions to Dulong-Petit's law as their specific heats decrease with temperature (at room temperature).
2. Heavier the element, lesser will be its specific heat

   (sp. Heat × atomic mass $\simeq$ 6.4).

   Thus, $C_{Hg} < C_{Cu} < C_{Al}$.

Example-18

A solid element has specific heat 1 J g^{-1} K^{-1}. If equivalent mass of element is 9g, calculate its atomic mass in g.

Solution :

According to Dulong and Petit's law

Atomic mass × specific heat = 6.4

$\because$ Atomic mass $= \dfrac{6.4}{1/4.184} = 6.4 \times 4.184$

$\therefore$ Valence $= \dfrac{\text{Atomic mass}}{\text{Equivalent mass}}$

$\therefore$ Valence $= \dfrac{6.4 \times 4.184}{9} = 3$ (an integer)

$\therefore$ Atomic mass = Equivalent mass × Valence

= 9 × 3 = 27

16. FOR DETERMINATION OF MOLECULAR MASS

(a) Victor Maeyer's process :

(for volatile substance)

Procedure : Some known weight of a volatile substance (w) is taken, converted to vapour and collected over water. The volume of air displaced over water is given (V) and the following expressions are used.

$$M = \frac{w}{PV}RT \text{ or } M = \frac{w}{(P - P')V}RT$$

If aq. tension is not given. If aq. tension is P′

Aqueous tension : Pressure exerted due to water vapours at any given temperature.

This comes in picture when any gas is collected over water. Can you guess why ?

(b) Silver salt method : (for organic acids)

Basicity of an acid : No. of replacible H^+ atoms in an acid (H bonded to more electronegative atom is acidic)

Procedure : Some known amount of silver salt (w_1 gm) is heated to obtain w_2 gm of white shining residue of silver. Then if the basicity of acid is n, molecular weight of acid would be

$Ag_nA \rightarrow nAg^+ + A^{-n}$

Ag_n A is the salt $\left(\dfrac{w_2}{108} \times \dfrac{1}{n}\right) \times M_{salt} = w_1$ and

molecular weight of acid $= M_{salt} - n(108)$

This is one good practical application of POAC.

(c) Chloroplatinate salt method: (for organic bases)

Lewis acid : electron pair acceptor

Lewis base : electron pair donor

Procedure : Some amount of organic base is reacted with H_2PtCl_6 and forms salt known as chloroplatinate. If base is denoted by B then salt formed.

(i) with monoacidic base = $B_2H_2PtCl_6$

(ii) with diacidic base = $B_2(H_2PtCl_6)_2$

(iii) with triacidic base = $B_2(H_2PtCl_6)_3$

The known amount (w_1 gm) of salt is heated and pt residue is measured. (w_2 gm). If acidity of base is 'n' then $\left(\dfrac{w_2}{195} \times \dfrac{1}{n}\right) \times M_{salt} = w_1$ and

$$M_{base} = \frac{M_{salt} - n(410)}{2}$$

- **For % determination of elements in organic compounds :**
- All these methods are applications of POAC
- Do not remember the formulas, derive them using the concept, its easy.

(a) Liebig's method : (Carbon and hydrogen) (w)

Organic Compound $\xrightarrow[\text{CuO}]{\Delta}$ (w_1) $CO_2 + H_2O$ (w_2)

$$\% \text{ of C} = \frac{w_1}{44} \times \frac{12}{w} \times 100$$

$$\% \text{ of H} = \frac{w_2}{18} \times \frac{2}{w} \times 100$$

where w_1 = wt. of CO_2 produced, w_2 = wt. of H_2O produced,

w = wt, of organic compound taken

(b) Duma's method : (for nitrogen)

(w) Organic Compound $\xrightarrow[\text{CuO}]{\Delta}$ $N_2 \rightarrow$ (P, V, T given)

use PV = nRT to calculate moles of N_2, n.

$\therefore$ % of N = $\frac{n \times 28}{w} \times 100$

w = wt of organic compound taken

(c) Kjeldahl's method : (for nitrogen)

(w) O.C. + $H_2SO_4 \rightarrow \xrightarrow{NaOH} (NH_4)_2SO_4$ $NH_3 + H_2SO_4 \rightarrow$ (molarity M and volume (V_1) consumed given)

$\Rightarrow$ % of N = $\frac{MV_1 \times 2 \times 14}{w} \times 100$

where M = molarity of H_2SO_4.

- Some N containing compounds do not give the above set of reaction as in Kjeldahl's method.

(d) Sulphur :

(w) O.C. + $HNO_3 \rightarrow H_2SO_4 + BaCl_2 \rightarrow (w_1)\ BaSO_4$

$\Rightarrow$ % of S = $\frac{w_1}{233} \times 1 \times \frac{32}{w} \times 100$

where w_1 = wt. of $BaSO_4$, w = wt. of organic compound

(e) Phosphorus :

O.C+ $HNO_3 \rightarrow H_3PO_4$ + [NH_3 + magnesia mixture ammonium molybdate] $\rightarrow MgNH_4\ PO_4 \xrightarrow{\Delta} Mg_2P_2O_7$

% of P = $\frac{w_1}{222} \times \frac{2 \times 31}{w} \times 100$

(f) Carius method : (Halogens)

O.C. + $HNO_3 + AgNO_3 \rightarrow AgX$

If X is Cl then colour = white

If X is Br then colour = dull yellow

If X is I then colour = bright yellow

- Flourine can't be estimated by this

% of $X = \frac{w_1}{(\text{M.weight of Agx})} \times \frac{1 \times (\text{At.wt of X})}{w} \times 100$

Example-19

0.607 g of a silver salt of a tribasic organic acid was quantitatively reduced to 0.370 g of pure silver. Calculate the molecular weight of the acid (Ag = 108)

Solution :

Suppose the tribasic acid is H_3A.

H_3A	$\rightarrow Ag_3A \rightarrow$	Ag
	acid	salt
	0.607 g	0.37 g

Since Ag atoms are conserved, applying POAC for Ag atoms,

moles of Ag atoms in Ag_3A = moles of Ag atoms in the product

3 × moles of Ag_3A = moles of Ag in the product

$$3 \times \frac{0.607}{\text{mol. wt. of } Ag_3A} = \frac{0.37}{108} \qquad (Ag = 108)$$

mol. wt. of Ag_3A = 531.

$\therefore$ mol. weight of tribasic acid (H_3A)

= mol wt. of the salt (Ag_3A) – 3 × at. wt. of Ag + 3 × at. wt. of H

= 531 – 324 + 3 = 210 **Ans.**

EXERCISE # 1

Based On — Significant Figures

1. In the final answer of the expression $\frac{(29.2-20.2)(1.79\times10^5)}{1.37}$. The number of significant figures is
(a) 1 (b) 2
(c) 3 (d) 4

2. The significant figures in 3400 are
(a) 2 (b) 5
(c) 6 (d) 4

3. The number of significant figures in 6.0023 are
(a) 5 (b) 4
(c) 3 (d) 1

4. Given $P = 0.0030m$, $Q = 2.40m$, $R = 3000m$, Significant figures in P, Q and R are respectively
(a) 2, 2, 1 (b) 2, 3, 4
(c) 4, 2, 1 (d) 4, 2, 3

5. The number of significant figures in 60.0001 is
(a) 5 (b) 6
(c) 3 (d) 2

6. A sample was weighted using two different balances. The result's were (i) 3.929 *g* (ii) 4.0 *g*. How would the weight of the sample be reported
(a) 3.929 *g* (b) 3 *g*
(c) 3.9 *g* (d) 3.93 *g*

Based On — Laws of Chemical Combination

7. There are two common oxides of Sulphur, one of which contains 50% O_2 by weight, the other almost exactly 60%. The weights of sulphur which combine with 1 g of O_2 (fixed) are in the ratio of -
(a) 1 : 1 (b) 2 : 1
(c) 2 : 3 (d) 3 : 2

8. Iron forms two oxides, in first oxide 56 gram. Iron is found to be combined with 16 gram oxygen and in second oxide 112 gram iron is found to be combined with 48 gram oxygen. This data satisfy the law of -
(a) Conservation of mass
(b) Reciprocal proportion
(c) Multiple proportion
(d) Combining volume

9. When 10 ml of propane (gas) is combusted completely, volume of CO_2(g) obtained in similar condition is -
(a) 10 ml (b) 20 ml
(c) 30 ml (d) 40 ml

10. 12 g carbon combines with 64 g sulphur to form CS_2. 12 g carbon also combines with 32 g oxygen to form CO_2. 10 g sulphur combines with 10 g oxygen to form SO_2. These data illustrate the -
(a) Law of multiple proportions
(b) Law of definite proportions
(c) Law of reciprocal proportions
(d) Law of gaseous volumes.

Based On — Avogadro's Hypothesis & Mole Concept

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

12. Number of *gm* of oxygen in 32.2 *g* $Na_2SO_4.10H_2O$ is
(a) 20.8 (b) 22.4
(c) 2.24 (d) 2.08

13. The number of oxygen atoms in 4.4 *g* of CO_2 is approx.
(a) 1.2×10^{23} (b) 6×10^{22}
(c) 6×10^{23} (d) 12×10^{23}

14. The volume occupied by 4.4 *g* of CO_2 at STP is
(a) 22.4 L (b) 2.24 L
(c) 0.224 L (d) 0.1 L

15. The number of water molecules present in a drop of water (volume 0.0018 *ml*) at room temperature is
(a) 6.023×10^{19} (b) 1.084×10^{18}
(c) 4.84×10^{17} (d) 6.023×10^{23}

16. One mole of calcium phosphide on reaction with excess of water gives
(a) One mole of phosphine
(b) Two moles of phosphoric acid
(c) Two moles of phosphine
(d) One mole of phosphorus pentoxide

17. 19.7 *kg* of gold was recovered from a smuggler. How many atoms of gold were recovered (*Au* =197)
(a) 100 (b) 6.02×10^{23}
(c) 6.02×10^{24} (d) 6.02×10^{25}

18. The total number of protons in 10 *g* of calcium carbonate is ($N_0 = 6.023\times10^{23}$)
(a) 1.5057×10^{24} (b) 2.0478×10^{24}
(c) 3.0115×10^{24} (d) 4.0956×10^{24}

19. The number of molecules in 16 *g* of methane is
(a) 3.0×10^{23} (b) 6.02×10^{23}
(c) $\frac{16}{6.02}\times10^{23}$ (d) $\frac{16}{3.0}\times10^{23}$

20. Number of molecules in 100 *ml* of each of O_2, NH_3 and CO_2 at STP are
(a) In the order $CO_2 < O_2 < NH_3$
(b) In the order $NH_3 < O_2 < CO_2$
(c) The same
(d) $NH_3 = CO_2 < O_2$

21. The number of water molecules in 1 litre of water is
(a) 18 (b) 18×1000
(c) N_A (d) $55.55\,N_A$

22. The number of electrons in a mole of hydrogen molecule is
(a) 6.02×10^{23} (b) 12.046×10^{23}
(c) 3.0115×10^{23} (d) Indefinite

23. The numbers of moles of $BaCO_3$ which contain 1.5 moles of oxygen atoms is
(a) 0.5 (b) 1
(c) 3 (d) 6.02×10^{23}

24. How many molecules are present in one gram of hydrogen
(a) 6.02×10^{23} (b) 3.01×10^{23}
(c) 2.5×10^{23} (d) 1.5×10^{23}

25. The total number of gm-molecules of SO_2Cl_2 in 13.5g of sulphuryl chloride is
(a) 0.1 (b) 0.2
(c) 0.3 (d) 0.4

26. The largest number of molecules is in
(a) 34g of water (b) 28g of CO_2
(c) 46g of CH_3OH (d) 54g of N_2O_5

27. The number of moles of sodium oxide in 620g of it is
(a) 1 mol (b) 10 moles
(c) 18 moles (d) 100 moles

28. 2g of oxygen contains number of atoms equal to that in
(a) 0.5g of hydrogen (b) 4g of sulphur
(c) 7g of nitrogen (d) 2.3g of sodium

29. How many atoms are contained in one mole of sucrose ($C_{12}H_{22}O_{11}$)
(a) $45\times6.02\times10^{23}$ atoms/mole
(b) $5\times6.62\times10^{23}$ atoms/mole
(c) $5\times6.02\times10^{23}$ atoms/mole
(d) None of these

30. The number of molecules of CO_2 present in 44*g* of CO_2 is
(a) 6.0×10^{23} (b) 3×10^{23}
(c) 12×10^{23} (d) 3×10^{10}

31. A sample of phosphorus trichloride (PCl_3) contains 1.4 moles of the substance. How many atoms are there in the sample
(a) 4 (b) 5.6
(c) 8.431×10^{23} (d) 3.372×10^{24}

32. The number of sodium atoms in 2 moles of sodium ferrocyanide is

(a) 12×10^{23} (b) 26×10^{23}

(c) 34×10^{23} (d) 48×10^{23}

33. 5 moles of A, 6 moles of Z and mixed with sufficient amount of C to produce final product F. How many maximum moles of 'F' can be produced as per the given sequence of reaction ?

$A + 2Z \rightarrow B$; $B + C \rightarrow Z + F$

(a) 3 (b) 2

(c) 4 (d) 5

34. At 100ºC and 1 atm, if the density of liquid water is 1 g cm^{-3} and that of water vapour is 0.0006 g cm^{-3}, then the volume occupied by water molecules in 1 litre of steam at that temperature is

(a) 6 cm^3 (b) 60 cm^3

(c) 0.6 cm^3 (d) 0.06 cm^3

35. At room temperature ratio of pressures of CH_4 and CO_2 kept in two separate containers of equal volume is 3 : 5. Then two containers have equal number of -

(a) moles (b) electrons

(c) atoms (d) molecules

36. If 0.5 moles of $BaCl_2$ is mixed with 0.2 moles of Na_3PO_4, the maximum moles of $Ba_3(PO_4)_2$ obtained is –

(a) 0.2 (b) 0.5

(c) 0.3 (d) 0.1

37. The average atomic mass of a mixture containing 79 mole % of ^{24}Mg 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

38. The number of oxygen atoms in 1.58 g of $KMnO_4$ is - [K = 39, Mn = 55]

(a) 6.02×10^{21} (b) 2.4×10^{23}

(c) 1.4×10^{22} (d) 3.0×10^{20}

39. Which sample contains the largest number of atoms -

(a) 1 mg of C_4H_{10} (b) 1 mg of N_2

(c) 1 mg of Na (d) 1 mL of water

40. The volume occupied by one molecules of water (density 1 g/cm^3) is -

(a) 18 cm^3 (b) 22400 cm^3

(c) 6.23×10^{-23} cm^3 (d) 3.0×10^{-23} cm^3

41. At STP 5.6 litre of a gas weigh 60 g. The vapour density of gas is -

(a) 60 (b) 120

(c) 30 (d) 240

42. The mass of CO_2 that shall be obtained by heating 10 kg of 80% pure limestone ($CaCO_3$) is -

(a) 4.4 kg (b) 6.6 kg

(c) 3.52 kg (d) 8.8

43. The number of atoms in 20g of SO_3 is approximately -

(a) 1×10^{23} (b) 1.5×10^{23}

(c) 2×10^{23} (d) 6×10^{23}

44. The number of moles of SO_2 in 6.4 g is -

(a) 0.1 (b) 0.2

(c) 0.3 (d) 0.4

45. The number of ions present in 2.0 L of a solution of 0.8 M $K_4[Fe(CN)_6]$ is

(a) 4.8×10^{22} (b) 4.8×10^{24}

(c) 9.6×10^{24} (d) 9.6×10^{22}

46. The number of moles of $BaCO_3$ which contains 1.5 moles of oxygen atoms is -

(a) 0.5 (b) 1

(c) 3 (d) 6.02×10^{23}

47. Caffeine has a molecular mass of 194. If it contains 28.9% by mass of nitrogen, number of atoms of nitrogen in one molecule of caffeine is -

(a) 4 (b) 6

(c) 2 (d) 3

48. The mass of 2 gram atoms of calcium (Relative atomic mass = 40)

(a) 2 g (b) 0.05 g

(c) 0.5 g (d) 80 g

49. Which of the following contains largest number of atoms -
(a) 1.0 g of O atoms
(b) 1.0 g of O_2
(c) 1.0 g of O_3
(d) All have equal atoms

50. The number of molecules present in 88 g of CO_2 (Relative molecular mass of CO_2 = 44)
(a) 1.24×10^{23} (b) 3.01×10^{23}
(c) 6.023×10^{24} (d) 1.2046×10^{24}

51. The number of Ca^{2+} and Cl^- ions present in anhydrous $CaCl_2$ is 3.01×10^{23} and 6.023×10^{23} respectively. The weight of the anhydrous sample is -
(a) 40 g (b) 55.5 g
(c) 222 g (d) 75.5 g

52. The largest number of molecules is present in
(a) 34 g of H_2O (b) 28 g of CO_2
(c) 46 g of CH_3OH (d) 54 g of N_2O_5

53. If N_A is Avogadro number, then the number of valence electrons in 4.2 g of N^{3-} ions is -
(a) 2.4 N_A (b) 4.2 N_A
(c) 1.6 N_A (d) 3.2 N_A

54. Two oxides of a metal contain 50% and 40% metal M respectively. If the formula of the first oxide is MO_2, the formula of the second oxide will be -
(a) MO_2 (b) MO_3
(c) M_2O (d) M_2O_5

55. Which of the following has the least mass ?
(a) 2 g atoms of nitrogen
(b) 3×10^{23} atoms of carbon
(c) 1 mol of sulphur
(d) 7.0 g of Ag

56. Insulin contains 3.4% sulphur. What will be the minimum molecular weight of insulin ?
(a) 94.176 (b) 1884
(c) 941.176 (d) 976

57. The volume occupied by 7.23×10^{23} molecules of carbon dioxide and 3.01×10^{23} molecules of Argon at 0°C and 1 atm pressure is -
(a) 38 mL (b) 3.80 L
(c) 3.8×10^4 mL (d) 3.8×10^3 mL

58. Weight of one atom of an element is 6.644×10^{-23} g. Calculate g atom of element in 40 kg.
(a) 10000 g atom (b) 1000 g atom
(c) 100 g atom (d) 10 g atom

59. The dot at the end of this sentence has a mass of about one microgram. Assuming that black stuff is carbon, calculate approximate atoms of carbon needed to make such a dot.
(a) 3.2×10^{13} atoms of C
(b) 5.6×10^{12} atoms of C
(c) 1.7×10^{9} atoms of C
(d) 5×10^{16} atoms of C

60. Which of the following has least mass ?
(a) 2g atom of nitrogen
(b) 3×10^{23} atoms of C
(c) 1 mole of S
(d) 7.0 g of Ag

61. 6×10^{20} molecules of SO_2 are removed from 320 milligram of SO_2. What are the remaining moles of SO_2.
(a) 4×10^{-3} moles (b) 5×10^{-3} moles
(c) 2×10^{-3} moles (d) 6×10^{-3} moles

62. The total number of protons in 10 g of calcium carbonate is ($N_0 = 6.023 \times 10^{23}$)
(a) 1.5057×10^{24} (b) 2.0478×10^{24}
(c) 3.0115×10^{24} (d) 4.0956×10^{24}

63. At S.T.P. the density of CCl_4 vapour in g/L will be nearest to
(a) 6.84 (b) 3.42
(c) 10.26 (d) 4.57

64. 1.24 gm P is present in 2.2 gm
(a) P_4S_3 (b) P_2S_2
(c) PS_2 (d) P_2S_2

65. The largest number of molecules is in
(a) 34g of water (b) 28g of CO_2
(c) 46g of CH_3OH (d) 54g of N_2O_5

66. The vapour density of a gas is 11.2. The volume occupied by 11.2 g of the gas at NTP will be
(a) 11.2 L (b) 22.4 L
(c) 1 L (d) 44.8 L

67. 7.5 grams of a gas occupy 5.8 litres of volume at STP the gas is
(a) NO (b) N_2O
(c) CO (d) CO_2

68. 10 gms each of CO_2, NH_3 and O_2 were taken in three separate flasks. What is the correct decreasing order of atoms?
(a) CO_2,NH_3, O_2 (b) NH_3, O_2, CO_2
(c) O_2, NH_3, CO_2 (d) NH_3, CO_2, O_2

69. If N_A is Avogadro's number then number of valence electrons in 4.2 g of nitride ions (N^{3-})
(a) 2.4 N_A (b) 4.2 N_A
(c) 1.6NV_A (d) 3.2 N_A

70. How much coulomb charge is present on 1 g ion of N^{3-}
(a) 5.2×10^6 Couloumb
(b) 2.894×10^5 Couloumb
(c) 6.6×10^6 Couloumb
(d) 8.2×10^6 Couloumb

71. The number of molecule at NTP in 1 ml of an ideal gas will be
(a) 6×10^{23} (b) 2.69×10^{19}
(c) 2.69×10^{23} (d) None of these

Based On | **Percentage Composition, Molecular Formula & Empirical Formula**

72. The percentage of oxygen in NaOH is
(a) 40 (b) 60
(c) 8 (d) 10

73. The percentage of nitrogen in urea is about
(a) 46 (b) 85
(c) 18 (d) 28

74. If two compounds have the same empirical formula but different molecular formula, they must have
(a) Different percentage composition
(b) Different molecular weights
(c) Same viscosity
(d) Same vapour density

75. A compound (80 *g*) on analysis gave $C = 24$ g, $H = 4\ g$, $O = 32\ g$. Its empirical formula is
(a) $C_2H_2O_2$ (b) C_2H_2O
(c) CH_2O_2 (d) CH_2O

76. The empirical formula of a compound is CH_2O. 0.0835 moles of the compound contains 1.0 *g* of hydrogen. Molecular formula of the compound is
(a) $C_2H_{12}O_6$ (b) $C_5H_{10}O_5$
(c) $C_4H_8O_8$ (d) $C_3H_6O_3$

77. The empirical formula of an acid is CH_2O_2, the probable molecular formula of acid may be
(a) CH_2O (b) CH_2O_2
(c) $C_2H_4O_2$ (d) $C_3H_6O_4$

78. In which of the following pairs of compounds the ratio of *C, H* and *O* is same
(a) Acetic acid and methyl alcohol
(b) Glucose and acetic acid
(c) Fructose and sucrose
(d) All of these

79. A carbon compound containing carbon and oxygen has molar mass equal to 288. On analysis it is found to contain 50% by mass of each element. Therefore molecular formula of the compound is -
(a) $C_{12}O_9$ (b) C_4O_3
(c) C_3O_4 (d) C_9O_{12}

80. A sample of impure cuprite, Cu_2O, contains 66.6% copper. What is the percentage of pure Cu_2O in the sample -
(a) 75% (b) 25%
(c) 60% (d) 80%

81. A given sample of pure compound contains 9.81 gm of Zn, 1.8×10^{23} atoms of chromium, and 0.60 mol of oxygen atoms. what is the simplest formula -
(a) $ZnCr_2O_7$ (b) $ZnCr_2O_4$
(c) $ZnCrO_4$ (d) $ZnCrO_6$

82. 510 mg of liquid on vaporization in Victor Meyer's apparatus displaces 67.2 cm^3 of air at (STP). The molecular weight of the liquid is -
(a) 130 (b) 17
(c) 170 (d) 1700

83. When 3.2 g S is vapourized at 450ºC and 723 mm pressure, the vapours occupy a volume of 780 ml. What is the molecular formula of S vapours under these conditions -
(a) S_2 (b) S_4
(c) S_6 (d) S_8

84. A carbon compound containing carbon and oxygen has approximate molar mass equal to 290. On analysis it is found to contain 50% by mass of each element. Therefore molecular formula of the compound is-
(a) $C_{12}O_9$ (b) C_4O_3
(c) C_3O_4 (d) C_9O_{12}

85. 105 ml of pure water at 4ºC is saturated with NH_3 (g) producing a solution of density 0.9 gm/ml. If this solution contain 30% of NH_3 by mass, therefore the total volume of solution is -
(a) 250 ml (b) 125 ml
(c) 166.67 ml (d) 111.11 ml

86. A certain compound has the molecular formula X_4O_6. If 10 gm of compound contain 6.06 gm of X, the atomic mass of X is -
(a) 32 amu (b) 37 amu
(c) 42 amu (d) 48 amu

87. Mr. Parker consume 1 kg of bread on average everyday. Bread contain 10% by mass of protein. Protein contain 7% by mass of nitrogen. If 10% of nitrogen present in protein is converted to urea, how much urea is produced in Mr. Parker in one day ?
(a) 750 mg (b) 70 mg
(c) 1500 mg (d) 150 mg

88. 0.078 g of hydrocarbon occupy 22.4 ml of volume at 1 atm and 0ºC. The empirical formula of the hydrocarbon is CH. The molecular formula is -
(a) C_2H_2 (b) C_4H_4
(c) C_6H_6 (d) C_8H_8

89. Which of the hydrated salts contain greatest % of water by mass?
[Ba = 137, S = 32, Cl = 35.5, Ni = 58.7]
(a) $BaCl_2.2H_2O$ (b) $CuSO_4.5H_2O$
(c) $CaCl_2.6H_2O$ (d) $Ni(ClO_4)_2.6H_2O$

90. What is the empirical formula of a compound composed of O and Mn in equal weight ratio? [Mn = 55]
(a) MnO (b) MnO_2
(c) Mn_2O_3 (d) Mn_2O_7

91. The weight of 305 mL of a diatomic gas at 0ºC and 2 atm pressure is 1 g. The weight of one atom is – (N is the Av. no.) :
(a) 16/N (b) 32/N
(c) 16 N (d) 32 N

92. The oxide of a metal contains 40% by mass of oxygen. The percentage of chlorine in the chloride of the metal is
(a) 84.7 (b) 74.7
(c) 64.7 (d) 44.7

93. Insulin contains 3.4% sulphur. Calculate minimum mol. wt. of insulin.
(a) 941 (b) 540
(c) 320 (d) 670

94. The sulphate of a metal M contains 9.87% of M. This sulphate is isomorphous with $ZnSO_4.7H_2O$. The atomic weight of M is
(a) 40.3 (b) 36.3
(c) 24.3 (d) 11.3

95. The number of moles of oxygen in one litre of air containing 21% oxygen by volume under standard conditions is
(a) 0.186 mole (b) 0.21 mole
(c) 0.0093 mole (d) 2.10 mole

Based On | Atomic Mass, Molecular Mass

96. The chloride of a metal contains 71% chlorine by weight and the vapour density of it is 50. The atomic mass of the metal will be (valency of metal is 2)-
(a) 29 (b) 58
(c) 35.5 (d) 71

97. A reaction required three atoms of Mg for two atoms of N. How many gm of N are required for 3.6 gm of Mg ?
(a) 2.43 (b) 4.86
(c) 1.4 (d) 4.25

98. A hydrated salt of Na_2SO_3 loses 22.22 % of its mass on strong heating. The hydrated salt is -
(a) $Na_2SO_3.4H_2O$ (b) $Na_2SO_3.6H_2O$
(c) $Na_2SO_3.H_2O$ (d) $Na_2SO_3.2H_2O$

99. The average molecular mass of a mixture of gas containing nitrogen and carbon dioxide is 36. The mixture contain 280 gm of nitrogen, therefore, the amount of CO_2 present in the mixture is -
(a) 440 gm (b) 44 gm
(c) 0.1mole (d) 880 gm

100. In an ionic compound moles ratio of cation to anion is 1 : 2. If atomic masses of metal and non-metal respectively are 138 and 19, then correct statement is -
(a) molecular mass of compound is 176
(b) formula mass of compound is 176
(c) formula mass of compound is 157
(d) molecular mass of compound is 157

101. A purified pepsin (protein containing several amino acids) isolated from bovine preparation was introduced in the amino acid analysis. It was seen 0.43 gm of lysine (mol wt = 146) was present in 100 gm of pepsin. Therefore minimum molecular wt of pepsin approximately is -
(a) 34000 (b) 39000
(c) 40,000 (d) None of these

102. The specific heat of a metal is 0.16. Its approximate atomic weight would be -
(a) 32 (b) 16
(c) 40 (d) 64

103. The atomic weights of two elements A and B are 40 and 80 respectively. If x g of A contains y atoms, how many atoms are present in 2x g of B
(a) y/2 (b) y/4
(c) y (d) 2y

104. A plant virus is found to consist of uniform cylindrical particles of 150 Å in diameter and 5000 Å long. The specific volume of the virus is 0.75 cm^3 /g. If the virus is considered to be single particle, find its molecular weight
(a) 7×10^7 (b) 2×10^4
(c) 4×10^1 (d) 9×10^3

Based On | **Limiting Reagent**

105. 3 gm of Mg is burnt in a closed vessel containing 3 gm of oxygen. The weight of excess reactant left is -
(a) 0.5 gm of oxygen (b) 1.0 gm of oxygen
(c) 1.0 gm of Mg (d) 0.5 gm of Mg

106. Phosphine (PH_3) decomposes to produce P_4 (g) and H_2 (g). What would be the change in volume when 100 ml of PH_3 (g) is completely decomposed ?
(a) 50 ml (b) 500 ml
(c) 75 ml (d) 250 ml

107. 2.4g of pure Mg (at. mass = 24) is dropped in 100 mL of 1M HCl. Which of the following statement is wrong ?
(a) 1.12 L of hydrogen is produced at S.T.P.
(b) 0.01 mol of magnesium is left behind
(c) HCl is the limiting reagent.
(d) None of these

108. 20 moles of A and 14 moles of B are mixed and allowed to react according to the equation :
$A + 2B \rightarrow 3C$
What is the maximum number of moles of C which could be prepared ?
(a) 14 (b) 21
(c) 13 (d) 7

109. A metal oxide has the formula Z_2O_3. It can be reduced by hydrogen to give free metal and water. 0.1596 *g* of the metal oxide requires 6 mg of hydrogen for complete reduction. The atomic weight of the metal is
(a) 27.9 (b) 159.6
(c) 79.8 (d) 55.8

110. VD of a metal chloride is 66. Its oxide contains 53% metal. The atomic weight of the metal is
(a) 21 (b) 54
(c) 27.06 (d) 2.086

EXERCISE # 2

Question	One or More Than One Correct Answer Type Questions

1. 1 mol BaF_2 + 2 mol $H_2SO_4 \rightarrow$ resulting mixture will be neutralised by ?

(a) 1 mol of KOH (b) 2 mol of $Ca(OH)_2$
(c) 4 mol KOH (d) 2 mol of KOH

2. 11.2 g of mixture of MCl (volatile) and NaCl gave 28.7 g of white ppt with excess of $AgNO_3$ solution. 11.2 g of same mixture on heating gave a gas that on passing into $AgNO_3$ solution gave 14.35 g of white ppt. Hence ?

(a) Ionic mass of M^+ is 18
(b) Mixture has equal mol fraction of MCl and NaCl
(c) MCl and NaCl are in 1 : 2 molar ratio
(d) Ionic mass of M^+ is 10

3. Which of the following has same percentage of carbon as in ethane -

(a) 2-Butene (b) Cyclohexane
(c) Cyclohexene (d) 2-Methyl but-2-ene

4. 10 g of a sample of silver which is contaminated with silver sulphide produced 11.2 mL of hydrogen sulphide at S.T.P. by treatment with excess of hydrochloric acid. The mass of silver sulphide in the sample is -
(Ag = 108; S = 32)

(a) 1.24 g (b) 124 mg
(c) 5×10^{-4} mol (d) 62 g

5. 2.0 g of a tri-atomic gaseous element was found to occupy a volume of 448ml at 76cm of Hg and 273K. The mass of its atom is ?

(a) 33.3 amu (b) 5.53×10^{-23} g
(c) 33.3 g (d) 5.53 amu

6. 2.4 g of pure Mg (at. mass 24) is dropped in 100ml of 1N HCl. What is true ?

(a) 1.122 L of hydrogen is produced at S.T.P.
(b) 0.01 mol of magnesium is behind
(c) 0.1 mol of Mg^+ ions are formed in solution
(d) HCl is the limiting reagent

7. The mole fraction of NaCl in aqueous solution is 0.2. The solution is -

(a) 13.9 m
(b) Mole fraction of H_2O is 0.8
(c) acidic in nature
(d) neutral

8. When 1.3 mole of butane (C_4H_{10}) is burned in excess of oxygen. What is true about this -

(a) Volume of CO_2 produce at S.T.P. is 116.48 L
(b) Volume CO_2 produce at S.T.P. is 89.6 L
(c) Mass of H_2O produce is 117 g
(d) None of these

9. On amu scale, atomic weight of Ca is 40. If one u is redefined, which of the following would be correct?

(a) Atomic weight of Ca is 20 if one u is defined as $1/6^{th}$ of weight of an atom of C-12
(b) Atomic weight of Ca is 60 if one u is defined as $1/15^{th}$ of weight of an atom of C-12
(c) Atomic weight of Ca is 70 if one u is defined as $1/21^{st}$ of weight of an atom of C-12
(d) Atomic weight of Ca is 80 if one u is defined as $1/30^{th}$ by weight of an atom of C-12

10. Which is/are correct about 4.25 g of NH_3?

(a) it contains 0.25 mole of NH_3
(b) it contains 0.75 mole of H–atoms
(c) it contains total of 0.1 mole of N and H–atoms
(d) it contains 1.5 × 1023 molecules of NH_3

11. A bivalent metal ion (M^{2+}) has equivalent mass of 12. then,

(a) equivalent mass of its oxide is 28
(b) molar mass of its oxide is 40
(c) equivalent mass of its hydride is 13
(d) molar mass of its hydride is 14

12. The atomic number of an element is always equal to

(a) Atomic number
(b) Number of neutrons
(c) Number of electrons
(d) Atomic mass

13. A certain compound has the molecular formula X_4O_6 having 57.2% X. thus,
(a) atomic mass of X is 32
(b) X may contain five valence electrons
(c) X is an electropositive metal
(d) A can be a non–metal

14. In diammonium hydrogen phosphate $(NH_4)_2$ HPO_4, (a fertilliser), percentage as
(a) P_2O_5 is 53.78 (b) NH_3 is 25.76%
(c) N is maximum (d) P is maximum

15. A sample of metal contains 0.516 × 1023 atoms and has a mass of 82.29 g. Select the correct statement(s) for this metal.
(a) it is natural occurring coin metal
(b) it is natural occurring alkaline metal
(c) Atomic mass of the metal is 1947
(d) Given amount has 0.42 mole

16. The molar mass of haemoglobin is about 65000 g mol^{-1}. Every haemoglobin contains 4 iron atoms. Thus,
(a) iron content in haemoglobin is 0.34% by mass
(b) If iron content is increased to 0.56%, molar mass of haemoglobin would be higher than 65000 g mol^{-1}
(c) 1 mole of haemoglobin contains 56 g of iron
(d) 1 mole of haemoglobin contain 224 g of iron

17. In the synthesis of urea (NH_2CONH_2) as given below:
$2NH_3(g) + CO_2(g) \rightarrow NH_2CONH_2(aq) + H_2O(I)$
637.2 g of NH_3 are allowed to react with 1142 g of CO_2. in this
(a) NH_3 is the limiting reactant and CO_2. is in excess
(b) NH_3 is in excess and CO_2 is the limiting reactant
(c) 18.74 moles of urea is formed
(d) 5.00 moles of CO_2 is left unreacted

18. We have 1.6g CH_4, 1.7g of NH_3 and 1.8 g H_2O select the correct alternate(s)
(a) There are equal number of moles of each reactant
(b) Total number of atoms in $CH_4 > NH_3 > H_2O$
(c) Mole fraction of H_2O is maximum if taken in mixture
(d) Mixture contains 0.1 mole of (aq) NH_3 if taken in mixture

19. Density of water 277 K is 1g mL^{-1}. In 1mL H_2O
(a) Molar concentration is 55.56 mol^{-1}
(b) There are 3.33×10^{22} oxygen atoms
(c) There are 3.33×10^{22} oxygen atoms
(d) at 340K, It contains 1 G H_2O

20. RH_2 is an ion exchange resin used to purify water in RO. it can replace Ca^{2+} in hard water.$[H^+] = 0.01M$ in water coming out of ion exchange resin. Thus,
(a) Hardness of water in ppm of Ca^{2+} is 200
(b) Hardness of water in ppm of $CaCO_3$ is 200
(c) 0.280g of CaO is requiresd to remove tempory hardness in 1 L H_2O
(d) 1.06 g of Na2 Co3 is required to remove permanent hardness in 1L H_2O

21. Select the correct statement(s).
(a) The equivalent mass of aluminium phosphate is M/3(M = Molar mass)
(b) The equivalent mass of beryllium hydride is M/2
(c) The equivalent mass of methane is M/4
(d) The equivalent mass of lithium hydride is M

22. Select the correct statement(s)
I. $P_4 + 5O_2 \rightarrow P_4O_{10}$
II. $P_4 + 3O_2 \rightarrow P_4O_6$
One takes 1.24g P_4 and 8.00g O_2 separately for each reaction.
(a) P_4 is the limiting reactant in I and O_2 is the limiting reactant in II
(b) P_4 is the limiting reactant in I and O_2 is the limiting reactant in I
(c) P_4 is the limiting reactant in both
(d) 2.20 g of P_4O_6 in II and 2.84 g of P_4O_{10} in I are formed

23. 2.4g of magnesium is burnt in a closed vessel which contains 0.112 L oxygen at STP. Thus
(a) Equivalent of MgO formed is equal to equivalent which taken
(b) Equivalent of MgO formed is equal to oxygen taken
(c) reactant and product are in equal moles
(d) reactant and product are in equal equivalents

24. Number of molecules present in 16 g O_2 gas is equal to that of

(a) 40g SO_3 (b) 22g CO_2

(c) 8 g CH_4 (d) 14g N_2

25. In the reaction,

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(I)$

when 1 mole of NH_3 and 1 mole of O_2 are allowed to react

(a) 1.0 mole of NO will be formed

(b) 1.0 mole of H2O will be formed

(c) All the O2 will be consumed

(d) All the NH_3 will be consumed

Question | Passage Based Questions

Passage # 1 (Q. 26 to Q.28)

Benzamin franklin did an experiment to estimate molecular size and Avogadros number. He spreaded one tea spoon of oil on water. Volume of oil franklin used was 4.9 c.c and the area covered by oil was 2.0×10^7 cm^2. Density of oil is 0.95 g/c.c and molar mass of oil is 200 gram. It is assumed that the oil molecules are tiny cubes that pack closely together and form a layer only one molecule thick.

26. Length of the side of one molecule is -

(a) 1.7 cm (b) 1.7×10^{-7} cm

(c) 2.45×10^{-7} cm (d) 1.225×10^{-7} cm

27. Number of molecules present in one teaspoon of oil is -

(a) 3.33×10^{20} (b) 3.33×10^{23}

(c) 6.02×10^{23} (d) 1.67×10^{20}

28. Value of Avogadro's number calculated by Benzamin's experiment is -

(a) 6.02×10^{23} (b) 1.43×10^{22}

(c) 6.02×10^{22} (d) 1.43×10^{23}

Passage # 2 (Q. 29 to Q.31)

Questions given below are based on two industrial observations :

(i) Phosphoric acid H_3PO_4, is widely used to make fertiliser & can be prepared by a two step process

Step I : $P_4 + 5O_2 \rightarrow P_4O_{10}$

Step II : $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

We allow 310 gms of phosphorus to react with excess oxygen, which forms tetraphosphorous dioxide P_4O_{10}, in 50 % yield. In sept II reaction 25 % yield of H_3PO_4 is obtained.

(ii) In order to remove organic sulphur from coal, following reactions occur -

X–S–Y+ 2 NaOH $\rightarrow$ X–O–Y+$Na_2S + H_2O$

$CaCO_3 \rightarrow CaO + CO_2$

$Na_2S + CO_2 + H_2O \rightarrow Na_2CO_3 + H_2S$

$CaO + H_2O \rightarrow Ca(OH)_2$

$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$

29. Assume 100 % yield, then number of moles of H_3PO_4 would be obtained -

(a) 1.25 (b) 10.0

(c) 5.0 (d) 2.5

30. Actual number of mole of H_3PO_4 obtained in experiment conditions is -

(a) 5 (b) 2.5

(c) 1.25 (d) 0.3125

31. In processing of 200 kg of coal having 4% sulphur content the weight of lime stone that must be decomposed to provide enough $Ca(OH)_2$ to regenerate the NaOH used in the original leaching step is -

(a) 6.25 kg (b) 12.5 kg

(c) 18.75 kg (d) 25 kg

Passage # 3 (Q. 32 to Q.34)

Cis platin, an anticancer agent used for the treatment of solid tumors, is prepared by the reaction of ammonia with potassium tetrachloroplatinate.

$K_2PtCl_4 + 2NH_3 \rightarrow [Pt(NH_3)_2Cl_2]$ 2KCl

Cis - platin

Assume that 10 gm of K_2PtCl_4 & 10 gm of NH_3 are allowed to react. (K = 39, Pt = 195, Cl = 35.5)

32. Number of moles of K_2PtCl_4 consumed -

(a) 0.048 (b) 0.024

(c) 0.012 (d) 0.096

33. Number of moles of NH_3 consumed -

(a) 0.048 (b) 0.024

(c) 0.096 (d) 0.192

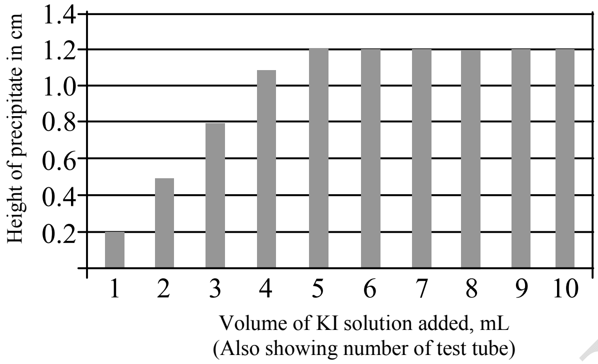
34. Number of moles of excess reactant which remains unreacted is -

(a) 0.024 (b) 0.34

(c) 0.54 (d) 0.56

Passage # 4 (Q. 35 to Q.38)

The following chart shows the height of a secret metal iodide precipitate that was formed in a series of 10 test tubes. Each test tube contained 3.0 mL of a metal nitrate solution (1.0 mol L^{-1} with respect to the metal ions). Measured volumes of 1.0 mol L^{-1} potassium iodide (KI) solution were added to each tube in turn to form the precipitate.



35. What is the formula of the metal iodide according to this chart ?

(a) MI_4 (b) MI

(c) MI_2 (d) MI_3

36. If the height of precipitate in test tubes 4 and 6 are considered to be authentic one, which test tubes are reporting wrong height of precipitate ?

(a) 1 and 2 (b) 2 and 3

(c) 2 and 5 (d) 5, 7, 8, 9 and 10

37. The molarity of I^- (aq) ion in the 9th test tube is

(a) 1.0 M (b) 0.5 M

(c) 0.33 M (d) 0.25 M

38. The constancy in height of precipitate after addition of 6.0 mL or higher volume of KI solution indicates that -

(a) the solution has become saturated in KI

(b) the weighing limit of balance has been exceeded

(c) the entire metal ion has been precipitated out

(d) the information available are insufficient to interpret this very observation

Passage # 5 (Q. 39 to Q.44)

The domestic water supply is treated by bleaching powder to remove unhygienic species in water and to make it safe for drinking water. However, this give rise to Ca^{2+} and Cl^- ion contamination in water. Both these ions are also injurious for health if a minimum concentration is crossed. The chloride ions are tested by a kit provided by many companies having $AgNO_3$ solution that is added drop by drop to 23 mL of water sample to which an indicator has been added. When sufficient silver nitrate is added to remove Cl^- ions as AgCl solid, the solid turns orange. The colour change is noticed by addition of $AgNO_3$ having molar concentration such that each drop (0.05 mL) of $AgNO_3$ converts 12.5 mg of Cl^- ions AgCl.

39. If 12 drops of $AgNO_3$ solution are used to reach the colour point, what mass of chloride ion is present in one litre sample :

(a) 6.52 g (b) 0.150 g

(c) 0.125 g (d) 1.25 g

40. The molar concentration of Cl^- in the sample of water used is :

(a) 4.225×10^{-3} M (b) 7.04×10^{-3} M

(c) 3.521 M (d) 0.1837 M

41. The molar concentration of $AgNO_3$ solution if one drop of $AgNO_3$ measure 0.05 mL is :

(a) 0.1837 M (b) 7.04×10^{-3}M

(c) 150 M (d) 3.52 M

42. Assuming that concentration of Ca^{2+} ions in solution is in equal equivalence ratio to chloride ions, the hardness of water is :

(a) 9.180×10^3 ppm

(b) 6.180×10^3 ppm

(c) 12.180×10^3 ppm

(d) 4.180×10^3 ppm

43. If all the Ca^{2+} ions are replaced by H^+, the pH of the solution would be :

(a) 0.7359 (b) 0.1837

(c) 0.3259 (d) 0.5359

44. The number of Ag^+ ion in one drop of silver nitrate solution is :

(a) 2.12×10^{20} (b) 7.2×10^{20}

(c) 7.2×10^{21} (d) 7.2×10^{19}

Passage # 6 (Q. 45 to Q.49)

Atomicity of an element is defined as the number of atoms of an element in its one molecule for example atomicity of He, N_2, O_3 are 1, 2, 3 respectively. The atomicity can be determined by calculating experimental value of observed atomic mass and then dividing by its normal atomic mass. Atomic mass of a metal is obtained by Dulong petits law. Atomic mass is the relative mass of atom of an element as compared to the mass of one ^{12}C atom. Average atomic mass of an element is due to the average of masses of its different isotopese.

45. An element has atomic mass 31. Mass of 1.12 litre at STP of vapours of this element weighs 6.2 g. The atomicity of this element is :

(a) 4 (b) 2
(c) 6 (d) 8

46. Atomic masses of most of the elements are fractional because of :

(a) mass is due to the sum of masses of p, n, e in it which are fractional
(b) average atomic mass of different isotopes of elements
(c) mass of ^{12}C is in fraction
(d) none of these

47. The specific heat of metal is 0.67 J/g. Its equivalent mass is 20. Its exact atomic mass is :

(a) 46.33 (b) 20
(c) 40 (d) 22

48. Naturally occurring B consists of two isotopes, whose atomic masses are 10.01 and 11.01. The atomic mass of natural boron is 10.81. The % of each isotope in natural boron.

(a) $^{10}B = 20\%$, $^{11}B = 80\%$
(b) $^{10}B = 80\%$, $^{11}B = 20\%$
(c) $^{10}B = 40\%$, $^{11}B = 60\%$
(d) $^{10}B = 60\%$, $^{11}B = 40\%$

49. The abundance of three isotopes of oxygen, each containing 8, 9, 10 neutrons respectively has the % of one isotope (containing 8 neutrons) 90%. The other % if the atomic mass of oxygen is 16.12 are :

(a) $^{17}O = 8\%$, $^{18}O = 2\%$
(b) $^{17}O = 2\%$, $^{18}O = 8\%$
(c) $^{17}O = 10\%$, $^{18}O = 0\%$
(d) $^{17}O = 4\%$, $^{18}O = 6\%$

Passage-7 (Question 50 to 51) :

Mass percentage of Na_2SO_3 and H_2O are equal in $Na_2SO_3 \cdot xH_2O$.

50. How many water molecules are contained in on formula unit of salt ?

(a) 5 (b) 6
(c) 7 (d) 8

51. Select the correct statement

(a) Number of atoms in anhydrous salt is equal to number of water molecules in hydrated salt
(b) There are total 28 atoms in one formula units
(c) There are total 10 oxygen atoms in one formula unit
(d) All above the correct statements

EXERCISE # 3

Question | **Column Match Type Questions**

1. Match the Column

Column-I		Column-II	
(A)	Concentration units in dependent of temperature variation	(i)	Molality
(B)	Concentration units dependent on temperature variation	(ii)	Molarity
(C)	Mg of solute present in 1 kg of solution represent	(iii)	ppm concentration
(D)	Moles of solute present in 1 kg of solvent represent	(iv)	Moles of solute in hundred moles of solution

2. Match the column

Column-I		Column-II	
(A)	On decomposition 50% increase in volume at the same temperature and pressure	(i)	NH_3
(B)	On decomposition 100% increase in volume at the same temperature and pressure	(ii)	HCl
(C)	ON decomposition no change in volume at the same temperature and pressure	(iii)	O_3
(D)	Gases highly soluble in water	(iv)	HBr

3. Experimental determination of molar mass of compounds may be made by the following methods. Match them properly. More than one match are possible :

Column-I	**Column-II**
(A) Gases	(i) Victor Meyer's method
(B) Volatile liquids	(ii) Hofmann's method
(C) Non volatile solids	(iii) Duma's method
(D) Solids of low m. mass	(iv) Ebullioscopy or cryoscopy
(E) Solids of high m. mass	(v) Osmotic pressure Such as polymers
	(vi) Raoult's law

4. Match list A with list B. More than one match are possible :

Column-I	**Column-II**
(A) 1.8 mL H_2O_l	(i) $\frac{1}{10}N_A$ molecules of H_2O (d = 1g / mL)
(B) 1.8 mL H_2O_vn at STP	(ii) 2.24 litre at STP H_2O_v
(C) 8.03×10^{-5} mole $H_2O_{(v)}$	(iii) 1.8 g of H_2O_l
	(iv) 1.446×10^{-3} g H_2O
	(v) 4.84×10^{19} molecules of H_2O

5. Equal mass (1 g) of CH_4, O_2, SO_2 and SO_3 are taken separately. Match the number of moles of these species in Column II and select answer from the codes.

Column - I	**Column-II**
(A) CH_4	(i) 1.0/80
(B) O_2	(ii) 1.25/80
(C) SO_2	(iii) 2.5/80
(D) SO_3	(iv) 5/80

Codes :

	(A)	**(B)**	**(C)**	**(D)**
(a)	(i)	(ii)	(iii)	(iv)
(b)	(iv)	(iii)	(ii)	(i)
(c)	(iv)	(iii)	(i)	(ii)
(d)	(iii)	(iv)	(ii)	(i)

6. Match the quantitative properties of the compounds in column I with the compounds in column II and select the answer for the codes given below.

Column I		Column II	
i.	identical % of C	p.	HCHO
ii.	identical % of H	q.	$C_6H_{12}O_6$
iii.	identical % of O	r.	CH_3COOH
iv.	Same molar mass	s.	NH_2CONH_2

Codes

	I	II	III	IV
(a)	(p, q, r)	(p, q, r, s)	(p, q, r)	(r, s)
(b)	(p, q, r)	(p, q, s)	(p, q, r)	(r, s)
(c)	(p, s)	(q, s)	(r, s)	(p, q)
(d)	(p, r)	(q, r)	(p, r, s)	(q, s)

7. Match of the compounds (1 mole each) in column I with corresponding properties in column II and select answer from the codes given below.

Column I		Column II	
i.	H_2SO_4	p.	60 g mol^{-1}
ii.	H_3PO_4	q.	98 g mol^{-1}
iii.	H_3PO_3	r.	N_0 ionisable H^+ ions
iv.	H_3PO_2	s.	$2N_0$ ionisable H^+ ions
v.	CH_3COOH	t.	$3N_0$ ionisable H^+ ions
vi.	NH_2CONH_2	u.	$4N_0$ H^+ atoms

Codes

	I	II	III	IV	V	VI
(a)	(q, r)	(q, t)	(t)	(r)	(r, u)	(p, u)
(b)	(q, r)	(q, t)	(t)	(t)	(p,r,u)	(p, u)
(c)	(q, s)	(q, t)	(s)	(r)	(p, r, u)	(p, u)
(d)	(q)	(q, t)	(t)	(t)	(r, u)	(p, u)

8. Match the gases in column I with their corresponding properties in column II and select answer from the codes given.

Column I		Column II	
i.	H_2 gas	p.	$2N_0$ atoms g mol^{-1}
ii.	O_2 gas	q.	Specific heat ratio 1.40
iii.	N_2 gas	r.	0.8 L g^{-1} at STP
iv.	CO_2 gas	s.	Lightest gas
v.	HCl gas	t.	Heaviest gas

Codes

	I	II	III	IV	V
(a)	(p, q, s)	(p, q)	(p, q, r)	(p, q, r)	(p, q, t)
(b)	(p, q, s)	(p, q)	(t)	(t)	(p, q)
(c)	(q, s)	(p, q)	(q)	(q, r)	(p)
(d)	(p)	(q)	(r)	(s)	(t)

9. Match the percentage of carbon in column I with the compounds in column II and select the answer for the codes given below.

Column I		Column II	
i.	20%	p.	Acetic acid
ii.	40%	q.	Urea
iii.	27%	r.	Corbon dioxide
iv.	75%	s.	formaldehyde
		t.	methane

Codes

	I	II	III	IV
(a)	(q)	(p, s)	(r)	(t)
(b)	(q)	(s)	(r)	(t)
(c)	(p)	(t)	(s)	(r)
(d)	(q)	(s)	(r)	(p, t)

10. Match the laws of chemical combination in column I with the examples followed in column II and select the answer for the codes given below.

Column I		Column II	
i.	law of conservation of mass	p.	CH_4 has carbon and hydrogen in 3 : 1 mass ratio.
ii.	law of multiple proportion	q.	10 mL N_2 combiness with 30 mL of H_2 to from 20 mL of NH_3
iii.	law of definite proportion	r.	S and O_2 combaine to from SO_2 and SO_3.
iv.	law of reciprocal proportion	s.	in H_2S and SO_2 mass ratio of H and O wrt sulphur is 1 : 16, Hence in H_2O, mass ratio if H And O is 1 : 8.
v.	Gas Lussac's Law	t.	4.2 g $MgCO_3$ gives 2.0 g of residue on heating

Codes

	I	II	III	IV
(a)	(q)	(p, s)	(r)	(t)
(b)	(q)	(s)	(r)	(t)
(c)	(p)	(t)	(s)	(r)
(d)	(q)	(s)	(r)	(p, t)

Question	Numerical Questions

11. A given mixture consists only of pure substance X and pure substance Y. The total weight of the mixture is 3.72 gm. The total number of moles is 0.06. If the weight of one mole Y is 48 gm and if there is 0.02 mole X in the mixture, what is the value of $\frac{\text{weight of one mole of X}}{10}$?

12. A mixture of CuO and Cu_2O contain 88% Cu. What is the approx. percentage of CuO present in the mixture ?

13. NaBr, used to produce AgBr for use in photography can itself be prepared as follows :
$Fe + Br_2 \rightarrow FeBr_2$
$FeBr_2 + Br_2 \rightarrow Fe_3Br_8$
(not balanced)
$Fe_3Br_8 + Na_2CO_3 \rightarrow NaBr + CO_2 + Fe_3O_4$
(not balanced)
How much Fe in kg is consumed to produce 2.50 kg NaBr.

14. A compound which contains one atom of X and two atoms of Y for each three atoms of Z is made by mixing 5.00 g of X, 1.15×10^{23} atoms of Y and 0.03 mole of Z atoms. Given that only 4.40 g of compound results. Calculate the value of $\frac{\text{atomic weight of Y}}{10}$ if the atomic weight of X and Z are 60 and 80 a.m.u. respectively.

15. 7.5 ml of a gaseous hydrocarbon was exploded with 36 ml of oxygen. The volume of gases on cooling was found to be 28.5 ml. 15 ml of which was absorbed by KOH and the rest was absorbed in solution of alkaline pyrogallol. If all volumes are measured under same conditions, if formula of the hydrocarbon isC_xH_y then value of Y.

16. A drop (0.5 mL) of 12.0 M HCl is spread over a sheet of thin aluminium foil. Assuming that all the acid dissolves through the foil, what will be the value of (area × 10), in cm^2, of the hole produced? (Density of Al = 2.70 g cm^{-3} ; thickness of the foil = 0.10 mm)

17. One mole of a mixture of CO and CO_2 requires exactly 20 gram of NaOH in solution for complete conversion of all the CO_2 into Na_2CO_3. How many grams more of NaOH would it require for conversion into Na_2CO_3 if the mixture (one mole) is completely oxidised to CO_2 ? Given answer in terms of grams/10.

18. Polyethylene can be produced from CaC_2 according to the following sequence of reactions
$CaC_2 + H_2O \rightarrow CaO + C_2H_2$
$C_2H_2 + H_2 \rightarrow C_2H_4$
$nC_2H_4 \rightarrow (CH_2CH_2)_n$
Calculate mass of polyethylene which can be produced from 20 kg of CaC_2. % Yield of each step is 50%.

19. How many moles of CH_4 are contained in 2.408×10^{25} atoms of CH_4

20. A coloured dye of molar mass 20000 g mol^{-1} is found to contain 0.84% Fe. Thus, number of Fe-atoms in one formula unit of dye is........ .

21. An alkene occupies 0.8 L g^{-1} at STP. Thus, total number of atoms of carbon and hydrogen in one formula unit are........

22. Atomic weight of Al on a non-conventional scale is found to be 18 while on conventional scale, it is 27. On the new scale an amu is defined as $\left(\frac{1}{x}\right)^{th}$ part by weight of C-12. Here x is.

23. If a protein has 0.07% Fe (M = 56) by weight as the only metal, its molar mass would be at least $M \times 10^4$ g. Here M is.

24. If 5 g H_2 is mixed with 14 g of nitrogen for the following reaction :
$N_2 + 3H_2 \rightarrow 2NH_3$
At the end, mass of H_2 left unreacted is.

25. Find the number of g-molecules of oxygen in 6.023×10^{24} CO molecules -

26. Haemoglobin contains 0.33% of iron by weight. The molecular weight of haemoglobin is approximately 67200. The number of iron atoms (at wt. of Fe = 56) present in one molecule of hemoglobin are -

27. The formula of a gas is [CO]x. If vapour density is 70, the value of x will be.

28. 2 moles of H_2S and 1.2 L SO_2 at STP react to form x moles of S in the following reaction,

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

Thus 2x is

29. Based on the following consecutive reactions

$$2KIClO_3 \longrightarrow 2KCl + 3O_2$$

$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

2 moles of $KClO_3$, of 50% purity on strong heating and then with excess of Al,Al_2O_3 formed is

30. In the following reaction, $2A + 2B \longrightarrow C$

8 mole of A and 5 moles of B will form

31. NH_3 is formed in the following step :

(i) $Ca + 2C \longrightarrow CaC_2$ (50% yield)

(ii) $CaC_2 + N_2 \longrightarrow CaCN_2 + C$ (100% yield)

(iii) $CaCN_2 + 3H_2O \longrightarrow 2NH_3 + CaCO_3$(50% yield)

2 moles of NH_3 are formed if we take

32. 1 mole BAF_2 is treated with 2 moles of H_2SO_4. Resultant solution is neutralized by

33. Mixture containing 2 mole each of $NaHCO_3$, Li_2CO_3 and Na_2CO_3 is heated strongly. CO_2 formed in this process will be

EXERCISE # 4

Question | **Previous Year (JEE Mains)**

1. How many moles of magnesium phosphate, $mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms ? **[AIEEE-2002]**
(a) 1.25×10^{-2} (b) 2.5×10^{-2}
(c) 0.02 (d) 3.125×10^{-2}

2. In a compound C, H and N atoms are present in 9 : 1 : 3.5 by weight. Molecular weight of compound is 108. Molecular formula of compound is **[AIEEE-2002]**
(a) $C_2H_6N_2$ (b) C_3H_4N
(c) $C_6H_8N_2$ (d) $C_9H_{12}N_3$.

3. Number of atoms in 558.5 gram Fe
(at. Wt. of Fe = 55.85 g mol^{-1}) is **[AIEEE-2002]**
(a) twice that in 60 g carbon
(b) 6.023×10^{22}
(c) half that in 8 g He
(d) $558.5 \times 6.023 \times 10^{23}$

4. What volume of hydrogen gas, at 273K and 1atm. Pressure will be consumed in obtaining 21.6 g elemental boron(atomic mass = 10.8) from the reduction of boron trichloride by hydrogen ? **[AIEEE-2003]**
(a) 67.2 L (b) 44.8 L
(c) 22.4 L (d) 89.6 L

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

6. In the reaction, **[AIEEE-2007]**
$2Al(s) + 6HCl(aq) \rightarrow 2Al^{3+}(aq) + 6Cl^{-}(aq) + 3H_2(g)$
(a) 11.2 L $H_2(g)$ at STp is produced for every mole HCl(aq) consumed
(b) 6 L $H_2(g)$ is consumed for every 3 L $H_2(g)$ produced
(c) 33.6 L $H_2(g)$ is produced regardless of temperature and pressure for every mole Al that reacts
(d) 67.2 L $H_2(g)$ at SPT is produced for every mole Al that reacts.

7. A gaseous hydrocarbon gives upon combustion 0.72 g of water and 3.08 g of CO_2. the empirical formula of the hydrocarbon is : **[JEE MAINS-2013]**
(a) C_2H_4 (b) C_3H_4
(c) C_6H_5 (d) C_7H_8

8. Experimentally it was found that a metal oxide has formula $M_{0.978}O$. Metal M, present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be **[JEE MAINS-2013]**
(a) 7.01% (b) 4.08%
(c) 6.05% (d) 5.08%

9. The most abundant elements by mass in the body of a healthy human adult are:
Oxygen (61.4%); Carbon (22.9%), Hydrogen (10.05); and Nitrogen (2.6%). The weight which a 75kg person would gain if all ^1H atoms are replaced by ^2H atoms is **[JEE MAINS-2017]**
(a) 15 kg (b) 37.5 kg
(c) 7.5 kg (d) 10 kg

10. 1 gram of a carbonate (M_2CO_3) on treatment with excess HCl produces 0.01186 mole of CO_2. The molar mass of M_2CO_3 in g mol^{-1} is : **[JEE MAINS-2017]**
(a) 1186 (b) 84.3
(c) 118.6 (d) 11.86

11. The ratio of mass percent of C and H of an organic compound ($C_XH_YO_Z$) is 6 : 1. If one molecule of the above compound ($C_XH_YO_Z$) contains half as much oxygen as required to burn one molecule of compound CXHY completely to CO_2 and H_2O. The empirical formula of compound $C_XH_YO_Z$ is : **[JEE MAINS-2018]**
(a) $C_3H_6O_3$ (b) C_2H_4O
(c) $C_3H_4O_2$ (d) $C_2H_4O_3$

12. For a reaction,
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$; indentify dihyodrogen (H_2) as a limiting reagent in the following reaction mixtures. **[JEE MAINS APRIL-2019]**
(a) 56 g of N_2 + 10g of H_2
(b) 35 g of N_2 + 8g of H_2
(c) 28 g of N_2 + 6g of H_2
(d) 14 g of N_2 + 4g of H_2

Question | **Previous Year (JEE Advanced)**

13. At 100ºC and 1 atm, if the density of liquid water is 1.0 g cm^{-3} and that of water vapor is 0.0006 g cm^{-3}, then the volume occupied by water molecules in 1 litre of steam at that temperature is - **[IIT 2000]**

(a) 6 cm^3 (b) 60 cm^3
(c) 0.6 cm^3 (d) 0.06 cm^3

14. How many moles of electron weight one kilogram ? **[IIT 2002]**

(a) 6.023×10^{23} (b) $\frac{1}{9.108} \times 10^{31}$

(c) $\frac{6.023}{9.108} \times 10^{54}$ (d) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

15. A 2L solution (X) contain 0.02 mole of $[Co(NH_3)_5SO_4]Br$ and 0.02 mol $[Co(NH_3)_5 Br] SO_4$. 1 L of this solution is - **[IIT 2003]** taken :

$X + AgNO_3$ (excess) $\rightarrow$ Y mol AgBr $\downarrow$

$X + BaCl_2$ (excess) $\rightarrow$ Z mol $BaSO_4 \downarrow$

Values of Y and Z are -

(a) 0.01, 0.02 (b) 0.02, 0.02
(c) 0.02, 0.01 (d) 0.01, 0.01

16. In which of the following number of atoms are maximum ? **[IIT 2003]**

(a) 24 gms C
(b) 27 gms of Al
(c) 56 gms of Fe
(d) 108 gms of Ag

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

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

18. A student performs a titration with different burettes and find titre values of 25.2 mL, 25.25 mL, and 25.0 mL. The number of significant figures in the average titre value is **[IIT 2010]**

19. Silver (atomic weight = 108 g mol^{-1}) has a density of 10.5 g cm^{-3}. The number of silver atoms on a surface of area 10^{-12} m^2 can be xpressed in scientific notation as $y \times 10^x$. The value of x is : **[IIT 2010]**

20. If the value of Avogadro number is 6.023×10^{23} mol^{-1} and the value of Boltzmann constant is 1.380×10^{-23} JK^{-1}, then the number of significant digits in the calculated value of the universal gas constant is **[IIT 2014]**

21. The ammonia prepared by treating ammonium sulphate with calcium hydroxide is completely used by $NiCl_2$, $6H_2O$ to form a stable coordination compound. Assume that both the reactions are 100% complete. If 1584 g of ammonium sulphate and 952 g of $NiCl_2.6H_2O$ are used in the preparation, the combined weight (in grams) of gypsum and the nickel-ammonia coordination compound thus produced is_______.
(Atomic weights in g mol^{-1}: H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Ca = 40, Ni = 59). **[IIT 2018]**

22. Galena (an ore) is partially oxidized by passing air through it at high temperature. After some time, the passage of air is stopped, but the heating continued in a closed furnace such that the contents undergo self-reduction. The weight (in kg) of Pb produced per kg of O_2 consumed is___.
(Atomic weights in g mol^{-1} : O = 16, S = 32, Pb = 207) **[IIT 2018]**

ANSWER KEY & SOLUTIONS

EXERCISE-1

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	b	a	a	b	b	d	d	c	c	c	a	b	a	b	a	c	d	c	b	c
Qus.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	d	a	a	b	a	a	b	b	a	a	c	d	a	c	c	d	c	b	d	d
Qus.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	b	c	d	a	b	a	a	d	a	d	b	a	a	b	b	c	c	a	d	b
Qus.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	a	c	a	a	a	a	a	d	a	b	b	a	a	b	d	a	b	b	a	a
Qus.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	b	c	d	a	c	b	c	c	c	d	a	b	a	c	c	a	c	d	a	b
Qus.	101	102	103	104	105	106	107	108	109	110										
Ans.	a	c	c	a	b	c	a	b	d	c										

EXERCISE-2

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	b,c	a,b	a,b,d	b,c	a,b	a,d	a	a,c	a,c	a,b,c,d	b,c	c,d	a,b,d	a,b	a,c,d
Qus.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	a,d	a,c	a,b,d	a,b,c	a,c	a,b,c,d	a,c	b	a,b,c,d	c	c	a	b	b	c
Qus.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	d	b	a	c	c	c	d	c	a	d	b	d	a	a	a
Qus.	46	47	48	49	50	51									
Ans.	a	c	a	a	c	c									

EXERCISE-3

1. A $\rightarrow$ (i, iii, iv) B $\rightarrow$ (ii) C $\rightarrow$ (iii), D $\rightarrow$ (i)   **2.** A $\rightarrow$ (iii) B $\rightarrow$ (i, iv) C $\rightarrow$ (ii), D $\rightarrow$ (i, ii, iv)

3. A $\rightarrow$ (i, iii, iii) B $\rightarrow$ (vi) C $\rightarrow$ (vi), D $\rightarrow$ (iv); E $\rightarrow$ (v)   **4.** A $\rightarrow$ (i, iii) B $\rightarrow$ (i, ii) C $\rightarrow$ (iv, v)

5. [b] **6.** [a] **7.** [c] **8.** [b] **9.** [a] **10.** [a] **11.** [9] **12.** [9] **13.** [5]
14. [7] **15.** [4] **16.** [2] **17.** [6] **18.** [1] **19.** [8] **20.** [3] **21.** [6] **22.** [8]
23. [8] **24.** [2] **25.** [5] **26.** [4] **27.** [5] **28.** [3] **29.** [2] **30.** [5] **31.** [4]
32. [4] **33.** [3]

EXERCISE-4

1. [d] **2.** [c] **3.** [a] **4.** [a] **5.** [d] **6.** [a] **7.** [d] **8.** [b] **9.** [c] **10.** [b]
11. [d] **12.** [a] **13.** [c] **14.** [d] **15.** [d] **16.** [a] **17.** [b] **18.** [3] **19.** [7] **20.** [4]
21. [2992] **22.** [6.47]