SOME BASIC CONCEPT

CONCEPT OF ATOMS AND MOLECULES

1.(a) ATOMS

Smallest neutral particles of matter which produce elements by aggregation. The fact that all substances obeyed the laws of chemical combination by weight made the scientists to speculate about the ultimate particles of matter. The most famous of these speculations is due to John Dalton.

Dalton's Atomic Theory

The main postulates of this atomic theory are

I. Matter is discrete (i.e. discontinuous) and is made up of atoms *An atom is the smallest (chemically) indivisible particle of an element, which can take part in a chemical change.*

II. Atoms of the same element are identical in all respect, size, shape, structure etc. and especially weight.

III. Atoms of different elements have different properties and different weights.

IV. Atoms cannot be created or destroyed. So a chemical reaction is nothing but a rearrangement of atoms and the same number of atoms must be present before and after the reaction.

V. A compound is formed by the union of atoms of one element with atoms of another in a fixed ratio of small whole number (1 : 1, 1 : 2, 2 : 3 etc.).

All the postulates of Dalton's atomic theory have been proved to be incorrect.

An atom is divisible in the sense that it has a structure. Sub-atomic particles are known.

The existence of isotopes for most elements shows that atoms of the same element need not have the same mass. The atomic weight of an element is, in fact, a mean of the atomic masses of the different isotopes of the element.

Parts of atomic mass can be destroyed and an equivalent amount of energy is released during nuclear fission.

Atoms combine is fixed integral ratios; however, there are instances where atoms combine in non-integral ratios. e.g. in zinc oxide, zinc oxide, zinc and oxygen have not combined in exactly an integral ratio. The atomic ratio of Zn : O (1 + x) : 1, where x is a very small fraction. Compounds of this kind are called non-stoichiometric compounds or Berthollide compounds as against compounds whose formulae are in accordance with atomic theory and Proust's law of definite proportions.

1.(b) ATOMIC WEIGHTS

An atom is so minute that it cannot be detected even with the most powerful microscope, let alone placed on a balance pan and weighed. So there is no question of determining the absolute weight of an atom. .It tells us that a given atom is how many times heavier than that of 1/12th of one atom of ^{12}C.

The modern reference standard for atomic weights is carbon isotope of mass number 12.

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

On this basis, atomic weight of oxygen 16 was changed to 15.9994.

Now days atomic weight is called relative atomic mass and denoted by amu (atomic mass unit). The standard for atomic mass is C^{12}.

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I. Atomic weight is not a weight but a number

II. Atomic weight is not absolute but relative to the weight of the standard reference element (C^{12}).

III. Gram atomic weight is atomic weight expressed in grams, but it has a special significance with reference to a mole.

Dulong and Petit measured the specific heats of a number of metals and found that the product of the specific heat and the atomic weight in a constant, having an approximate value of 64.

Specific heat (cal/g–deg) $\times$ atomic weight (g/g – atom) = 6.4 (cal/deg.g.atom).

This correlation has been used to 'correct' the atomic weights of some elements in the periodic table. Dulong and Petit's law is applicable only to metals.

1.(c) THE MOLECULE

An independent smallest entity of a substance which posses which all its physical and chemical props. is known as 'molecule. Avogadro (1811) suggested that the fundamental chemical unit is not an atom but a molecule, which may be a cluster of atoms held together in some manner causing them to exist as a unit. The term molecule means the smallest particle of an element or a compound that can exist free and retain all its properties.

Consider a molecule of sulphur dioxide. It has been established that it contains one atom of sulphur and two atoms of oxygen. This molecule can be split up into atoms of sulphur and oxygen. So the smallest particle of sulphur dioxide that can exist free and retain all its properties is the molecule of sulphur dioxide. A compound molecule should contain at least 2 different atoms.

The term molecule is also applied to describe the smallest particle of an element which can exist free. Thus a hydrogen molecule is proved to contain 2 atoms; when it is split up into atoms there will be observed a change in properties (You may know that nascent hydrogen which may be thought of as atomic hydrogen is a more powerful reducing agent than ordinary hydrogen).

Molecules of elementary gases like hydrogen, oxygen, nitrogen, chlorine, etc., contain 2 atoms in a molecule; they are diatomic. Molecules of noble gases like helium, neon, argon, krypton and xenon are monatomic. Molecules of phosphorus contain 4 atoms (tetratomic) while those of sulphur contain 8 atoms.

The number of atoms of an element in a molecule of the element is called its atomicity.

1.(d) MOLECULAR WEIGHT

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

$$\text{Molecular weight} = \frac{\text{Weight of 1 molecule}}{\frac{1}{12} \times \text{weight of 1 carbon-12 atom}}$$

I. Molecular weight is not a weight but a number.

II. Molecular weight is relative and not absolute

III. Molecular weight expressed in grams is called gram-molecular weight

IV. Molecular weight is calculated by adding all the atomic weights of all the atoms and a molecule. Thus, the molecular weight of oxygen which contains 2 atoms in a molecular would be (2×16)=32. The molecular weight of carbon dioxide, which contains 1 atom of carbon and 2 atoms of oxygen would be $[(12+ (2 \times 16)] = 44$. Molecular weight of sulphur acid, which contains 2 atoms of hydrogen, 1 atom of sulphur and 4 atoms of oxygen is $[(2 \times 1) + (1 \times 32) + (4 \times 16)] = 98$.

V. Molecular weight is now called relative molecular mass.

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1.(e) AVOGADRO'S HYPOTHESIS

It states that equal volume of gases at the same temperature and pressure contain equal number of molecules. It means that 1 ml of hydrogen, oxygen, ammonia, or a mixture of gases taken at the same temperature and pressure contains the same number of molecules.

Application of Avogadro's hypothesis

(i) To prove that simple elementary gas molecules are diatomic.

Consider the experimental result,

1 volume of hydrogen + 1 volume of chlorine $\rightarrow$ 2 volumes of hydrogen chloride at the same temperature and pressure

1 volume contains 'n' molecules. Then n molecules of hydrogen + n molecules of chlorine $\rightarrow$ 2n molecules of hydrogen chloride

Cancelling the common 'n' we have 1 molecule of hydrogen + 1 molecule of chlorine $\rightarrow$ 2 molecules of hydrogen chloride.

A Molecule of hydrogen chloride should contain at least 1 Atom of hydrogen and 1 Atom of chlorine. Two molecules of hydrogen chloride should contain at least 2 atoms of hydrogen and 2 atoms of chlorine and these should have come from 1 molecule of hydrogen and 1 molecule of chlorine respectively. Thus Avagadro's hypothesis enables us to establish that hydrogen and chlorine molecules must contain at least 2 atoms (Measurement of the ratio of specific heats of these gases at constant pressure and at constant volume, $C_p/C_v = 1.4$, establishes that these gases are diatomic).

(ii) To establish the relationship between molecular weight and vapour density of a gas. The absolute density of gas is the weight of 1 litre (dm^3) of the gas at S.T.P.

[Standard Temperature (0^0C) and pressure (1 atmosphere)]

The relative density of vapour density of a gas $= \dfrac{\text{Density of the gas}}{\text{Density of hydrogen}}$

Vapour density of a gas $= \dfrac{\text{Weight of 1 litre of gas at STP}}{\text{Weight of 1 litre of hydrogen at STP}}$

$$= \frac{\text{Weight of certain volume of the gas}}{\text{Weight of the same volume of hydrogen at the same temperature and pressure}}$$

So the vapour density of a gas is defined as the ratio of the weight of a certain volume of the gas to the weight of the same volume of hydrogen at the same temperature and pressure.

Vapour density (V.D.) of a gas

$$= \frac{\text{Weight of 'V' litres of the gas}}{\text{Weight of 'V' litres of hydrogen at the same temperature and pressure}}$$

Let 'V' litres of the gas contains 'n' molecules

$$\text{V.D. of gas} = \frac{\text{Weight of 'n' molecules of the gas}}{\text{Weight of 'n' molecules of hydrogen}} = \frac{\text{Weight of 'n' molecules of the gas}}{\text{Weight of 'n' molecules of hydrogen}}$$

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$$\text{V.D.of gas} = \frac{\text{Weight of 1 molecules of the gas}}{\text{Weight of 2 atom of hydrogen}} = \frac{1}{2} \times \frac{\text{Weight of 1 molecules of the gas}}{\text{Weight of 1 atom of hydrogen}}$$

$$\text{V.D. of a gas} = \frac{1}{2} \times \text{Molecular weight of the gas}$$

$\therefore$ Molecular weight of the gas = 2 $\times$ vapour density of the gas

(iii) Gram-Molecular volume or molar volume

$$\text{Molecular weight of a gas} = 2 \times \frac{\text{Weight of 1 Lof the gas at STP}}{\text{Weight of 1L of hydrogen at STP}}$$

$$\text{Molecular weight of a gas} = 2 \times \frac{\text{Weight of 1 Lof the gas at STP}}{0.089 \text{ g}}$$

$$\text{Gram-Molecular weight of a gas} = \frac{2}{0.089} \times \text{weight of 1 L of the gas at STP}$$

Gram-Molecular weight of a gas = 22.4 $\times$ Weight of 1 L of he gas at STP

= Weight of 22.4 L of the gas at STP

This establishes that gram-molecular weight of any gas (or vapour) occupies the same volume of 22.4 L at S.T.P. The volume occupied by a gram-molecular weight of any gas is called a molar volume and its value is 22.4 L at STP

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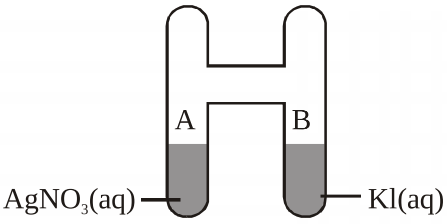
LOWS OF CHEMICAL COMBINATION

2.(a) LAWS OF CONSERVATION OF MASS

The great french chemist, Antoine Laurent Lavoisier stated " matter is neither created nor destroyed during the course of chemical reaction, it may change from one form to another. For example $AgNO_3$(aq) and Kl(aq) are filled in the limbs A & B respectively of a H-shaped tube. Now reactants are allowed to react according to following reaction.

$$AgNO_3 + Kl \rightarrow Agl + KNO_3$$



The mass of H-shaped tube before and after the reaction was found to be same. This implies that the mass remain conserved as atoms are neither created nor destroyed during a chemical reaction. This is the law of conservation of mass.

QUESTION :– 8.4 g of sodium bicarbonate was added to 6.0 g of acetic acid. Carbon dioxide gas was produced which was allowed to escape and weight of the residue was 10 g. What mass of CO_2 escaped out into the atmosphere ?

$$NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + H_2O + CO_2$$

ANSWER : –

According to the law of conservation of mass,

Total mass before the reaction = Total mass after the reaction

Mass of $NaHCO_3$ + mass of CH_3COOH = mass of residue ($CH_3COONa + H_2O$) + mass of CO_2

$8.4 + 6.0 = 10.0+$ mass of CO_2

Mass of CO_2 = 4.4 g

2.(b) LAW OF CONSTANT (OR DEFINITE) PROPORTION

Proust a chemist stated that " A pure chemical compound, irrespective of its source always contain the same elements combined together in the same proportion by mass. For example, carbon dioxide gas has the formula CO_2 and one molecule of CO_2 always contain one atom of carbon and two atoms of oxygen, or we can say 44 g of CO_2 always contain 12 g of carbon and 32 g of oxygen, from whatever source we obtain it.

QUESTION :– 10.8 g of copper wire was allowed to react with nitric acid. The resulting solution was dried and ignite when 1.35 g of CuO was obtained. In another experiment, 2.30 g of CuO was heated in presence of hydrogen yielding 1.84 g of Cu. Is the above data proves the law of constant proportion?

ANSWER : –

The following reaction takes place in two experiments

Experiment 1 : - $\underset{1.08g}{Cu} + HNO_3 \longrightarrow Cu(NO_3)_2 \xrightarrow{\Delta} \underset{1.35g}{CuO}$

Experiments 2 :- $\underset{2.30g}{CuO + H_2} \xrightarrow{\Delta} \underset{1.84g}{CuH_2O}$

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According to the law of constant proportion, 79.5 g of CuO always contains 63.5 g of Cu and 16 g of oxygen

Percentage of Cu in CuO = $\frac{63.5}{79.5} \times 100 = 80$

Percentage of O in CuO = 100 – 80 =20

In first experiment

1.35 g of CuO contains = 1.08 g of Cu

$\therefore$ Percentage of Cu in CuO = $\frac{1.08}{1.35} \times 100 = 80$

Percentage of O in CuO = 100–80=20

In second experiment,

2.30g of CuO contains = 1.84 g of Cu

$\therefore$ Percentage of Cu in CuO = $\frac{1.84}{2.30} \times 100 = 80$

Percentage of O in CuO=100–80=20

As percentage of Cu and O in CuO in both the cases is same, thus the law of constant proportion is obeyed.

2.(c) LAW OF MULTIPLE PROPORTIONS

According to John Dalton "Whenever 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 proportion of simple whole numbers". For example in SO_2 & SO_3, 32 g of sulphur combines with 32 g & 48 g of oxygen respectively. So fixed mass of sulphur (32 g) in SO_2 & SO_3 combine with mass of oxygen in the ratio of 32 : 48 i.e. 2 : 3

QUESTION :– Carbon combines with hydrogen to form three compounds A, B & C. The percentage of hydrogen in A, B & C is 25, 14.3 & 7.7 respectively. How the law of multiple proportions is illustrated by these compounds ?

ANSWER : –

In compound A, the percentage of carbon = 100– 25 = 75

Ratio of hydrogen and carbon is 25 : 75 i.e. 1 : 3

In compound B, the percentage of carbon = 100 – 14.3 = 85.7

Ratio of hydrogen and carbon is 14.3 : 85.7 i.e. 1 : 6

In compound C, the percentage of carbon = 100 – 73 = 92.3

Ratio of hydrogen and carbon is 7.7 : 92.3 i.e. 1 : 12

So in above three different carbon-hydrogen compounds, the ratio of carbon required is 3 : 6 : 12 i.e. 1 : 2 : 4 for a fixed weight of hydrogen. This is a simple ratio & thus the law of multiple proportion is illustrated by them

2.(d) LAW OF GASEOUS VOLUME

The French chemist Gay Lussac found that when gases combine, the volume of reactants and products are related to each other by small integer, under similar conditions.

For example

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

One volume of N_2 reacts with three volumes of hydrogen to produce 2 volumes of ammonia

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STOICHIOMETRY

Chemical stoichiometry deals with the determination of quantities of reactants or products of a chemical reaction. The word "stoichiometry" is derived from Greek word "stoichiori" means element and "metry" means measure. Stoichiometry is divided into two subsections.

(i) Gravimetric analysis

(ii) Volumetric analysis

The problems on gravimetric and volumetric analysis can be solved using two well known concepts i.e. mole concept and equivalent concept. But generally, the problems on gravimetric analysis are solved using mole concept since mole concept is easier to apply in such cases while problems on volumetric analysis are solved making use of equivalent concept since it does not require the use of balanced chemical reaction. However, there is no hard and fast rule that these guidelines should be followed strictly. We can make use of equivalent concept for gravimetric problems and mole concept for volumetric problems. Let us first understand the mole concept and its use in chemical reactions and then we will learn about equivalent concept.

3.(a) MOLE

The concept of amount of substance is confined to the chemical measurements. The amount of substance of a system is proportional to the number of elementary entities (which may be atoms or molecules or ions or specified group of such particles) of that substance present in the system

Let us take elements Ag, Mg and Hg with masses equal to their atomic masses in grams and then to our surprise, each element contains equal number of atoms. This is not only limited to atoms but also applicable to molecules. For example, if we have molecules like CO_2, NO_2 and SO_2 with masses equal to their molecular masses in grams, then they would also contain equal number of molecules. This specified number of atoms or molecules is referred as a "mole".

Thus a system containing a specified number (6.023×10^{23}) of elementary entities is said to contain 1 mole of the entities. Thus 1 mole of an iron sample mean that the sample contain 6.023×10^{23} atoms of iron. Similarly, 1 mole of NaCl crystal contains 6.023×10^{23} ion paris (Na^+Cl^-).

This specific number 6.023×10^{23} elementary entities is called Avogadro number or constant (N_{AV}). This SI unit for amount of substance is the mole. The mole is defined as the amount of substance in exactly 12g of carbon–12. One mole of any substance contains the same number of elementary entities as there are carbon atoms in exactly 12g of carbon –12.

The mass of specific number (6.023×10^{23}) of elementary entities is equal to atomic mass for atoms and molecular mass for molecules.

Let M g/mole be the molecular mass of a species. Thus M g be the mass of 1 mole (equal to the mass of 6.023 $\times 10^{23}$ molecules) of the species. Then, x g of the species contain $\left(\frac{1}{M} \times x\right)$ mole. Hence

$$\text{Number of moles of a species} = \frac{\text{Weight (grams)}}{\text{Atomic or molecular mass (g / mole)}} = \frac{W}{M}$$

It is also known that one mole of a gas at STP occupies a volume of 22.4 litres. Thus, if a gas occupies x L at STP, then the number of moles of the gas can be calculated by dividing the actual volume occupied by the gas at STP with the volume occupied by 1 mole of the gas at STP.

$$\text{Thus, number of moles of a gas} = \frac{\text{Volume occupied by gas at STP}}{\text{Volume occupied by 1 mole of the gas at STP}}$$

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The volume of gas and the number of moles of gas at temperature and pressure other than the STP can be related by ideal gas equation, PV = nRT.

3.(b) CHEMICAL EQUATION AND STOICHIOMETRY

Let the balanced chemical equation we have is

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

The quantitative information drawn from this balanced chemical equation is

(I) The molar ratio in which two reactants (MnO2 and HCl) reacting is 1 : 4

(II) The molar ratio between two products can also be known i.e. moles of H_2O produced would be double the moles of $MnCl_2$ produced.

(III) The initial moles of MnO_2 and HCl (to be taken in vessel) for the reaction to occur not necessarily be 1 and 4 respectively or also should not be in the molar ratio of 1 : 4

(IV) We can start reaction with MnO_2 and HCl taken in any molar ratio, but the moles of two reacting will always be in the molar ratio of 1 : 4.

(V) The balanced chemical equation should follow the law of conservation of mass.

Let us consider the same chemical system with initial composition (in terms of mole) as $n^o_{MnO_2}, n^o_{HCl}, n^o_{MnCl_2}, n^o_{H_2O}$ and $n^o_{Cl_2}$ The n^o_{HCl} is four times of $n^o_{MnO_2}$. When the reaction occur, these mole numbers change as the reaction progresses. The mole numbers of the various species do not change independently but the changes are related by the stoichiometric coefficients in the chemical equation. Let after time 't' from the commencement of reaction, the moles of MnO_2 reacting be x, then the moles of HCl reacting in the same time interval be 4x since MnO_2 and HCl reacting in the same time interval be 4x since MnO_2 and HCl react in the molar ratio of 1 : 4.

Thus, after time t, the composition of the system would be

$$n_{MnO_2} = n^o_{MnO_2} - x$$

$$n_{HCl} = n^o_{HCl} - 4x$$

$$n_{MnCl_2} = n^o_{MnCl_2} + x$$

$$n_{H_2O} = n^o_{MnO_2} + 2x$$

$$n_{Cl_2} = n^o_{Cl_2} + x$$

The algebraic signs, + and – indicates that the reactants are consumed and products are produced.

In general, mole numbers of various species at any time would be given as

$$n_i = n^o_i + v^o_i x$$

Where n^o_i is the initial amount, x is the degree of advancement and v_i is the stoichiometric coefficient which will be given a negative sign for reactants and a positive sign for products.

After long time interval from the commencement of reaction i.e. after ∞ time, the composition of the system would be

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$$n_{MnO_2} = O, n_{HCl} = 0$$

$$n_{MnCl_2} = n^o_{MnCl_2} + n^o_{MnO_2} = n^o_{MnCl_2} + \frac{n^o_{HCl}}{4}$$

$$n_{H_2O} = n^o_{H_2O} + 2n^o_{MnO_2} = n^o_{H_2O} + \frac{n^o_{HCl}}{2}$$

$$n_{Cl_2} = n^o_{Cl_2} + 2n^o_{MnO_2} = n^o_{Cl_2} + \frac{n^o_{HCl}}{4}$$

3.(c) LIMITING REAGENT

Let the initial moles of MnO_2 and HCl be $n^o_{MnO_2}$ and n^o_{HCl} respectively and $n^o_{HCl} \neq +4n^o_{MnO_2}$. Thus, in the given chemical reaction, after ∞ time , one of the reactant will be completely consumed while the other would be left in excess. Thus, the reactant which is completely consumed when a reaction goes to completion and which decides the yield of the product is called limiting reagent.

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

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

	MnO_2	$4HCl$	$MnCl_2$	Cl_2	$2H_2O$
Initially	$n^o_{MnO_2}$	n^o_{HCl}	0	0	0
After ∞ time	0	$n^o_{HCl} - 4n^o_{MnO_2}$	$n^o_{MnO_2}$	$n^o_{MnO_2}$	$2n^o_{MnO_2}$

Thus, MNO_2 is the limiting reagent and the yield of all the products is governed by the amount of MnO_2 taken initially.

Similarly, if in the given case $n^o_{HCl} > 4n^o_{MnO_2}$ and no $MnCl_2$, Cl_2 & H_2O are present initially, then

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

	MnO_2	$4HCl$	$MnCl_2$	Cl_2	$2H_2O$
Initially	$n^o_{MnO_2}$	n^o_{HCl}	0	0	0
After ∞ time	$n^o_{MnO_2} - \frac{n^o_{HCl}}{4}$	0	$\frac{n^o_{HCl}}{4}$	$\frac{n^o_{HCl}}{4}$	$\frac{n^o_{HCl}}{2}$

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

3.(d) YIELD OF PRODUCT

Let us suppose that the amount of $MnCl_2$ product in the last case actually be less than $\frac{n^o_{HCl}}{4}$ while the theoretical yield should be $\frac{n^o_{HCl}}{4}$. This means that the yield of the product is not 100%. Thus, percentage yield of the product is given as ratio of actual yield by theoretical maximum yield multiplied by 100.

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$$\therefore \ \% \text{ yield of product } = \frac{\text{Acutal yield}}{\text{Theoretical maximum yield}} \times 100$$

3.(f) GRAVIMETRIC ANALYSIS

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

The gravimetric analysis is broadly classified into three heads.

(I) Mass-mass relationship

(II) Mass - volume relationship

(III) Volume - volume relationship

3.(g) MASS-MASS RELATIONSHIP

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

Let us consider a chemical reaction

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

Let the mass of $CaCO_3$ taken be x g and we want to calculate the mass of CaO obtained by heating x g $CaCO_3$. Then the moles of $CaCO_3$ taken would be $\frac{x}{M_1}$ (where M_1 represents the molar mass of $CaCO_3$).

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

3.(h) MASS - VOLUME RELATIONSHIP

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

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

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

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

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

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

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

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

3.(i) VOLUME - VOLUME RELATIONSHIP

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

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

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

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

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

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

Thus, when x L of H_2 is taken at Pressure P atm and temperature TK, then at the same pressure and temperature, the volume, of H_2 required would be 3 x L (since the volume ratio of N_2 & H_2 would be same as molar ratio i.e. 1 : 3). But if the volume of H_2 required is to be calculated at another pressure P atm and temperature TK, then

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

$\therefore$ Volume of H_2 required at pressure P' atm & temperature TK'

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

QUESTION :– How much zinc should be added to 0.01 mol $AgNO_3$ solution to displace all the silver in the solution ?

ANSWER : –

The involved balanced reaction would be

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

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Moles of $AgNO_3$ in the solution = 0.01

Moles of Zn to be added to solution = 0.005

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

$\therefore$ Mass of Zn to be added to solution = $0.005 \times 65.4 = 0.327$ g

QUESTION :– NaCl of 95% purity is used to prepare salt cake (Na_2SO_4) by the reaction

$2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$

If the product (Na_2SO_4) is only 85% pure, what weight of NaCl is used up in producing 1 kg of the impure salt cake ?

ANSWER : –

Let the weight of NaCl used up in producing 1 kg of impure product be x g

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

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

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

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

$\therefore$ x = 737.2 g

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VOLUMETRIC ANALYSIS

Quantitative studies of acid base neutralization reaction and/or redox reactions are most conveniently carried out using a technique called titration.

In titration, a solution of accurately known concentration, called a standard solution, is added gradually to another solution of unknown concentration, until the chemical reaction between the two solution is complete.

Before heading for the volumetric analysis (which involves titration), let us first discuss certain definitions.

4.(a) MOLARITY (M)

It is defined as the number of moles of solute present in one lite of solution.

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

Let the weight of solute by w.g. molar mass of solute be Mg/mol and the volume of solution be V liter. Number of moles of solute $= \dfrac{\text{weight of solute}}{\text{Atomic or molar mass of solute}} = \dfrac{w}{M_1}$

$$\therefore M = \frac{w}{M_1} \times \frac{1}{V(\text{in litres})}$$

$$\therefore \text{Number of moles of solute } = \frac{w}{M_1} = M \times V(\text{in litres})$$

4.(b) NORMALITY (N)

It is defined as the number of equivalents of a solute present in one litre of solution, Equivalent is also the term used for amount of substance like mole with the difference that one equivalent of a substance in different reactions may be different as well as the one equivalent of each substance is also different.

$$\text{Normality}(N) = \frac{\text{number of equivalents of solute}}{\text{Volume of solution (in litres)}}$$

Let the weight of solute be w.g. equivalent mass of solute be E g/eqv. and the volume of solution be V litre.

$$\text{Number of equivalents of solute} = \frac{\text{weight of solute}}{\text{Equivalent mass of solute}} = \frac{w}{E}$$

$$\therefore N = \frac{w}{E} \times \frac{1}{V(\text{in litres})}$$

$$\therefore \text{Number of equivalents of solute} = \frac{w}{E} \times N \times V(\text{in litre})$$

4.(c) EQUIVALENT MASS

$$\text{Equivalent mass} = \frac{\text{Atomic or molecular mass}}{\text{'n' factor}} = \frac{M_1}{n}$$

$$\therefore \quad \text{Number of equivalents of solute} = \frac{w}{E} = \frac{w}{M_1/n} = \frac{w \times n}{M_1}$$

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∴ Number of equivalents of solute = n × number of moles of solute

$$\text{Also, } N = \frac{w}{M_1/n} \times \frac{1}{V(\text{in litre})} = \frac{w}{M_1} \times \frac{1}{V(\text{in litre})} \times n$$

N = M ´ n

∴ Normality of solution = n × molarity of solution

4.(d) DILUTION EFFECT

When a solution is diluted, the moles and equivalents of solute do not change but molarity and normality changes while on taking out a small volume of solution from a larger volume, the molarity and normality of solution do not change but moles and equivalents change proportionately.

In stoichiometry, the biggest problem is that for solving a problem we need to know a balanced chemical reaction. Since the number of chemical reactions are too many, it is not possible to remember all those chemical reactions. So, thee is need to develop an approach which do not require the use of balanced chemical reaction. This approach makes use of a law called law of equivalence. The law of equivalence provide us the molar ratio of reactants and products without knowing the complete balanced reaction, which is as good as having a balanced chemical reaction. The molar ratio of reactants and products can be known by knowing the n - factor of relevant species.

According to the law of equivalence, whenever two substances react, the equivalents of one will be equal to the equivalents of other and the equivalents of any product will also be equal to that of the reactants

Let us suppose we have a reaction, $A + B \rightarrow C + D$. In this reaction, the number of moles of electrons lost by 1 mole of A are x and the number of mole of electrons, gained by 1 mole of B are y. Since, the number of mole of electrons lost and gained are not same. The molar ratio which A & B react cannot be 1 : 1 Thus, if we take y moles of A, then the total moles of electrons lost by y moles of A would be (x × y). Similarly, if x moles of B are taken, than the total mole of electrons gained by x moles of A would be the number of electrons lost by A and number of electrons gained by B becomes equal. For reactant A, its n-factor is x and the number of moles used are y. So. The equivalents of A reacting = moles of A reacting × n - factor of A = y × x.

Similarly, for reactant B, its n-factor is y and the number of moles used are x, so.

The equivalents of B reacting = moles of B reacting × n - factor B

= x × y

Thus, the equivalents of A reacting would be equal to the equivalents of B reacting. Thus the balancing coefficients of the reactant would be as

$$\underset{(\text{n-factor} = x)}{yA} + \underset{(\text{n-factor} = y)}{xB} \rightarrow C + D$$

The n-factor of A & B are in the ratio of x : y, and their molar ratio is y : x. Thus, molar ratio is inverse of the n-factor ratio.

In general, whenever two substances react with their n-factors in the ratio of a : b, then their molar ratio in a balanced chemical reaction would be b : a

To get the equivalents of a substance. Its n-factor to be known. Let he weight of the substance used in the reaction be w g.

Then, equivalents of substance reacted would be $\frac{w}{E}$ or $\frac{w}{M_1/n} = \frac{w}{M_1} \times n$ (where E and M_1 are the equivalent mass and molar mass of the substance). Thus, in order to calculate the equivalents of a substance, knowledge of n-factor is a must.

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EXERCISE - I

Q1. Number of digits expressing significant number in 10.216 are

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

Q2. The number of significant figures in 6.02×10^{23} is

(a) 23 **(b)** 3
(c) 4 **(d)** 26

Q3. Express 0.006006 into scientific notation in three significant digits ?

(a) 6.01×10^{-3} **(b)** 6.006×10^{-3}
(c) 6.00×10^{-3} **(d)** 6.0×10^{-3}

Q4. What is the number of significant figures in 38.0 + 0.0035 + 0.00003 is

(a) 38 **(b)** 38.0035
(c) 38.00353 **(d)** 38.0

Q5. How many significant figures are there in

$$\frac{(5.56)^2(8.24)}{(3.6)}$$

(a) 2 **(b)** 3
(c) 4 **(d)** 6

Q6. Number of significant figures in the answer of

$$\frac{(7.11+29.2)\times 6.022\times 10^{23}}{(3.6)}$$

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

Q7. Which of the following stoicheometric laws suggests that different elements combine with each other by their equivalent weight ?

(a) Law of definite proportion
(b) Law of multiple proportion
(c) Law of reciprocal proportion
(d) Law of conservation of mass

Q8. One part of an element A combines with two parts of another element B. If A and C combine together the ratio of their weights will be governed by

(a) Law of definite proportion
(b) Law of multiple proportion
(c) Law of reciprocal proportion
(d) Law of conservation of mass

Q9. Law of definite proportions when expressed in terms of volumes becomes.

(a) Dalton's law
(b) Berzelius hypothesis
(c) Gay-Lussac's law
(d) Avogadro's law

Q10. Law of reciprocal proportions can be used to determine

(a) Atomic weight of a gas
(b) Equivalent weights
(c) Molecular weights of gases
(d) None of these

Q11. Significant figures in a number show

(a) All digits with reasonable certainity
(b) Except last digit, all digit with certainity
(c) All digit with uncertainity
(d) All digit with certainity up to decimal point only

Q12. Which of the following contains the least number of atoms ?

(a) 4.4 gm CO_2 **(b)** 3.4 gm NH_3
(c) 1.6 gm CH_4 **(d)** 3.2 gm SO_2

Q13. Elements A and B form two compounds B_2A_3 and B_2A 0.05 moles of B_2A_3 weight 9.0 gms and 0.10 mole of B_2A weight 10 gms atomic weight of A and B are

(a) 20 and 30 **(b)** 30 and 40
(c) 40 and 30 **(d)** 30 and 20

Q14. The weight of one atom of Uranium is 238 amu. It actual weight is .... gm.

(a) 1.43×10^{26} **(b)** 3.94×10^{-22}
(c) 6.99×10^{-23} **(d)** None of these

Q15. Vapour density of ammonia is 8.5, 85 gms of NH_3 at NTP occupy.

(a) 22.4 litre **(b)** 112 litre
(c) 224 litre **(d)** 1120 litre

Q16. Which of the following has the highest mass ?

(a) 1 g atom of C
(b) ½ mole of CH_4
(c) 10 ml of water
(d) 3.011×10^{23} atoms of oxygen

Q17. Significant number in 0.00930

(a) 6 **(b)** 5
(c) 4 **(d)** 3

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Q18. The total number of ions present in 1 ml of 0.1 ml of 0.1 M barium nitrate solution is

(a) 6.02×10^{18} **(b)** 6.02×10^{19}

(c) $3.0 \times 6.02 \times 10^{19}$ **(d)** $3.0 \times 6.02 \times 10^{18}$

Q19. Molecular weight of tribasic acid is W. Its equivalent weight will be

(a) $\frac{W}{2}$ **(b)** $\frac{W}{3}$

(c) W **(d)** 3W

Q20. According to the rules of addition of significant number, the addition product of 118.017 and 11.0 will be

(a) 129.017 **(b)** 129.0

(c) 129 **(d)** None of these

Q21. 0.01 mole of iodoform (CHI_3) reacts with Ag to produce a gas whose volume at NTP is

(a) 224 ml **(b)** 112 ml

(c) 336 ml **(d)** none of these

Q22. Assuming that petrol is octane (C_8H_{18}) and has density 0.8 g/ml. 1.425 litre of petrol on complete combustion will consume

(a) 50 mole of O_2 **(b)** 100 mole of O_2

(c) 125 mole of O_2 **(d)** 200 mole of O_2

Q23. 2.75 g of silver carbonate on being strongly heated yields a residue weighing

(a) 2.16 g **(b)** 2.48 g

(c) 2.32 g **(d)** 2.64 g

Q24. $CaCO_3$ is 90% pure. Volume of CO_2 collected at STP when 10gms of $CaCO_3$ is decomposed is

(a) 2.24 – 0.224 litres **(b)** 1.12 – 0.112 litres

(c) 11.2 – 1.12 litres **(d)** 22.4 – 2.24 litres

Q25. One litre of CO_2 is passed over hot coke. The volume becomes 1.4 litre. The composition of products is

(a) 0.6 litre CO

(b) 0.8 litre CO_2

(c) 0.6 litre CO_2 and 0.8 litre CO

(d) None

Q26. While substracting 24.24 from 25.7630 the correct answer to be express in significant number will be

(a) 1.52 **(b)** 1.523

(c) 1.5230 **(d)** 1.5

Q27. The number of significant figures in 0.01010, 0.1010 and 0.0101 are respectively

(a) 5,4,3 **(b)** 4,4,4

(c) 4,4,3 **(d)** 5,3,4

Q28. 0.126 g of an acid required 20 ml of 0.1 N NaOH for complete neutralisation. Eq.wt. of the acid is

(a) 45 **(b)** 53

(c) 40 **(d)** 63

Q29. Equivalent weight of a divalent metal is 24. The volume of hydrogen liberated at STP by 12 gms of the same metal when added to excess of an acid solution is

(a) 2.8 litres **(b)** 5.6 litres

(c) 11.2 litres **(d)** 22.4 litres

Q30. 9 gms of Al will react, with

(a) 6 gms O_2 **(b)** 8 gms O_2

(c) 9 gms O_2 **(d)** 4 gms O_2

Q31. The ratio of amount of H_2S needed to precipitate all the metal ions from 100 ml of 1M $AgNO_3$ and 100 ml of 1M $CuSO_4$ is

(a) 1 : 2 **(b)** 2 :1

(c) Zero **(d)** Infinite

Q32. A compound of X and Y has equal mass of them. If their atomic weights are 30 and 20 respectively. Molecular formula of that compound (its mol. wt. is 120) could be

(a) X_2Y_2 **(b)** X_3Y_3

(c) X_2Y_3 **(d)** X_3Y_2

Q33. In the reaction $N_2 + 3H_2 \rightarrow 2NH_3$, ratio by volume of N_2, H_2 and NH_3 is 1 : 3 : 2. This illustrates law of

(a) Difinite proportion

(b) Multiple proportion

(c) Reciprocal proportion

(d) Gaseous volumes

Q34. A hydrocarbon contains 80% of carbon, then the hydrocarbon is

(a) CH_4 **(b)** C_2H_4

(c) C_2H_6 **(d)** C_2H_2

Q35. An oxide of metal M has 40% by mass of oxygen. Metal M has relative atomic mass of 24. The emperical formula of the oxide

(a) M_2O **(b)** M_2O_3

(c) MO **(d)** M_3O_4

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Q36. Outer most shells of two elements X and Y have two and six electrons respectively. If they combine, expected formula of the compound will be

(a) X_2Y **(b)** X_2Y_3

(c) XY_2 **(d)** XY

Q37. 2.2 gm of a compound of phosphorous and sulphur has 1.24 gms of 'p' in it. Its emperical formula is

(a) P_2S_3 **(b)** P_3S_2

(c) P_3S_4 **(d)** P_4S_3

Q38. The empirical formula of an organic compound containing carbon and hydrogen is CH_2. The mass of one litre of this organic gas is exactly equal to that of one litre of N_2. Therefore, the molecular formula of the organic gas is

(a) C_2H_4 **(b)** C_3H_6

(c) C_6H_{12} **(d)** C_4H_8

Q39. Different proportions of oxygen in the various oxides of nitrogen prove the low of

(a) Equivalent proporiton

(b) Multiple propotion

(c) Constant proportion

(d) Conservation of matter

Q40. When an element forms an oxide in which oxygen in 20% of the oxide by mass, the equivalent mass of the element will be

(a) 32 **(b)** 40

(c) 60 **(d)** 128

Q41. The molecular mass of metal chloride, MCl, is 74.5. The equivalent mass of the metal M will be

(a) 39 **(b)** 74.5

(c) 110.0 **(d)** 35.5

Q42. Oxygen combines with two isotopes of carbon 12C and 14C to form two sample of carbon dioxide. The data illustrates

(a) Law of conservation of mass

(b) Law of multiple proportions

(c) Law of reciprocol

(d) Law of conservation of mass

Q43. The specific heat of an element is 0.214 cal/gm. The approximate atomic weight is

(a) 0.6 **(b)** 12

(c) 30 **(d)** 65

Q44. The carbonate of a metal is isomorphous with $MgSO_3$ and contains 6.091% of carbon. Atomic weight of the metal is nearly

(a) 48 **(b)** 68.5

(c) 137 **(d)** 120

Q45. There are two oxides of sulphur. They contain 50% and 60% of oxygen respectively by weights. The weights of sulphur which combine with 1 gm of oxygen in the ratio of

(a) 1 : 1 **(b)** 2 : 1

(c) 2 : 3 **(d)** 3 : 2

Q46. 0.39 gm of a liquid on vapourisation gave 112 ml of vapour at STP. Its molecular weight is

(a) 39 **(b)** 18.5

(c) 78 **(d)** 112

Q47. 510 mgm of a liquid on vapourisation in Victor Mayer's apparatus displaces 67.2 CCs of dry air (at NTP). The molecular weight of liquid is

(a) 130 **(b)** 17

(c) 1700 **(d)** 170

Q48. Which of the following contain highest number of molecules.

(a) 2.8 gms of CO

(b) 3.2 gms of CH_4

(c) 1.7 gms of NH_3

(d) 3.2 gms of SO_2

Q49. 5.6 litre of oxygen at NTP is equivalent to

(a) 1 mole

(b) 2 mole

(c) ½ mole

(d) 1/8 mole

Q50. One litre of a certain gas weighs 1.16 gm under standard conditions. The gas may possibly be

(a) C_2H_2

(b) CO

(c) O_2

(d) NH_3

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EXERCISE - II

Q1. The number of atoms present in 0.05 g of water
(a) 1.67×10^{23} **(b)** 1.67×10^{22}
(c) 5.02×10^{21} **(d)** 1.67×10^{21}

Q2. The volume of concentrated sulphuric acid (98 mass % H_2SO_4, density 1.84 g cm^{-3}) required to prepare 5 dm^3 of 0.5 mol dm^{-3} solution of sulphuric acid is
(a) 68 cm^3 **(b)** 136 cm^3
(c) 204 cm^3 **(d)** 272 cm^3

Q3. The combusion of 4.24 mg of an organic compound produces 8.45 mg of CO_2 and 3.46 mg of water. The mass percentages of C and H in the compound respectively are
(a) 54.4, 9.1 **(b)** 9.1, 54.4
(c) 27.2, 18.2 **(d)** 18.2, 27.2

Q4. The molarity of concentrated sulphuric acid (ρ = 1.834 g cm^{-3}) containing 95% of H_2SO_4 by mass is
(a) 4.44 M **(b)** 8.88 M
(c) 13.32 M **(d)** 17.78 M

Q5. A 2.0 g mixture of Na_2CO_3 and $NaHCO_3$ suffered a loss of 0.12 g on heating. The percentage of Na_2CO_3 in the mixtue is
(a) 83.8 **(b)** 16.2
(c) 38.8 **(d)** 61.2

Q6. Which of the following expressions is dimensionally correct ?
(a) T = t + 273.15 **(b)** T/K = t/^{0}C + 273.15
(c) T = t + 273.15 K **(d)** T =t + 273.15^{0}C

Q7. The Celsius and Fahrenheit temperatures corresponding to 64.15 K respectively are
(a) – 209^{0}C–334.2^{0}F **(b)** – 20.9^{0}C–34.4^{0}F
(c) 209^{0}C, 344.2^{0}F **(d)** 20.9^{0}C, 34.4^{0}F

Q8. Which of the following expressionsis not dimensionally correct ?
(a) $\eta = \pi r^4 pt/8l/V$ **(b)** $m = ItM/F_z$
(c) $E = -2\pi^2 m\,(e^2/4\pi\varepsilon_0)^2/n^2h^2$
(d) $K_c = K_p\,(RT)^{a:l/g}$
Where the various symbols have their usual meaning

Q9. Which of the following conversion units is not correct ?
(a) J $Pa^{-1} \equiv m^3$ **(b)** $(J\, s^2\, kg^{-1})^{1/2} \equiv m$
(c) J $kg^{-1}m^{-1} \equiv ms^{-1}$ **(d)** $J^{1/2}kg^{-1}/2m^{-1}$ = Hz

Q10. In the IUPAC recommendations, the number of dimensionally independent physical quantities is
(a) 1 **(b)** 3
(c) 5 **(d)** 7

Q11. An insecticide contains 47.5% C, 2.54% H and 50% Cl by mass. Its empirical formula is
(a) $C_{13}H_8Cl_5$ **(b)** $C_{14}H_9Cl_5$
(c) $C_{12}H_{10}Cl_5$ **(d)** $C_{15}H_{12}Cl_6$

Q.12 An organic compound weighing 0.778 g was subjected to Kjeldahl's method to determine its mitogen content. The evolved ammonia was absorbed in 100cm^3 of 1 N HCl. The excess acid required 147.4 cm^3 of 0.5N KOH for complete neutralization. The mass per cent of nitrogen in the compound was
(a) 23.67 **(b)** 32.67
(c) 47.33 **(d)** 74.33

Q13. An organic compound contains 20.0% C, 6.66% H, 47.33% N and the rest was oxygen. Its molar mass is 60g mol^{-1}. The molecular formula of the compound is
(a) CH_4N_2O **(b)** CH_2NO_2
(c) C_2H_6NO **(d)** $CH_{18}NO$

Q14. The unit of 'amount of substance' is
(a) g **(b)** cm^3
(c) kg **(d)** mol

Q15. The value of Avogadro constant is
(a) 6.023×10^{23}
(b) 6.023×10^{23} mol^{-1}
(c) 6.023×10^{23} mol
(d) 6.023×10^{-23} mol^{-1}

Q16. The simplest formula of the compound containign 32.5% K, 0.839% H, 26.7% S and 39.9% O by mass is
(a) $KHSO_2$ **(b)** $KHSO_3$
(c) $KHSO_4$ **(d)** $K_2H_2S_2O_7$

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Q17. The simplest formula of a compound which contains 85.6%C and 50.3% O by mass is
(a) CH **(b)** CH_2
(c) C_2H_3 **(d)** CH_3

Q18. The simplest formula of a compound containing 21.9% Mg, 27.8% P and 50.3% O by mass is
(a) $Mg_2P_3O_5$ **(b)** MgP_2O_4
(c) $Mg_2P_2O_7$ **(d)** Mg_3PO_4

Q19. A certain compound has the molecular formula X_4O_6. If 10.0 g of the compound contains 5.62 g of X, the atomic mass of X is
(a) 62.0 amu **(b)** 48.0 amu
(c) 32.0 amu **(d)** 30.8 amu

Q20. If in a reaction HNO_3 is reduced to NO, the mass of HNO_3 absorbing one mole of electrons would be
(a) 12.6 g **(b)** 21.0 g
(c) 31.5 g **(d)** 63.0 g

Q21. If in a given reaction NO_3^- is reduced to NH_4^+, the mass of NO_3^- absorbing one mole of electons would be
(a) 31.0 g **(b)** 12.4 g
(c) 6.29 g **(d)** 7.75 g

Q22. Iron has a density of 7.86 g cm^{-3} and an atomic mass of 55.85 amu. The volume occupied by 1 mol of Fe is
(a) 0.141 cm^3 mol^{-1} **(b)** 7.11 cm^3 mol^{-1}
(c) 4.28×10^{24} $cm^3 mol^{-1}$
(d) 22.8 cm^3 mol^{-1}

Q23. Select the quantity of NO_2 which has the highest mass
(a) 100 amu
(b) 1.0×10^{-3}g
(c) 7.0×10^{22} molecules
(d) 8.0×10^{-1}mol

Q24. Molarity of liquid water at 4^0C is
(a) 5.56 mol L^{-1} **(b)** 55.56 mol L^{-1}
(c) 0.556 mol L^{-1} **(d)** 18 mol L^{-1}

Q25. The length 10^9 m may be represented as
(a) 10km **(b)** 100Mm
(c) 1 Gm **(d)** 1 Tm

Q26. One micrometer stands for
(a) 10^{-3}m **(b)** 10^{-6} m
(c) 10^{-9}m **(d)** 10^{-22}m

Q27. The molarity of 20.0 mass % H_2SO_4 solution of density 11.14g cm^{-3} is
(a) 1.52 mol dm^{-3} **(b)** 2.02 mol dm^{-3}
(c) 2.32 mol dm^{-3} **(d)** 2.82 mol dm^{-3}

Q28. Which of the following is not the unit of energy?
(a) kg m^2s^{-2} **(b)** Nm
(c) Pa m^3 **(d)**Pa m^{-1}

Q29. The unit siemens is of physical quantity
(a) resistance
(b) conductance
(c) molar conductivity
(d) conductivity

Q30. The prefix for the multiple 10^{18} is
(a) tera **(b)** peta
(c) exa **(d)** atto

Q31. Molarity of H_2SO_4 (density 1.8 g/mL) is 18 M. The molality of this H_2SO_4 is
(a) 36 **(b)** 200
(c) 500 **(d)** 18

Q32. 10.78 g of H_3PO_4 in 550 mL solution in 0.40 N. Thus this acid
(a) has been neutralised to HPO_4^{2-}
(b) has been neutralised to PO_4^{3-}
(c) has been changed to HPO_3
(d) has been neutralised to $H_2PO_4^-$

Q33. 20 mL of x M HCl neutralizes completely 10mL of 0.1 $NaHCO_3$ and a further 5 mL of 0.2 M Na_2CO_3 solution to methyl orange end point. The value of x is
(a) 0.167 M **(b)** 0.133 M
(c) 0.150 M **(d)** 0.200 M

Q34. 0.7 g of $Na_2CO_3 \cdot xH_2O$ is dissolved in 100 mL H_2O 20 mL of which required 19.8 mL of 0.1 N HCl. The value of x is
(a) 4 **(b)** 3
(c) 2 **(d)** 1

Q35. The percentage of sodium in a breakfast cereal be labeled as 110 mg of sodium per 100 g of cereal is
(a) 11% **(b)** 1.10%
(c) 0.11% **(d)** 1.10%

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Q36. 4.4 g of CO_2 and 2.24 litre of H_2 at STP are mixed in a container. The total number of molecules present in the container will be

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

Q37. The equivalent weight of Fe_3O_4 in the reaction $Fe_3O_4 + KMnO_4 \rightarrow Fe_2O_3 + MnO_2$ would be

(a) M/6 **(b)** M
(c) 2M **(d)** M/3

Q38. $4I^- + Hg^{2-} \rightarrow HgI_4^{2-}$; 1 mole each of Hg^{2+} and I^- will form

(a) 1 mole of HgI_4^{2-} **(b)** 0.5 mole of HgI_4^{2-}
(c) 0.25 mole of HgI_4^{2-} **(d)** 2 mole of HgI_4^{2-}

Q39. 0.3 g of an oxalate salt was dissolved in 100 mL solution. The solution required 90 mL of N/20 $KMnO_4$ for complete oxidation. The % of oxalate ion in salt is

(a) 33% **(b)** 66%
(c) 70% **(d)** 40%

Q40. The equivalent weight of $Na_2S_2O_3$ as reductant in the reaction

$Na_2S_2O_3 + H_2O + Cl_2 \rightarrow Na_2SO_4 + 2HCl + S$ would be

(a) (Molecular weight)/1
(b) (Molecular weight)/2
(c) (Molecular weight)/6
(d) (Molecular weigh)/8

Q41. When the same amount of zinc is treated separately with excess of H_2SO_4 and excess of NaOH, the ratio of volumes of H_2 evolved is

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

Q42. H_3PO_4 is a tri basic acid and one of its salt is NaH_2PO_4. What volume of 1M NaOH solution should be added to 12g of NaH_2PO_4 to convert it into Na_3PO_4 ?

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

Q43. Sulphuryl chloride, SO_2Cl_2, reacts with H_2O to give mixture of H_2SO_4 and HCl. Aqueous solution of 1 mol of SO_2Cl_2 will be neutralised by

(a) 3 mol of NaOH **(b)** 2 mol of $Ca(OH)_2$
(c) both **(d)** none of these

Q44. The dehydration yield of cyclohexanol to cyclohexene is 75%. What would be the yield if 100g of cyclohexanol is dehydrated ?

(a) 61.5 g **(b)** 16.5 g
(c) 6.15 g **(d)** 0.615 g

Q45. 100 mL of a sample of hard water requires 25.1 mL of 0.02 N H_2SO_4 for complete reaction. The hardness of water (density 1 g/mL) is

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

Q46. When the $Cr_2O_7^{2-}$ ion acts as an oxidant in acidic medium, Cr^{3+} ion is formed. The number of mole of Sn^{2+} that are oxidised to Sn^{4+} by one mole of $Cr_2O_7^{2-}$ ion would be

(a) 2/3 **(b)** 3/2
(c) 2 **(d)** 3

Q47. The equivalent weight of the salt $KHC_2O_4 \cdot H_2C_2O_4 \cdot 4H_2O$ used as reducing agent is

(a) Molecular weight
(b) Molecular weight/2
(c) Molecular weight/3
(d) Molecular weight/4

Q48. In the redox reaction, $MnO_4^- + I_2 + H^+ \rightarrow Mn_2 + IO_3^- + H_2O$. MnO_4^- and I_2 would react in the molar ratio of

(a) 1 : 2 **(b)** 2 : 1
(c) 1 : 5 **(d)** 5 : 1

Q49. The red pigment in blood contains 0.32% iron by weight. Molecular mass of the pigment is 70,000 g mol^{-1}. The number of iron atoms in each molecule of the pigment would be

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

Q50. If the equivalent weight of a compound 'A' is M/4 when it reacts with compound 'B' whose equivalent weigh in M/5, then 4 mol of 'A' requires

(a) 4 mol of 'B' **(b)** 5 mol of 'B'
(c) less than 4 mol of 'B'
(d) more than 5 mol of 'B'

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EXERCISE - III Previously Asked MCQs

Q1. Maximum number of mol of $PbSO_4$ that can be precipitated by mixing 20.00 ml of 0.1 M $Pb(NO_3)_2$ and 30.00 ml of 0.1 M Na_2SO_4 will be
(a) 0.002 **(b)** 0.003
(c) 0.005 **(d)** 0.001

Q2. The largest number of molecules is in
(a) 28 gm of CO **(b)** 46 gm of C_2H_5OH
(c) 36 gm of H_2O **(d)** 54 gm of N_2O_5

Q3. The molarity of pure water is almost
(a) 5.55 M **(b)** 55.55 M
(c) 2 M **(d)** $\frac{1}{18}$ M

Q4. 50 ml of 0.1 M Hcl solution is mixed with 50 ml. of 0.1 M NaCl solution. What is molarity of Cl^- ion in resulting solution.
(a) .05 M **(b)** 0.1 M
(c) .15 M **(d)** .2 M

Q5. What volume of 0.1 M $K_2Cr_2O_7$ solution be required to oxidise 60 ml. of 0.1N H_2O_2 solution
(a) 10 ml **(b)** 30 ml
(c) 60 ml **(d)** 20 ml

Q6. The total number of ions present 1 ml of 0.1 M barium nitrate solution is
(a) 6.02×10^8 **(b)** 6.02×10^{10}
(c) $3.0 \times 6.03 \times 10^{19}$ **(d)** $3.0 \times 6.02 \times 10^8$

Q7. What volume of CO_2 at STP will evolve when 1 gram of $CaCO_3$ reacts with excess of dil HCl?
(a)224 ml **(b)** 112 ml
(c) 56 ml **(d)** 448 ml

Q8. On diluting a solution. It's normality _____whereas gm equiv of solute remains ___.
(a) constant, constant
(b) changes, changes
(c) changes, constant
(d) none of these

Q9. How many gm of $K_2Cr_2O_7$ is present in 1 lit of its N/10 solution in acid medium ?
(a) 4.9 **(b)** 49
(c) .49 **(d)** 3.9

Q10. What is the n factor for (Cu_2S) if the reaction $Cu_2S \rightarrow Cu_2+ + SO_2$?
(a) 6 **(b)** 7
(c) 8 **(d)** 9

Q11. X% of 0.84 gm iron in +2 state converts completely into +3 state when treated with X ml $K_2Cr_2O_7$ solution. The strength of solution is
(a) 5.74 gm / lit
(b) 1.225 gm/lit
(c) 44.1 gm / lit
(d) 7.35 gm/lit

Q12. The volume in ml of 0.05 $KMnO_4$ (acidic) required to oxidise 2 gm $FeSO_4$ in dilute solution is
(a) 42.6 **(b)** 58.6
(c) 52.6 **(d)** 24.6

Q13. 1.82 gm of metal require 32.5 ml of 1N HCl to dissolve it. What is equivalent weight of metal ?
(a) 46 **(b)** 65
(c) 56 **(d)** 42

Q14. Monosodium salt of oxalic acid is titrated with NaOH solution. In the second titration it is titrated with $KMnO_4$ solution The ratio of equivalent weights of monosodiummoxalate is
(a) 1 : 1 **(b)** 1 : 2
(c) 2 : 1 **(d)** 3 : 2

Q15. 5.3 gm of M_2CO_3 is dissolved in 150 mL of N HCl. Unused acid requirred 100mL of 0.5 N NaOH. Hence equivalen wt. of M.
(a) 23 **(b)** 12
(c) 24 **(d)** 13

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Q16. 0.28 gram of CaO is added into 150 ml of dil. HCl solution. The remaining acid required 50 ml of 0.1 N NaOH for complete neutralisation. What is normality of acid.

(a) 0.05 N **(b)** 0.1 N
(c) 0.2 N **(d)** 0.15 N

Q17. The vapour density of a volatile choride of metal is 59.5 equivalent mass of the metal is 24. The atomic mass of element will be ____

(a) 96 **(b)** 48
(c) 24 **(d)** 12

Q18. $2H_2O_2$ (I) $\rightarrow$ $2H_2O$(I) + O_2(g) 100 ml of X molar H_2O_2 gives 3L of O_2 gas under the condition when 1 mol occupies 24L, value of X is

(a) 1.5 **(b)** 2.5
(c) 0.5 **(d)** 0.3

Q19. The normality of solution obtained by mixing 100 ml of 0.2 M H_2SO_4 with 100 ml of 0.2 M NaOH is

(a) 0.1 **(b)** 0.2
(c) 3 **(d)** 4.5

Q20. 1 g of Ca was burnt in excess of O2 and the oxide was dissolved in water to make up one litre solution. The normality of solution is

(a) 0.04 **(b)** 0.4
(c) 0.05 **(d)** 0.5

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EXERCISE - IV Questions with Assertion A and Reason R

These questions consist of two statements each, printed as Assertion and Reason. While answering these questions you are required to choose any one of the following four responses.

A. If both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.

B. If both Assertion & Reason are True but Reason is not a correct explanation of the Assertion

C. If Assertion is True but the Reason is False

D. If both Assertion & Reason is False.

Q1. Assertion : 0.28 g of N_2 has equal volume as 0.44 g of another gas at same conditions of temperature and pressure.
Reason : Molecular mass of another gas is 44 g mol^{-1}.

Q2. Assertion : Boron has relative atomic mass 10.81.
Reason : Boron has two isotopes $^{10}_{5}B$ and $^{11}_{5}B$ and their relative abundance is 19% and 81%.

Q3. Assertion : The percentage of nitrogen in urea is 46.6%.
Reason : Urea is Ionic compound.

Q4. Assertion : The oxidation state of central sulfur of $Na_2S_2O_3$ is + 6.
Reason : The oxidation state of an element should be determined from structures.

Q5. Assertion : Molarity of a solution and molality of a solution both change with density.
Reason : Density of the solution changes when percentage by mass of solution changes.

Q6. Assertion : Carbon and oxygen combined together only in one fined ratio
Reason : In a chemical compound the elements are combined together in a fixed ratio

Q7. Assertion : 0.005 cm contains only one significant figure
Reason : All zeros placed to the left of the non zero digit are never significant

Q8. Assertion : 16 gm each of O_2 and O_3 contains $\frac{N_A}{2}$ and $\frac{N_A}{3}$ atoms respectively
Reason : 16 gm O_2 and O_3 contain same no. of molecules.

Q9. Assertion : The mass of the products formed in a reaction depends upon the limiting reactant
Reason : Limiting reactant reacts completely in the reaction.

Q10. Assertion : Volume occupied by 1 mol H_2O is equals to 22400 cc at NTP.
Reason : 1 mol of any substance occupies 22.4 lit volume at NTP

Q11. Assertion : At same temp & pressure 1 lit O_2 and 1 lit SO_2 contains equal no. of molecules
Reason : Acc. to avogadros hypothesis equal volume of all gases under similar condition of temp and pressure contains equal no. of molecules

Q12. Assertion : Under similar conditions of temp and pressure O_2 defuses 1.4 times faster than SO_2
Reason : Density of SO_2 is 1.4 times greater than that of O_2

Q13. Assertion : 44 gm of CO_2 28 gm of CO have same volume at STP
Reason : Both CO_2 and CO are formed by C and oxygen

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Q14. Assertion : Equivalent wt of Cu in both CuO and Cu_2O is 31.75
Reason : equivalent wt. of an element is constant

Q15. Assertion : On compressing a gas to half the volume, the number of moles is halved
Reason : Number of moles present decreases with decrease is volume.

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EXERCISE - V   Questions Based on Comprehension

PASSAGE-A

(A) Normality is number of gram equivalents dissolved per litre of solution. It changes with change in temperature. In case of monobasic acid, normality and molarity are equal but in case of dibasic acid, normality is twice the molarity. In neutralization and redox reactions, number of milliequivalent of reactant as well as products are always equal.

The following questions 1 to 5 are based on the above passage (A).

Q1. On heating a litre of N/2 HCl solution, 2.750 g of HCl is lost and the volume of solution becomes 750 mL. The normality of resulting solution will be
(a) 0.58 **(b)** 0.75 **(c)** 0.057 **(d)** 5.7

Q2. The volume of 0.1 M $Ca(OH)_2$ required to neutralize 10 mL of 0.1 N HCl will be
(a) 10 mL **(b)** 20 mL **(c)** 5 mL **(d)** 40 mL

Q3. Molarity of 0.5 N Na_2CO_3 is
(a) 0.25 **(b)** 1.0 **(c)** 0.5 **(d)** 0.125

Q4. 6.90 N KOH solution in water contains 30% by weight of KOH. The density of solution will be
(a) 1.288 **(b)** 2.88 **(c)** 0.1288 **(d)** 12.88

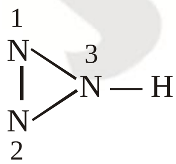
Q5. The amount of ferrous ammonium sulphate required to prepare 250 mL of 0.1 N solution is
(a) 1.96 g **(b)** 1.8 g **(c)** 9.8 g **(d)** 0.196 g

PASSAGE-B

(B) Redox reactions are those in which oxidation and reduction take place simultaneously. Oxidizing agent can gain electron whereas reducing agent can lose electron easily. The oxidation state of any element can never be in fraction. If oxidation number of any element comes out be in fraction, it is average oxidation number of that element which is present in different oxidation states.

The following questions 6 to 10 are based on the above passage (B).

Q6. The oxidation state of Fe in Fe_3O_4 is
(a) 2 and 3 **(b)** 8/3 **(c)** 2 **(d)** 3

Q7. 

, In this compound HN_3 (hydrazoic acid), oxidation state of N^1, N^2 and N^3 are
(a) 0, 0, 3 **(b)** 0, 0, –1 **(c)** 1, 1, –3 **(d)** –3, –3, –3

Q8. Equivalent weight of chlorine molecule in the equation
$3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$
(a) 42.6 **(b)** 35.5 **(c)** 59.1 **(d)** 71

Q9. Which of the following can be both oxidizing as well as reducing agent.
(a) H_2 **(b)** I_2 **(c)** H_2O_2 **(d)** All of these

Q10. The oxidation number of sulphur in $K_2S_2O_8$ is
(a) + 2 **(b)** + 4 **(c)** + 7 **(d)** + 6

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PASSAGE-C

(C) 1.00 g of a mixture consisting of equal number of moles of carbonates of two alkali metals, required 44.4 ml of 0.5 N hydrochloric acid for complete reaction. If the atomic weight of one of the metals is 7.00.

The following questions 11 to 15 are based on the above passage (C).

Q11. The number of equivalents of HCl used is

(a) 0.222 **(b)** 2.22 **(c)** 22.22 **(d)** 0.0222

Q12. The number of moles of each metal carbonate are

(a) 0.1 **(b)** 0.0111 **(c)** 0.0055 **(d)** 0.00275

Q13. The molecular weights of the two alkali metal carbonate are

(a) 74 and 60 **(b)** 134 and 160 **(c)** 160 and 60 **(d)** 74 and 106

Q14. The total amount of the sulphate formed on a quantitative conversion of 1.00 g of a mixture into sulphate is

(a) 110 g **(b)** 1.10 g **(c)** 1.4 g **(d)** 0.110 g

Q15. One gram of a mixture contains

(a) 0.022 moles of each metal carbonate

(b) The two alkali metals are Li and Na respectively

(c) The two alkali metals are Li and K respectively

(d) The two alkali metals are Li and Ag

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ANSWER SHEET

Q.No.	ANS.	Q.No.	ANS.	Q.No.	ANS.	Q.No.	ANS.
EXERCISE – I							
Q.1	(d)	Q.14	(b)	Q.27	(c)	Q.40	(a)
Q.2	(b)	Q.15	(b)	Q.28	(d)	Q.41	(a)
Q.3	(a)	Q.16	(a)	Q.29	(b)	Q.42	(d)
Q.4	(b)	Q.17	(c)	Q.30	(b)	Q.43	(c)
Q.5	(a)	Q.18	(c)	Q.31	(a)	Q.44	(c)
Q.6	(b)	Q.19	(b)	Q.32	(c)	Q.45	(d)
Q.7	(c)	Q.20	(b)	Q.33	(d)	Q.46	(c)
Q.8	(c)	Q.21	(b)	Q.34	(c)	Q.47	(d)
Q.9	(c)	Q.22	(c)	Q.35	(c)	Q.48	(b)
Q.10	(b)	Q.23	(a)	Q.36	(d)	Q.49	(c)
Q.11	(b)	Q.24	(a)	Q.37	(d)	Q.50	(a)
Q.12	(d)	Q.25	(c)	Q.38	(a)		
Q.13	(c)	Q.26	(a)	Q.39	(b)		
EXERCISE – II							
Q.1	(c)	Q.14	(d)	Q.27	(c)	Q.40	(b)
Q.2	(b)	Q.15	(b)	Q.28	(d)	Q.41	(a)
Q.3	(a)	Q.16	(b)	Q.29	(b)	Q.42	(b)
Q.4	(d)	Q.17	(b)	Q.30	(c)	Q.43	(b)
Q.5	(a)	Q.18	(c)	Q.31	(c)	Q.44	(a)
Q.6	(b)	Q.19	(d)	Q.32	(a)	Q.45	(c)
Q.7	(a)	Q.20	(b)	Q.33	(c)	Q.46	(d)
Q.8	(d)	Q.21	(d)	Q.34	(c)	Q.47	(d)
Q.9	(c)	Q.22	(b)	Q.35	(c)	Q.48	(b)
Q.10	(d)	Q.23	(d)	Q.36	(b)	Q.49	(d)
Q.11	(b)	Q.24	(b)	Q.37	(b)	Q.50	(c)
Q.12	(a)	Q.25	(c)	Q.38	(c)		
Q.13	(a)	Q.26	(b)	Q.39	(b)		

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ANSWER SHEET

Q.No.	ANS.	Q.No.	ANS.	Q.No.	ANS.	Q.No.	ANS.
EXERCISE – III (Previously Asked Questions)							
Q.1	(a)	Q.6	(c)	Q.11	(d)	Q.16	(b)
Q.2	(c)	Q.7	(a)	Q.12	(c)	Q.17	(b)
Q.3	(b)	Q.8	(c)	Q.13	(a)	Q.18	(b)
Q.4	(b)	Q.9	(a)	Q.14	(c)	Q.19	(a)
Q.5	(a)	Q.10	(c)	Q.15	(a)	Q.20	(c)
EXERCISE – IV (Questions with Assertion A and Reason R)							
Q.1	(b)	Q.5	(a)	Q.9	(a)	Q.13	(b)
Q.2	(a)	Q.6	(d)	Q.10	(d)	Q.14	(d)
Q.3	(c)	Q.7	(a)	Q.11	(a)	Q.15	(d)
Q.4	(b)	Q.8	(d)	Q.12	(c)		
EXERCISE – V (Questions Based on Comprehension)							
Q.1	(a)	Q.5	(c)	Q.9	(d)	Q.13	(d)
Q.2	(c)	Q.6	(a)	Q.10	(d)	Q.14	(c)
Q.3	(a)	Q.7	(b)	Q.11	(d)	Q.15	(b)
Q.4	(a)	Q.8	(a)	Q.12	(c)		

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