1. STOICHIOMETRY AND REDOX REACTIONS

THE MOLE AND EQUIVALENT CONCEPT

1. INTRODUCTION

Some important terminologies required to master the concepts of chemistry are as follows:

(a) **Chemical Equation:** It is the symbolic representation of a true chemical reaction. The equation provides qualitative and quantitative information about a chemical change in a simple manner. For e.g. in the reaction,

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

The '+' sign on left hand side means 'react with' and on the right of arrow as 'produces'. The substances which react ae called 'reactants' and those produced in the reaction are called 'products' and they are represented on the LHS and RHS of the arrow respectively.

(b) **Thermo Chemical Equation:** The equations which represent chemical as well as thermal changes are called thermo chemical equations. The energy change is shown by putting value on the RHS of the reaction. For eg.

$$\text{(Exothermic)}: C(s) + O_2(g) \longrightarrow CO_2(g); \quad \Delta H = -ve$$

$$\text{(Endothermic)}: C(s) + 2S(s) \longrightarrow CS_2(g); \quad \Delta H = +ve$$

(c) **Molecule and Atom:** A molecule is defined as the smallest possible particle of a substance which has all the properties of that substance and can exist freely in nature. On the other hand an atom is the smallest particle of an element (made up of still smaller particles like electrons, protons, neutrons, etc.) which can take part in a chemical reaction. It may or may not exist free in nature.

(d) **Atomicity of an Element:** The term refers for the number of atoms present in one molecule of an element, e.g., atomicity of H_2, O_3, S_8, P_4 is 2, 3, 8 and 4 respectively.

(e) **Mole:** A mole is defined as the amount of matter that contains as many objects (atoms, molecules, electron, proton or whatever, objects we are considering) as the same number of atoms in exactly 12 g of C^{12}. This number is also known as **Avogadro's number (N_A)**. Avogadro's number = 6.023×10^{23} molecule/mole. Thus, 1 mole of an entities contains N_A particles of that entity.

Number of objects (N) in n mole = number of mole (n) × number of objects per mole (N_A)

$$N = n \times N_A = \frac{w}{M} \times N_A, \left[n = \frac{w}{M}\right] \text{ where } N_A \text{ is Avogadro's number.}$$

(f) **Molar Mass:** The mass in gram of 1 mole of a substance is known as molar mass or molecular weight of substance.

(g) **Atomic Weight:** The atomic mass of an element is defined as the average relative mass of its atoms as compared to the mass of a carbon atom taken as 12. Note that the atomic weight of an element is a relative weight of one atom and not the absolute weight.

(h) **Gram Molecular Weight:** Molecular weight or gram molecular weight of a substance is weight of N-molecules of that substance in grams.

Illustration 1: Calculate the mass of single atom of sulphur and a single molecule of carbon dioxide.

(JEE MAIN)

Sol: Know the gram atomic and the molecular mass of sulphur and CO_2 and then divide by N_A.

Mass of one sulphur atom $= \dfrac{\text{Gram atomic mass}}{6.02\times10^{23}} = \dfrac{32}{6.02\times10^{23}} = 5.33\times10^{-23}\,\text{g}$

Formula of carbon dioxide = CO_2

Molecular mass of CO_2 = 12 + 2 × 16 = 44

Gram-molecular mass of CO_2 = 44 g

Mass of one molecule of CO_2 $= \dfrac{\text{Gram molecular mass}}{6.02\times10^{23}} = \dfrac{44}{6.02\times10^{23}} = 7.308\times10^{-23}\,\text{g}$

Illustration 2: How many electrons are present in 1.6 g of methane? **(JEE ADVANCED)**

Sol: Know the molar mass of methane, the moles and the no. of molecules.Then calculate no. of electrons for the solved no. of molecules.

Gram molecular mass of methane, (CH_4) = 12 + 4 = 16 g

Number of moles in 1.6 g of methane $= \dfrac{1.6}{16} = 0.1$

Number of molecule of methane in 0.1 mole $= 0.1\times6.023\times10^{23} = 6.02\times10^{22}$

One molecules of methane has = 6 + 4 = 10 electrons

So, 6.02×10^{22} molecules of methane have $= 10\times6.02\times10^{22}$ electrons $= 6.02\times10^{23}$ electrons

2. STOICHIOMETRY

The quantitative aspect, dealing with mass and volume relations among reactants and products is termed stoichiometry. Consider for example, the reaction represented by a balanced chemical equation:

Chemical Equation	$2H_2(g)$	+	$O_2(g)$	$\longrightarrow$	$2H_2O(g)$
Mole ratio :	2 mol or		1 mol or		2 mol or
Molecule ratio :	$2\times6.023\times10^{23}$ molecules or 2 molecules		$1\times6.023\times10^{23}$ molecules or 1 molecules		$2\times6.023\times10^{23}$ molecules or 2 molecules
Weight ratio :	4g		32g		36 g
Volume ratio :	2 vol		1 vol		2 vol

(valid only for gaseous state at same P and T)

The given reaction suggests the combination ratio of reactants and formation ratio of products in terms of:

(a) **Mole ratio:** 2 mol H_2 reacts with 1 mol of O_2 to form 2 mol of H_2O vapors.

(b) **Molecular ratio:** 2 molecule of H_2 reacts with 1 molecule of O_2 to form 2 molecules of H_2O vapors.

(c) **Weight ratio:** 4 g H_2 reacts with 32 g O_2 to form 36 g of H_2O vapors.

(d) **Volume ratio:** In gaseous state 2 volume H_2 reacts with 1 volume O_2 to form 2 volume H_2O vapors at same conditions of P and T.

Therefore, coefficients in the balanced chemical reaction can be interpreted as the relative number of moles, molecules or volume (if reactants are gases) involved in the reaction. These coefficients are called stoichiometrically equivalent quantities and may be represented as:

$$2 \text{ mol } H_2 \equiv 1 \text{ mol } O_2 \equiv 2 \text{ mol } H_2O$$

Or $\quad$ Mole of H_2: Mole of O_2: Mole of H_2O = 2: 1: 2

Where the symbol ≡ is taken to mean 'stoichiometrically equivalent to'. The stoichiometric relation can be used to give conversion factors for relating quantities of reactants and products in a chemical reaction.

2.1 Some Important Laws

(a) **Law of conservation of mass:** "In all physical and chemical changes, the total mass of the reactants is equal to that of the products" or "matter can neither be created nor destroyed."

(b) **Law of constant composition/definite proportion:** "A chemical compound is always found to be made up of the same elements combined together in the same fixed ratio by weight".

(c) **Law of multiple proportions:** "When two elements combine together to form two or more chemical compounds, then the weight of one of the elements which combine with a fixed weight of the other bear a simple ratio to one another".

(d) **Law of reciprocal proportions:** The ratio of the weights of two elements A and B which combine with a fixed weight of the third element C is either the same or a simple multiple of the ratio of the weights of A and B which directly combine with each other.

(e) **Gay-Lussac's law of gaseous volumes:** "When gases react together, they always do so in volumes which bear a simple ratio to one another and to the volumes of the products, if gaseous, all measurements are made under the same conditions of temperature and pressure".

Illustration 3: What mass of sodium chloride would be decomposed by 9.8 g of sulphuric acid, if 12 g of sodium bisulphate and 2.75 g of hydrogen chloride were produced in a reaction assuming that the law of conservation of mass is true? **(JEE MAIN)**

Sol: Apply the law of conservation of mass.

$$NaCl + H_2SO_4 \rightleftarrows NaHSO_4 + HCl$$

According to law of conservation of mass, Total mass of reactant = Total mass of product

Let the mass of NaCl decomposed be x, so

$$\begin{aligned} x + 9.8 &= 12 + 2.75 \\ &= 14.75 \end{aligned}$$

$$x = 4.95 \text{ g}$$

Illustration 4: How much volume of oxygen will be required for complete combustion of 40 mL of acetylene (C_2H_2) and how much volume of carbon dioxide will be formed? All volumes are measured at NTP. **(JEE ADVANCED)**

Solution: Write the balanced chemical reaction and from the given data determine the volume.

$$\begin{array}{llcll} 2C_2H_2 & + \; 5CO_2 & \rightleftharpoons & 4CO_2 & + \; 2H_2O \\ 2 \text{ vol} & 5 \text{ vol} & & 4 \text{ mol} & \\ 40 \text{ ml} & \frac{5}{2} \times 40 \text{ ml} & & \frac{4}{2} \times 40 \text{ ml} & \\ 40 \text{ ml} & 100 \text{ ml} & & 80 \text{ ml} & \end{array}$$

So, for complete combustion of 40 mL of acetylene, 100 mL of oxygen are required and 80 mL of carbon dioxide is formed.

2.2 Avogadro's Hypothesis

"Equal volumes of all gases/vapors under similar conditions of temperature and pressure contain equal number of molecules."

This statement leads to the following facts:

(a) One mole of all gases contain Avogadro's number of molecules, i.e., 6.023×10^{23} molecules.

(b) The volume of 1 mole of gas at NTP or STP is 22.4 litre.

(c) NTP or STP refers for $P = 1$ atm, $T = 0^{\circ}C$ or 273 K.

(d) Molecular weight = 2 × vapour density (for gaseous phase only)

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

2.3 Dulong and Petit's Law

This law is valid for metals only. According to this law, atomic weight × specific heat (in cal/g) ≈ 6.4. Also, heavier the element, lesser will be its specific heat. Therefore, $C_{Hg} < C_{Cu} < C_{Al}$.

2.4 Equivalent Weight

For comparing reacting weights of substances participating in a chemical reaction, chemists coined the term 'equivalent weight'. The substances react in their equivalent weight ratios.

2.4.1 Equivalent Weight of an Element or Compound in a Non-Redox Change

Equivalent weight of an element is its weight which reacts with 1 part by weight of hydrogen, 8 parts by weight of oxygen and 35.5 parts by weight of chlorine. This definition leads to following important generalisations.

(a) **Equivalent weight of an element:** $'E' = \frac{\text{Atomic weight of element}}{\text{Valence of element}}$

(b) **Equivalent weight of an ionic compound:** $(E) = \frac{\text{Formula weight of compound}}{\text{Total charge on cationic or anionic part}}$

Also, Eq. wt. of compound $E = \text{Eq. wt. of I part} + \text{Eq. wt. of II part}$

(c) **Equivalent weight of an acid or base:**

$$E_{Acid} = \frac{\text{Molecular weight}}{\text{Basicity}}$$

Basicity = Number of H-atoms replaced from one molecule of acid

$$E_{Base} = \frac{\text{Molecular weight}}{\text{Acidity}}$$

Acidity = Number of OH-groups replaced from one molecule of base.

(d) **Equivalent weight of acid salt:** $= \frac{\text{Molecular weight of acid salt}}{\text{Replaceable H-atom in it}}$

An acid salt is one which has replaceable H-atom, e.g., $NaHCO_3$, $NaHSO_4$, Na_2HPO_4, Na_2HPO_3 is not an acid salt, since it does not have replaceable H-atom.

Note: An acid salt possesses acidity as well as basicity both.

(i) Equivalent weight of basic salt: $= \dfrac{\text{Molecular weight of basic salt}}{\text{Replacable OH gps in basic salt}}$

A basic salt is one which has replaceable OH gps e.g., $Ca(OH)Cl$, $Al(OH)_2Cl$, $Al(OH)Cl_2$ etc.

2.4.2 Equivalent Weight of an Element or Compound in a Redox Change

For a redox change, the equivalent weight of a substance is given by,

$$\text{Equivalent weight of an oxidant or reductant} = \frac{\text{Molecular weight}}{\text{Number of electrons lost or gained by one molecule of oxidant or reductant}}$$

2.4.3 Gram Equivalent Weight

The equivalent weight of a substance expressed in grams is called gram eq. wt. or one gram equivalent. Now we can define gram-equivalent (g meq) in gms of a substance whose equivalent weight is as follows: No. of equivalents $= \dfrac{g}{E}$

Illustration 5: An unknown element forms an oxide. What will be the equivalent mass of the element if the oxygen content is 20% by mass? **(JEE MAIN)**

Sol: Use the equation of equivalent weight.

$$\text{Equivalent mass of element} = \frac{\text{Mass of element}}{\text{Mass of oxygen}} \times 8 = \frac{80}{20} \times 8 = 32$$

Illustration 6: The equivalent weight of a metal is double than that of oxygen. How many times is the weight of its oxide greater that the weight of metal? **(JEE ADVANCED)**

Sol: First calculate the equivalent weight of the metal and from the molecular formula, determine the ratio.

Equivalent mass of metal = 16 = $\dfrac{x}{n}$

Where x= atomic mass of metal

N = valency of metal

Molecular formula of metal oxide = M_2O_n

$$\frac{\text{Mass of metal oxide}}{\text{Mass of metal}} = \frac{2(16n) + 16(n)}{2(16n)} = 1.5$$

2.5 The Limiting Reagent

The reagent producing the least number of moles of products is the limiting reagent. For example, consider a chemical reaction given below, containing 10 mol of H_2 and 7 mol of O_2. Since, 2 mol H_2 reacts with 1 mol O_2, thus,

	$2H_2(g)$	$+\ O_2(g)$	$\longrightarrow\ 2H_2O(V)$
Moles before reaction	10	7	0
Moles after reaction	0	2	10

It is thus, evident that the reaction stop only after consumption of 5 moles of O_2 since, no further amount of H_2 is left to react with unreacted O_2. The substance that is completely consumed in a reaction is called **limiting reagent** because it determines or limits, the amount of product. The other reactants present in excess are sometimes called as **excess reagents**.

Calculation of limiting reagent

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

(b) By calculating amount of anyone 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 numbers of reactants are more than two].

2.6 Reaction Yield

The theoretical yield of a product is the maximum quantity that can be expected on the basis of stoichiometry of a chemical equation. The percentage yield is the percentage of a theoretical yield actually achieved. The lower yield of a chemical reaction is due to side reactions.

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

Illustration 7: 10 mL N_2 and 25 mL H_2 at same P and T are allowed to react to give NH_3 quantitatively. Predict (i) the volume of NH_3 formed, (ii) limiting reagent. **(JEE MAIN)**

Sol: Frame the reaction and lay down the conditions, due to which volume of NH_3 can be found which leads to the limiting reagent.

$$\begin{array}{lccc} & N_2 & +3H_2 \longrightarrow & 2NH_3 \\ \text{V at t} = 0 & 10 & 25 & 0 \\ \text{V at final condition} & \left[10 - \frac{25}{3}\right] & 0 & \frac{50}{3} \end{array}$$

$\therefore$ Volume of $2NH_3$ formed $= \frac{50}{3}$ mL

Limiting reagent is H_2.

Illustration 8: A chloride of an element contains 49.5% chlorine. The specific heat of the element is 0.056. Calculate the equivalent mass, valency and atomic mass of the element. **(JEE ADVANCED)**

Sol: Calculate mass of the metal from the given percentage and the equivalent mass of the metal. Using the Dulong and Petit's law, specific heat gives the atomic mass of the metal and then the valency can be found.

Mass of chlorine in the metal chloride = 49.5%

Mass of metal = (100 – 49.5) = 50.5

Equivalent mass of the metal $= \frac{\text{Mass of metal}}{\text{Mass of chlorine}} \times 35.5 = \frac{50.5}{49.5} \times 35.5 = 36.21$

According to Dulong and Petit's law,

Approximate atomic mass of the metal $= \frac{6.4}{\text{Specific heat}} = \frac{6.4}{0.056} = 114.3$

$$\text{Valency} = \frac{\text{Approximate atomic mass}}{\text{Equivalent mass}} = \frac{114.3}{36.21} = 3.1 \approx 3 \text{ v}$$

Hence, exact atomic mass = 36.21 × 3 = 108.63

3. METHODS OF EXPRESSING CONCENTRATION OF SOLUTION

(a) Strength of Solution: Amount of solute present in one litre solution

$$S = \frac{\text{Weight of solute}}{\text{Volume of solution in litre}} = \frac{w}{V \text{ in (l)}}$$

$$= \text{Normality} \times \text{Equivalent weight}$$

$$= \text{Molarity} \times \text{Molecular weight}$$

(b) Mass Percentage or Percent by Mass:

$$\%(w/w) \text{ Mass percentage of solute} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

(c) Percent Mass by Volume: $\%(w / v) = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$

(d) Parts Per Million (ppm): $= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6$

(e) Molarity: It is expressed as moles of solute contained in one litre of solution or it is also taken as millimoles of solute in 1000 cc(mL) of solution. It is denoted by M.

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Litres of solution}} = \frac{\text{Millimoles of solute}}{\text{Millilitres of solution}}; \qquad M = \frac{n_B}{V_{lt}} = \frac{g_B / m_B}{V_{lt}}$$

(f) Molality: It is the number of mole present in 1kg solvent.

$$\text{Molality(m)} = \frac{\text{No. of moles of solute}}{\text{Weight (in kg) of solvent}}$$

Let w_A grams of the solute of molecular mass m_A be present in w_B grams of the solvent, then

$$\text{Molality(m)} = \frac{w_A}{m_A \times w_B} \times 1000$$

(g) Normality: It is define as number of equivalent of a solute present in one litre of solution.

$$N = \frac{\text{Equivalent of solute}}{\text{Volume of solution in litre}} = \frac{\text{Weight of solute}}{\text{Equivalent weight of solute} \times \text{V in litre}}$$

$$N = \frac{w}{E \times V \text{ in (l)}} = \frac{w \times 1000}{E \times V \text{ in mL}}$$

Note: A striking fact regarding equivalent and milli equivalent is equivalent and milli equivalent of reactants react in equal number to give same number of equivalent or milli equivalent of products separately.

(h) Formality: Since molecular weight of ionic solids is not determined accurately due to their dissociative nature and therefore molecular weight of ionic solid is often referred as formula weight and molarity as formality. $\text{Formality} = \frac{\text{Wt. of solute}}{\text{Formula wt.} \times \text{V(in l)}}$ i.e., molarity

(i) Specific Gravity of Solution: $= \dfrac{\text{Weight of solution}}{\text{Volume of solution}}$ i.e., weight of 1 mL solution.

PLANCESS CONCEPTS

- Molality, % by weight, mole fractions are independent of temperature since these involve weights.
- Rest all, i.e., normality, molarity, % by volume, % by strength and strength are temperature dependent, normally decrease with increase in temperature since volume of solution increases with T.
- Molar solution having normality 1N and molarity 1M respectively.
- On diluting a solution, eq. meq. mole or m mole of solute do not change however N and M change.

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(j) Mole Fraction: It is the fractional part of the moles that is contributed by each component to the total number of moles that comprises the solution. In containing n_A moles of solvent and n_B moles of solute. Mole fraction of B $= x_B = \dfrac{n_B}{n_A + n_B}$

Mole fraction of A $= x_B = \dfrac{n_A}{n_A + n_B}$

(k) Ionic Strength: The ionic strength (μ) of the solution obtained by mixing two or more ionic compounds is given by: $\mu = \dfrac{1}{2}\Sigma cZ^2$. Where c is the concentration (molarity) of that ion and Z is its valence.

Illustration 9: 30 mL of 0.1 N $BaCl_2$ is mixed with 40 mL of 0.2 N $Al_2(SO_4)_3$. How many g of $BaSO_4$ are formed? **(JEE MAIN)**

Sol: Frame the reaction and place the given data to find the milliequivalents at the end of the reaction. Using the formula below, weight of $BaSO_4$ can be found.

	$BaCl_2$	$+\ Al_2(SO_4)_3$	$\longrightarrow BaSO_4$	$+\ AlCl_3$
Meq. before reaction	30×0.1 $= 3$	40×0.2 $= 8$	0 $= 0$	0 $= 0$
Meq. after reaction	0	5	3	3

3 Meq. of $BaCl_2$ reacts with 3 Meq. of $Al_2(SO_4)_3$ to produce 3 Meq. of $BaSO_4$ and 3 Meq. of $AlCl_3$

$$\therefore \quad \text{Meq. of } BaSO_4 \text{ formed} = \frac{w_{BaSO_4}}{E_{BaSO_4}} \times 1000 = 3$$

$$w_{BaSO_4} \quad \text{formed} = \frac{3 \times 233}{2 \times 1000} = 0.3495 \text{ g}$$

Illustration 10: 500 mL of aM solution and 250 mL of bM solution of the same solute are mixed and diluted to 2 litre. The diluted solution shows the molarity 1.6 M. If a: b is 2: 5, then calculate a and b. **(JEE ADVANCED)**

Sol: Using the mixture molarity formula $\dfrac{M_1 \times V_1 + M_2 \times V_2}{V_1 + V_2}$, a and b is calculated.

$\frac{500 \times a + 250 \times b}{2000} = 1.6$; 500 a + 250 b = 3200

If, $\frac{a}{b} = \frac{2}{5}$ then $\frac{500 \times b \times 2}{5}$ + 250 b = 3200; 450 b = 3200; b = 7.11

Similarly, $500a + \frac{250 \times 5a}{2} = 3200$; $\therefore$ $a = \frac{3200}{1125}$ = 2.84

4. SOME CHARACTERISTIC APPLICATION OF MOLE CONCEPT

4.1 Gravimetric Analysis

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

(a) **Mass–Mass Relationship:** It relates the mass of a species (reactant or product) with the mass of another species (reactants or products)

Let us consider a chemical reaction,

$$2NaHCO_{3(s)} \xrightarrow{\Delta} Na_2CO_{3(s)} + H_2O + CO_{2(g)}$$

Suppose the mass of $NaHCO_3$ being heated is 'x' g and we want to calculate the weight of Na_2CO_3 being produced by heating of 'a' g $NaHCO_3$.

The moles of $NaHCO_3 = \frac{x}{84}$

According to the above balanced equation 2 moles of $NaHCO_3$ upon heating gives 1 mole of Na_2CO_3

(b) **Mass–Volume Relationship:** It relates the mass of a species (reactant or product) and the volume of a gaseous species (reactant or product) involved in a chemical reaction. Suppose we are provided with 'a' gms of $NaHCO_3$ in a vessel of capacity VL and the vessel is heated, so that decomposes as $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + H_2O + CO_2$

Now, we want to calculate the volume of CO_2 gas being reduced.

Moles of $NaHCO_3$ taken $= \frac{X}{84}$

Now, since 2 moles of $NaHCO_3$ gives 1 mole of CO_2 at STP. Thus

Moles of CO_2 produced $= \frac{1}{2} \times \frac{X}{84}$

As we know that 1 mole of any gas at STP occupies a volume of 22.4 L.

So, volume of CO_2 produced $= \left(\frac{1}{2} \times \frac{X}{84} \times 22.4\right)L$

(i) **Volume–Volume Relationship:** It relates the volume of gaseous species (reactants or products) with the volume of another gaseous species (reactant or product) involved in a chemical reaction.

Illustration 11: An ore containing Mn_2O_3 is analysed for the manganese content by quantitatively converting the manganese to Mn_3O_4 and weighing it. A 1.52 g sample of ore yields 0.126 g Mn_3O_4. Calculate the percent of Mn and Mn_2O_3 in the sample. **(JEE ADVANCED)**

Sol: From the given data, find out the amount of Mn_2O_3 and calculate the %.

Equate the no. of moles of Mn_2O_3 with the no. of moles of Mn and hence find % of Mn. $3Mn_2O_3 \longrightarrow 2Mn_3O_4$

Mole ratio $Mn_2O_3 : Mn_3O_4 :: 3 : 2$

$\therefore$ Moles of $Mn_2O_3 = \frac{3}{2} \times$ Moles of $Mn_3O_4 = \frac{3}{2} \times \frac{0.126}{229} = 5.253 \times 10^{-4}$

$\therefore$ Amount of $Mn_2O_3 = 8.253 \times 10^{-4} \times 158 = 0.13$ g

$\therefore$ % of $Mn_2O_3 = \frac{0.13}{1.52} \times 100 = 8.58$

Also, $Mn_2O_3 \longrightarrow 2Mn$

$\therefore$ Mole of Mn = 2 × Mole of Mn_2O_3 = $2 \times 8.253 \times 10^{-4} = 16.51 \times 10^{-3}$

$\therefore$ Amount of Mn $= 16.51 \times 10^{-3} \times 55$

$\therefore$ % Mn $= \frac{0.09}{1.52} \times 100 = 5.29$

Illustration 12: A 1.0 g sample of pure organic compound containing chlorine is fused with Na_2O_2 convert chlorine to NaCl. The sample is then dissolved in water, and the chloride precipitated with $AgNO_3$, giving 1.96 g of AgCl. If the molecular weight of organic compound is 147, how many chlorine atoms does each molecule contain?

(JEE MAIN)

Sol: Calculate the moles of chloride ions in silver chloride and the organic compound; and compare the ratio.

Moles of AgCl = Moles of chloride= $\frac{1.96}{143.5} = 0.0136$

Moles of organic compound = $\frac{1}{147} = 6.8 \times 10^{-3}$

Chlorine atoms in each molecules of organic compound = $\frac{0.0136}{6.5 \times 10^{-3}} = 2$

4.2 Volumetric Analysis

It is the process of determination of conc. of a solution with the help of another solution of known conc. It may also be defined as experimental method of determination of volume of a solution of known strength needed for a definite volume of another solution of unknown strength.

Titration: It is an operation forming the basis of volumetric analysis. The addition of measured amount of a solution of one reagent (called the **titrant**) from a burette to a definite amount of another reagent (called **analyte**) until the reaction between them is complete, i.e., till the second reagent (analyte) is completely used up, i.e., upto end point.

Type of Titrations: There are four general classes of volumetric titrations.

(a) **Acid-Base Titration:** Acid or base solutions are titrated against a standard solution of a strong base or strong acid using suitable acid-base indicator.

(b) **Precipitation Titration:** In such titration, the titrant forms an insoluble product with analyte e.g., titration of chloride ions against $AgNO_3$ solution.

(c) **Complexometric Titrations:** In such titrations, the titrant is a complexing agent and forms a water-soluble complex with the analyte, usually containing a metal ion. The titrant is often a chelating agent, e.g., ethylenediaminetetraacetic acid (EDTA).

(d) **Redox Titrations:** These involves the titration of an oxidizing agent against a reducing agent or vice versa.

Standard Solution: It is the solution of known strength.

Primary Standard Solution: The solution for which conc. is known is called primary standard solution.

Note: For primary standard solution,

(a) Solute should not be reactive towards solvent or air.

(b) Solute should not be hygroscopic.

(c) Temperature should be constant.

In **acids**, oxalic acid ($H_2C_2O_2.2H_2O$), benzoic acid (C_6H_5COOH), sulphamic acid (HNH_2SO_3), etc. are taken as primary standard solution.

In **bases**, washing soda ($NaCO_3.10H_2O$), borax ($Na_2B_4O_7$), etc are taken as primary standard solution.

In **oxidizing agents**, only potassium dichromate ($K_2Cr_2O_7$) is taken as primary standard solution.

In **reducing agents**, hypo ($Na_2S_2O_3.5H_3O$), Mohr's salt ($FeSO_4.(NH_3)_2SO_4.6H_2O$), sodium oxalate ($Na_2C_2O_4$), etc are taken as primary standard solutions.

End point: End point of titration is normally detected by a sudden change in color of the solution.

Indicator: These compound mixed in the solution in very small amount, which responses the sudden change in color of the solution and show the end point of titration. In acid–base titration, the indicators used are either weak organic acid or weak organic bases. Some examples are

Acidic Indicator: Phenolphthalein, litmus paper etc.

Basic Indicator: Methyl orange, methyl red, etc.

Acid	Base	Indicator
Strong	Strong	Any
Strong	Weak	Methyl orange, methyl red, etc
Weak	Strong	Phenolphthalein etc

Principle of Titration: Titration means stoichiometry and hence its problems may be solved by mole as well as equivalent concept. But for simplicity equivalent concept is preferred, according to which the number of g-equivalents of all reactants reacted will be equal and the same number of g-equivalents of each products will form. The number of g-equivalents of substances may be determined by using the following formulae:

$$\text{Number of g-equivalents } = \frac{\text{Wt.(in gm)}}{\text{Gm. eq.wt.}} = \frac{VS}{1000} = \frac{\text{Vol. of gas}}{\text{Eq. vol.}} = \text{Mole} \times x - \text{factor}$$

Where, S = strength in normality

Illustration 13: 30 mL of a certain solution of Na_2CO_3 and $NaHCO_3$, required 12 mL of 0.1 N H_2SO_4 using phenolphthalein as indicator. In presence of methyl orange, 30 mL of same solution required 40 mL of 0.1 N H_2SO_4. Calculate the amount of Na_2CO_3 per litre in mixture. **(JEE MAIN)**

Sol: Use titration principles to understand the numerical. Find out the milliequivalents of H_2SO_4 and Na_2CO_3.

Phenolphthalein as indicator:

Meq. of H_2SO_4 used = 12 × 0.1 = 1.2 for 30 mL mixture

$$\therefore \quad \frac{1}{2} \text{ Meq. of } Na_2CO_3 \text{ in 30 mL mixture} = 1.2 \qquad \text{...(i)}$$

Methyl orange as indicator: This time fresh solution is titrated with H_2SO_4 using methyl orange as indicator. By equating the data of the bases with the required acid, solve the milliequivalents and then calculate the strength of the bases.

$$\text{Meq. of } Na_2CO_3 + \text{Meq. of } NaHCO_3 = \text{Meq. of } H_2SO_4 \text{ used}$$
$$= 40 \times 0.1 = 4 \qquad \text{...(ii)}$$

By Eq. (i)

Meq. of Na_2CO_3 = 2.4

$$\therefore \quad \frac{w}{53} \times 1000 = 2.4$$

or $\quad w_{Na_2CO_3} = 0.1272$ g in 30 mL

$\therefore$ Strength of Na_2CO_3 = 4.24 g $litre^{-1}$

Also, Meq. of $NaHCO_3$ = 4 – 2.4 = 1.6; $\frac{w}{84} \times 1000 = 1.6$

$\therefore \quad w_{NaHCO_3} = 0.1344$ g in 30 mL

Strength of $NaHCO_3 = \frac{0.1344 \times 1000}{30}$ = 4.48 g $litre^{-1}$

Illustration 14: 0.5 g mixture of $K_2Cr_2O_7$ and $KMnO_4$ was treated with excess of KI in acidic medium. Iodine liberated required 150 cm^3 of 0.10N solution of thiosulphate solution for titration.

Find the percentage of $K_2Cr_2O_7$ in the mixture. **(JEE MAIN)**

Solution: Determine the equivalent weight of chromate and permanganate solution and compare the mili. Eq of each components to determine the % of chromate.

Reactions of $K_2Cr_2O_7$ and $KMnO_4$ with KI may be given as :

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

$$2KMnO_4 + 8H_2SO_4 + 10KI \rightarrow 6K_2SO_4 + 2MnSO_4 + 5I_2$$

Thus equivalent wt. of $K_2Cr_2O_7 = \frac{294}{6} = 49$

Equivalent weight of $KMnO_4 = \frac{158}{5} = 31.6$

m.eq. of $K_2Cr_2O_7$ + m.eq. of $KMnO_4$ = m.eq. of I_2 = m.eq of hypo.

Let the mass of $K_2Cr_2O_7$ = x g

Mass of $KMnO_4$ = (0.5-x)g

$$\frac{x}{49} + \frac{(0.5-x)}{31.6} = 150 \times 0.1 \times 10^{-3} \; x = 0.0732$$

$$\% \text{ of } K_2Cr_2O_7 = \frac{0.0732}{0.5} \times 100 = 14.64$$

4.3 Double Indicators Titration

For the titration of alkali mixtures (e.g., NaOH + Na_2CO_3) or (Na_2CO_3 + $NaHCO_3$), two indicators phenolphthalein and methyl orange are used. This will be discussed in detail in Ionic Equilibrium.

4.4 Eudiometry

Eudiometry or gas analysis involves the calculation based on gaseous reactions in which the amounts of gases are represented by their volumes, measured at STP. Some basic assumptions for calculations

(a) Gay-Lussac's law of volume combination holds good.

(b) For non-reacting mixture. Amagat's law holds good. According to this, the total volume of a non-reacting gaseous mixture is equal to the sum of partial volumes of all the component gases. The volume of solids or liquids is considered to be negligible in comparison to the volumes of gases.

Thus, we can summarize the above points as – eudiometry involves volume measurement during the reaction. Since, Volume of gas, V is directly proportional to number of moles at constant P, T and thus, volume ratio of gases can be directly used in place of mole ratio for analysis.

Illustration 15: A mixture of ethane (C_2H_6) and ethene (C_2H_4) occupies 40 litre at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of O_2 to produce CO_2 and H_2O. Assuming ideal gas behaviour, calculate the mole fraction of C_2H_4 and C_2H_6 in the mixture. **(JEE MAIN)**

Sol: Using the Ideal gas equation, find out no. of moles. Frame the balanced combustion reactions of the hydrocarbons and lay down the values.Calculate the mole fraction accordingly.

For a gaseous mixture of C_2H_6 and C_2H_4

$$PV = nRT$$

$\therefore \quad 1 \times 40 = n \times 0.082 \times 400$

Total mole of (C_2H_6 + C_2H_4) = 1.2195

Let mole of C_2H_6 and C_2H_4 be a and b respectively.

$$a + b = 1.2195 \qquad \text{...(i)}$$

$$C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$$

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$$

$\therefore$ Mole of O_2 needed for complete reaction of mixture = 7a/2 + 3b

$$\therefore \quad \frac{7a}{2} + 3b = \frac{130}{32} \qquad \text{...(ii)}$$

By Eqs. (i) and (ii), a = 0.808

b = 0.4115

$\therefore$ Mole fraction of C_2H_6 = $\frac{0.808}{1.2195} = 0.66$ and Mole fraction of C_2H_4 = 0.34

4.5 To Represent Concentration of H_2O_2 Solution

(a) In percentage: The amount of H_2O_2 present in 100 mL H_2O_2 solution is H_2O_2 concentration in percentage of H_2O_2 solution.

(b) In volume: The volume of O_2 at STP given by 1 mL H_2O_2 solution on decomposition is H_2O_2 concentration of H_2O_2 in volume.

Note:

(i) Direct conversions can be made by using following relations

- % strength $= \frac{17}{56} \times$ volume strength
- Volume strength = 5.6 × Normality
- Volume strength = 11.2 × Molarity

(ii) The volume strength of H_2O_2 solution decreases on long standing due to decomposition of H_2O_2 and O_2.

Illustration 16: Report the concentration of 1.5 N solution of H_2O_2 in terms of volume. **(JEE MAIN)**

Sol: From the given equivalent of H_2O_2, calculate the weight and then the volume of O_2. This itself can solve the volume strength of H_2O_2.

$\because$ Equivalent of H_2O_2 in 1 litre solution = 1.5

$\therefore \quad w_{H_2O_2}$ in 1 litre solution $= 1.5 \times \frac{34}{2} = 25.5$ g

∴ Volume of O_2 obtained by 1000 mL H_2O_2 solution $= \frac{22400 \times 25.5}{68} = 8400$ mL

∴ Volume strength of $H_2O_2 = \frac{8400}{1000} = 8.4$

4.6 To Represent the Concentration of Oleum

(100 – X%) of oleum means 'X' g H_2O reacts with equivalent amount of free SO_3 to give H_2SO_4.

Illustration 17: 0.5 g of fuming H_2SO_4 (oleum) is diluted with water. The solution requires 26.7 mL of 0.4N NaOH for complete neutralization. Find the % of free SO_3 in the sample of oleum. Also report % of oleum solution.

(JEE ADVANCED)

Sol: Principle of titration is used. Equation of oleum and the base in terms of their milliequivalents is done wherein the amount of oleum is found. % of SO_3 is thus found. Reaction of SO_3 with H_2O gives H_2SO_4. Lay down the calculated and the given values and solve the % of oleum.

Fuming H_2SO_4 contains H_2SO_4 and SO_3. Both react with NaOH. Let a g and b g SO_3 be present.

For reaction, ∴ Meq. of H_2SO_4 + Meq. of SO_3 = Meq. of NaOH; $\frac{a}{98/2} \times 1000 + \frac{b}{80/2} \times 1000 = 26.7 \times 0.4$

∴ $80a + 98b = 41.87$ ...(i)

Also, $a + b = 0.5$ ...(ii)

∴ % of $SO_3 = \frac{0.1039}{0.5} \times 100 = 20.78\%$

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

80 g SO_3 = 18 g H_2O

∴ 20.78 g $SO_3 = \frac{18 \times 20.78}{80} = 4.68$

% of oleum = 100 + 4.68 = 104.68%

4.7 To Determine Hardness of Water

Water, which gives foams easily with soap is called soft water and if not then hard water. The hardness of water is due to the presence of bicarbonates, chlorides and sulphates of Ca and Mg. The extent of hardness is known as **degree of hardness** defined usually as the no. of parts by weight of $CaCO_3$ present per million parts by weight of water. Hardness is expressed in ppm i.e., 1 ppm = 1 part of $CaCO_3$ in 10^6 part of hard water.

Note: The reason for choosing $CaCO_3$ as the standard to express hardness, inspite of the fact that $CaCO_3$ is not soluble in water but its molecular weight is 100 which makes calculation easy.

4.8 Mass Balance Equations

The principle of mass balance is based on the law of conservation of mass, i.e., the number of atoms of an element remains constant in a chemical reaction.

4.9 Charge Balance Equations

The principle of charge balance equations is based on the principle of electroneutrality, i.e., all solution are electrically neutral since sum of positive charges equals the sum of negative charges.

4.10 Saponification Value

It is the amount of KOH in mg required to neutralize a fatty acid obtained by the hydrolysis of 1 g of oil.

REDOX REACTIONS

1. INTRODUCTION

Molecular Equations: $2FeCl_3 + SnCl_2 \rightarrow 2FeCl_2 + SnCl_4$

The reactants and products have been written in molecular forms; thus, the equation is termed as **molecular equation**.

Ionic Equations: The reactions in which the reactants and products are present in the form of ions are called **ionic reactions**.

For example: $2Fe^{3+} + 6Cl^- + Sn^{2+} + 2Cl^- \rightarrow 2Fe^{2+} + 4Cl^- + Sn^{4+} + 4Cl^-$

Or $2Fe^{3+} + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+}$

Illustration 18: Represent the following equation in ionic form. **(JEE MAIN)**

$K_2Cr_2O_7 + 7H_2SO_4 + 6FeSO_4 = 3Fe_2(SO_4)_3 + Cr_2(SO_4)_3 + 7H_2O + K_2SO_4$

Sol: Knowing the oxidation numbers of the elements present, balanced ionic form can be represented. In this equation except H_2O, all are ionic in nature. Representing these compounds in ionic forms,

$$2K^+ + Cr_2O_7^{2-} + 14H^+ + 7SO_4^{2-} + 6Fe^{2+} + 6SO_4^{2-} \longrightarrow$$
$$6Fe^{3+} + 9SO_4^{2-} + 2Cr^{3+} + 3SO_4^{2-} + 2K^+ + SO_4^{2-} + 7H_2O$$

$2K^+$ ions and $13SO_4^{2-}$ ions are common on both sides, so these are cancelled. The desired ionic equation reduces to, $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2-} \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$

Phenomenon of Oxidation and Reduction:

Oxidation or de-electronation is a process which liberates electrons.

Reduction or electronation is a process which gains electrons.

Oxidation	Reduction
a. $M \longrightarrow M^{n+} + ne^-$	$M^{n+} + ne^- \longrightarrow M$
b. $M^{n_1+} \longrightarrow M^{n_2+} + (n_2 - n_1)e^- \quad (n_2 > n_1)$	$M^{n_2+} + (n_2 - n_1)e^- \longrightarrow M^{n_1+} \quad (n_2 > n_1)$
c. $A^{n-} \longrightarrow A + ne^-$	$A + ne^- \longrightarrow A^{n-}$
d. $A^{n_1-} \longrightarrow A^{n_2-} + (n_1 - n_2)e^-$	$A^{n_2^-} + (n_1 - n_2)e^- \longrightarrow A^{n_2^-}$

Note: M may be an atom or a group of atoms; A may be atom or a group of atoms.

Oxidizing and Reducing Agent:

(a) If an element is in its highest possible oxidation state in a compound, it can function as an oxidizing agent, e.g. $KMnO_4, K_2Cr_2O_7, HNO_3, H_2SO_4, HClO_4$ etc.

(b) If an element is in its lowest possible oxidation state in a compound, it can function as a reducing agent, e.g. H_2S, $FeSO_4, Na_2S_2O_3, SnCl_2$ etc.

(c) If an element is in its intermediate oxidation state in a compound, it can function both as an oxidizing agent as well as reducing agent, e.g. H_2O_2, H_2SO_3, HNO_3, SO_2 etc.

(d) If highly electronegative element is in its higher oxidation state in a compound, that compound can function as a powerful oxidizing agent, e.g. $KClO_4$, $KClO_3$, KIO_3 etc.

(e) If an electronegative element is in its lowest possible oxidation state in a compound or in free state, it can function as a powerful reducing agent, e.g. I^-, Br^-, N_3^- etc.

2. MODERN CONCEPT OF OXIDATION AND REDUCTION

According to the modern concept, loss of electrons is oxidation whereas gain of electrons is reduction. Oxidation and reduction can be represented in a general way as shown below:

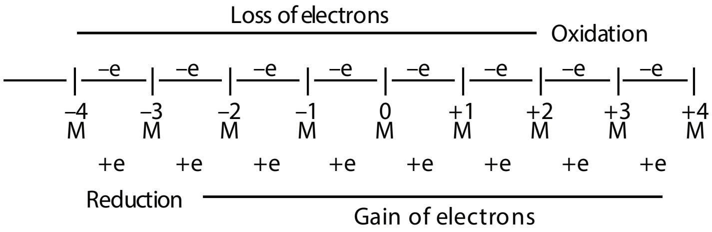


Figure 1.1: Oxidation and Reduction

PLANCESS CONCEPTS

- In a redox process the valency of the involved species changes. The valency of a reducing agent increases while the valency of an oxidising agent decreases in a redox reaction. The valency of a free element is taken as zero.
- Redox reaction involves two half reactions, one involving loss of electron or electrons (oxidation) and the other involving gain of electron or electrons (reduction).

Saurabh Gupta (JEE 2010, AIR 443)

3. ION ELECTRON METHOD FOR BALANCING REDOX REACTIONS

This method involves the following steps:

(a) Divide the complete equations into two half reactions

  (i) One representing oxidation

  (ii) The other representing reduction

(b) Balance the atoms in each half reaction seperately according to the following steps

  (i) Balance all atoms other than oxygen and hydrogen

  (ii) To balance oxygen and hydrogen

(c) **Acidic Medium**

  (i) Add H_2O to the side which is oxygen deficient to balance oxygen atoms

  (ii) Add H^+ to the side which is hydrogen deficient to balance H atoms

(d) Basic Medium

(i) Add OH^- to the side which has less negative charge

(ii) Add H_2O to the side which is oxygen deficient to balance oxygen atoms

(iii) Add H^+ to the side which is hydrogen deficient

Illustration 19: $H_2C_2O_4 + KMnO_4 \longrightarrow CO_2 + K_2O + MnO + H_2O$ **(JEE MAIN)**

Sol:

Step 1: Select the oxidant, reductant atoms and write their half reactions, one representing oxidation and other reduction. i.e., $\overset{+3}{C_2} \longrightarrow 2C^{+4} + 2e^-$

$$5e^- + Mn^{+7} \longrightarrow Mn^{+2}$$

Step 2: Balance the no. of electrons and add the two equation.

$$5\overset{+3}{C_2} \longrightarrow 10C^{+4} + 10e^-$$

$$\frac{10e^- + 2Mn^{+7} \longrightarrow 2Mn^{+3}}{5\overset{+3}{C_2} + 2Mn^{+7} \longrightarrow 10C^{+4} + 2Mn^{+2}}$$

Step 3: Write complete molecule of the reductant and oxidant from which respective redox atoms were obtained.

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO$$

Step 4: Balance other atoms if any (except H and O).

In above example K is unbalanced, therefore,

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO + K_2O \text{ (Mentioned as product)}$$

Step 5: Balance O atom using H_2O on desired side.

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO + H_2O + 5H_2O$$

4. OXIDATION STATE AND OXIDATION NUMBER

4.1 Oxidation State

It is defined as the charge (real or imaginary) which an atom appears to have when it is in combination. In the case of electrovalent compounds, the oxidation number of an element or radical is the same as the charge on the ion.

4.2 Oxidation Number

(a) Oxidation number of an element in a particular compound represents the number of electrons lost or gained by an element during its change from free state into that compound or Oxidation number of an element in a particular compound represent the extent of oxidation or reduction of an element during its change from free state into that compound.

(b) Oxidation number is given positive sign if electrons are lost. Oxidation number is given negative sign if electrons are gained.

(c) Oxidation number represent real change in case of ionic compounds. However, in covalent compounds it represents imaginary charge.

Rules for Calculation of Oxidation Number:

Following rules have been arbitrarily adopted to decide oxidation number of elements on the basis of their periodic properties.

(a) In uncombined state or free state, oxidation number of an element is zero.

(b) In combined state oxidation number of-

- **(i)** F is always –1.
- **(ii)** O is –2. In peroxide it is –1, in superoxides it is –1/2. However in F_2O it is +2.
- **(iii)** H is +1. In ionic hydrides it is –1. (i.e., IA, IIA and IIIA metals).
- **(iv)** Halogens as halide is always –1.
- **(v)** Sulphur as sulphide is always –2.
- **(vi)** Metal is always +ve.
- **(vii)** Alkali metals (i.e., IA group – Li, Na, K, Rb, Cs, Fr) is always +1.
- **(viii)** Alkaline earth metals (i.e., IIA group – Be, Mg, Ca, Sr, Ba, Ra) is always +2.

(c) The algebraic sum of the oxidation number of all the atoms in a compound is equal to zero. e.g. $KMnO_4$.

Ox. no. of K + Ox. no. of Mn + (Ox. no. of O) × 4 = 0

$(+1) + (+7) + 4x\,(-2) = 0$

(d) The algebraic sum of all the oxidation no. of elements in a radical is equal to the net charge on the radical. e.g. CO_3^{-2}.

Oxidation no. of C + 3 × (Oxidation no. of O) = $-2(4) + 3x\,(-2) = -2$

(e) Oxidation number can be zero, +ve, –ve (integer or fraction)

(f) Maximum oxidation no. of an element is = Group no. (Except O and F)

Minimum oxidation no. of an element is = Group no. –8 (Except metals)

Redox reactions involve oxidation and reduction both. Oxidation means loss of electrons and reduction means gain of electrons. Thus redox reactions involve electron transfer and the number of electrons lost are same as the number of electrons gained during the reaction. This aspect of redox reaction can serve as the basis of a pattern for balancing redox reactions.

Oxidation number of Mn in $KMnO_4$: Let the oxidation number of Mn be x. Now we know that the oxidation numbers of K is +1 and that of O is –2.

$$\begin{matrix} K & Mn & O_4 \\ +1 & +x & +4\times-2 \end{matrix} \quad \text{or} \quad \begin{matrix} K & Mn & O_4 \\ +1 & +x & -8 \end{matrix}$$

Now to the sum of oxidation numbers of all atoms in the formula of the compound must be zero, i.e. $+1 + x - 8 = 0$. Hence, the oxidation number of Mn in $KMnO_4$ is +7.

Illustration 20: What is the oxidation number of Cr in $K_2Cr_2O_7$? **(JEE MAIN)**

Sol: Let the Ox. no. of Cr in $K_2Cr_2O_7$ be x.

We know that, Ox. no. of K = +1

Ox. no. of O = –2

So, 2(Ox. no. K) + 2(Ox. no. Cr) + 7(Ox. no. O) = 0

$2(+1) \quad 2(x) \quad 7(-2) \quad = 0$

or $+2 + 2x - 14 = 0$

or $2x = +14 - 2 = +12$

or $x = +\frac{12}{2} = +6$ Hence, oxidation number of Cr in is +6.

Illustration 21: H_2S act only as reductant, whereas SO_2 acts as oxidant and reductant both. **(JEE ADVANCED)**

Sol: Oxidation number of S is –2 in H_2S. It can increase only oxidation number up to +6.

Oxidation number of S is +4 in SO_2. It can increase or decrease as it lies between maximum (+6) and minimum (–2) oxidation number of S.

Illustration 22: Which compound amongst the following has the highest oxidation number of Mn?
$KMnO_4$, K_2MnO_4, MnO_2 and Mn_2O_3. **(JEE MAIN)**

Sol:

		Ox. no. of Mn
$KMnO_4$	+1+x-8=0 x=+7	+7
K_2MnO_4	+2+x-8=0 x=+6	+6
MnO_2	x-4=0 x=+4	+4
Mn_2O_3	2x-6=0 x=+3	+3

Thus, the highest oxidation number for Mn is in $KMnO_4$.

4.3 Balancing of Redox Reactions by Oxidation State Method

This method is based on the fact that the number of electrons gained during reduction must be equal to the number of electrons lost during oxidation. Following steps must be followed while balancing redox equations by this method.

(a) Write the skeleton equation (if not given, frame it) representing the chemical change.

(b) With the help of oxidation number of elements, find out which atom is undergoing oxidation/reduction, and white separate equations for the atom undergoing oxidation/reduction.

(c) Add the respective electrons on the right for oxidation and on the left for reduction equation. Note that the net charge on the left and right side should be equal.

(d) Multiply the oxidation and reduction reactions by suitable integers so that total electrons lost in one reaction is equal to the total electrons gained by other reaction.

(e) Transfer the coefficients of the oxidizing and reducing agents and their products as determined in the above step to the concerned molecule or ion.

(f) By inspection, supply the proper coefficient for the other formulae of substances not undergoing oxidation and reduction to balance the equation.

Illustration 23: $Cr_2O_7^{2-} + I^- + H^+ \longrightarrow Cr^{3+} + I_2$ **(JEE MAIN)**

Sol: (i) Find the oxidation state of atoms undergoing redox change

$$\overset{+6\times 2}{Cr_2}O_7^{2-} + \overset{-1}{I^-} \longrightarrow \overset{+3}{Cr^{3+}} + \overset{0}{I_2}$$

(ii) Balance the number of atoms undergoing redox change.

$$\overset{(+6)\text{x}2}{Cr_2}\,O_7^{2-} + \overset{2\text{x}(-1)}{2I^-} \longrightarrow \overset{(+3)\text{x}2}{2Cr^{3+}} + \overset{0\text{x}2}{I_2}$$

(iii) Find the change in oxidation state and balance the change in oxidation states by multiplying the species with a suitable integer.

$$\overset{+12}{Cr_2}\,O_7^{2-} + \overset{-2}{2I^-} \longrightarrow \overset{+6}{2Cr^{3+}} + \overset{0}{I_2}$$

Change in ox. state = 6 Change in ox. state = 2×3

As the decrease in oxidation state if chromium is 6 and increase in oxidation state of iodine is 2, so we will have to multiply I^- / I_2 by 3 equalize the changes in oxidation state.

$$Cr_2O_7^{2-} + 6I^- \longrightarrow 2Cr^{3+} + 3I_2$$

(iv) Find the total charges on both the sides and also find the difference of charges.

Charge on LHS = −2 + 6 × (−1) = −8

Charge on RHS = 2 × (+3) = +6

Difference in charge = + 6 − (−8) = 14

(v) Now, as the reaction is taking place in acidic medium, we will have to add the ions, to H^+ the side falling short in positive charges, so we will add $14H^+$ and LHs to equalize the charges on both sides.

$$Cr_2O_7^{2-} + 6I^- + 14H^+ \longrightarrow 2Cr^{3+} + 3I_2$$

(vi) To equalize the H and O atoms, add $7H_2O$ on RHS

$$Cr_2O_7^{2-} + 6I^- + 14H^+ \longrightarrow 2Cr^{3+} + 3I_2 + 7H_2O$$

Illustration 24: Balance the following equation by oxidation number method:

$$Cl_2 + IO_3^- + OH^- \longrightarrow IO_4^- + Cl^- + H_2O$$

(JEE ADVANCED)

Sol: Writing oxidation numbers of all atoms,

$$\overset{0}{Cl_2} + \overset{+5}{I}\,\overset{-2}{O_3^-} + \overset{-2}{O}\,\overset{+1}{H^-} \longrightarrow \overset{+7}{I}\,\overset{-2}{O_4^-} + \overset{-1}{Cl^-} + \overset{+1}{H_2}\,\overset{-2}{O}$$

Oxidation numbers of Cl and I have changed.

$$\overset{0}{Cl_2} \longrightarrow 2\overset{-1}{Cl^-} \qquad \text{...(i)}$$

$$\overset{+5}{I}\,O_3^- \longrightarrow \overset{+7}{I}\,O_4^- \qquad \text{...(ii)}$$

Decrease in Ox. no. of Cl = 2 units per Cl_2 molecule

Increase in Ox. no. of I = 2 units per IO_3^- molecule

$$Cl_2 + IO_3^- \longrightarrow IO_4^- + 2Cl^-$$

To balance oxygen, $2OH^-$ ions be added on LHS and one H_2O molecule on RHS. Hence, the balanced equation is

$$Cl_2 + IO_3^- + 2OH^- \longrightarrow IO_4^- + 2Cl^- + H_2O$$

5. TYPES OF REACTIONS

The redox reactions are of the following types:

(a) Combination reactions: A compound is formed by chemical combination of two or more elements. The combination of an element or compound with oxygen is called combustion. The combustion and several other combinations which involve change in oxidation state are called redox reactions.

e.g.,

$$\overset{-4}{C}\overset{+1}{H}_4 + 2\overset{0}{O}_2 \longrightarrow \overset{+4}{C}\overset{-2}{O}_2 + 2\overset{+1}{H}_2\overset{-2}{O}$$

$$\overset{0}{C}(s) + \overset{0}{O}_2(g) \longrightarrow \overset{+4}{C}\overset{-2}{O}_2(g)$$

$$3\overset{0}{Mg} + \overset{0}{N}_2 \longrightarrow \overset{+2}{Mg}_3\overset{-3}{N}_2$$

$$\overset{0}{H}_2 + \overset{0}{Cl}_2 \longrightarrow 2\overset{+1}{H}\overset{-1}{Cl}$$

(b) Decomposition reactions: Decomposition is the reverse process of combination, it involves the breakdown of the compound into two or more components. The product of decomposition must contain at least one component in elemental state.

e.g.,

$$2\overset{+1}{H}_2\overset{-2}{O}(g) \xrightarrow{\Delta} 2\overset{0}{H_2}(g) + \overset{0}{O_2}(g)\,; \qquad 2NaH(s) \xrightarrow{\Delta} 2\overset{0}{Na}(s) + \overset{0}{H}_2(g)$$

$$2\overset{+1}{K}\overset{+5}{Cl}\overset{-2}{O}_3(s) \longrightarrow 2\overset{+1}{K}\overset{-1}{Cl} + 3\overset{0}{O}_2(g)$$

In above example, there is no change in oxidation state of potassium. Thus, it should be noted that the decomposition does not result into change in the oxidation number of each element.

(c) Displacement reactions: The reactions in which an atom or ion in a compound is displaced by another atom or ion are called displacement reactions. The displacement reactions are of 2 types:

(i) Metal displacement: In these reactions, a metal in a compound is replace by another metal in an uncombined state. It is found that a metal with stronger reducing character can displace the other metal having a weaker reducing character.

e.g.,

$$\overset{+3}{Cr}_2\overset{-2}{O}_3 + 2\overset{0}{Al}(s) \longrightarrow \overset{+3}{Al}_2\overset{-2}{O}_3(s) + 2\overset{0}{Cr}(s)$$

$$\overset{+2}{Cu}\overset{+6}{S}\overset{-2}{O}_4 + \overset{0}{Zn}(s) \longrightarrow \overset{+2}{Zn}\overset{+6}{S}\overset{-2}{O}_4(aq) + \overset{0}{Cu}(s)$$

(ii) Non-metal displacement: These displacement reactions generally involve redox reactions, where the hydrogen is displaced. Alkali and alkaline earth metals are highly electropositive, they displace hydrogen from cold water.

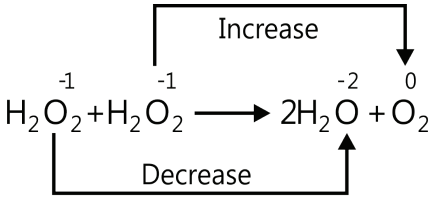
$$2\overset{0}{Na}(s) + 2\overset{+1}{H}_2\overset{-2}{O}(l) \longrightarrow 2\overset{+1}{Na}\overset{-2}{O}\overset{+1}{H}(aq) + \overset{0}{H}_2(g)$$

$$\overset{0}{Ca}(s) + 2\overset{+1}{H}_2\overset{-2}{O}(l) \longrightarrow \overset{+1}{Ca}(\overset{-2}{O}\overset{+1}{H})_2(aq) + \overset{0}{H}_2(g)$$

(d) Disproportionation and Oxidation–Reduction: One and the same substance may act simultaneously as an oxidizing agent with the result that a part of it gets oxidized to a higher state and rest of it is reduced to lower state of oxidation. Such a reaction, in which a substance undergoes simultaneous oxidation and reduction is called disproportionation and the substance is said to **disproportionate**.

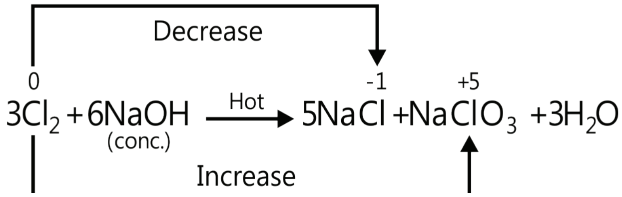
The following are some of the examples of disproportionation:

(a)



$$\overset{-1}{H_2O_2} + \overset{-1}{H_2O_2} \longrightarrow 2H_2\overset{-2}{O} + \overset{0}{O_2}$$

(b)



$$3\overset{0}{Cl_2} + \underset{\text{(conc.)}}{6NaOH} \xrightarrow{\text{Hot}} 5Na\overset{-1}{Cl} + Na\overset{+5}{Cl}O_3 + 3H_2O$$

(e) Oxidation state of chlorine lies between –1 to +7; thus out of ClO^-, ClO_2^-, ClO_3, ClO_4^-; ClO_4^- does not undergo disproportionation because in this oxidation state of chlorine is highest, i.e., +7. Disproportionation of the other oxoanions are:

$$3\overset{+1}{Cl}O^- \longrightarrow 2\overset{-1}{Cl} + \overset{+5}{Cl}O_3^-$$

$$6\overset{+3}{Cl}O_2^- \longrightarrow 4\overset{+5}{Cl}O_3^- + 2\overset{-1}{Cl^-}\ ; \qquad 4\overset{+5}{Cl}O_3^- \longrightarrow \overset{-1}{Cl^-} + 3\overset{+7}{Cl}O_4^-$$

FORMULAE SHEET

Mass

Atomic mass

Atomic mass $= \frac{\text{Average mass of an atom}}{1/12 \times \text{Mass of an atom of } C^{12}}$

Molecular mass

Molecular mass = The sum of the atomic masses of each atom in the molecule

Equivalent weight

Equivalent weight $= \frac{\text{Molecular weight}}{\text{Valency factor or n factor}}$

Methods

Atomic mass

(i) Dulong and Petit's method

At mass x Sp.heat (cal/gram) = 6.4 (approx.)

(ii) Vapour density method

-suitable for elements whose chlorides are volatile.

(iii) Valency of the element

$= \frac{\text{Molecular mass of chloride}}{\text{Equivalent mass metal } +35.5}$

$= \frac{2 \times \text{vapour density of chloride}}{\text{Equivalent mass metal } +35.5}$

Atomic mass = Equivalent mass of metal x Valency

Molecular mass

(i) Dulong Method

(For Gases)- The ratio of rates of diffusion of two gases is inversely proportional to the square root of their molecular mass or densities.

$$\frac{r_1}{r_1} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{d_2}{d_1}}$$

(ii) Vapour density method (For gases only)-

Mass of a fixed volume of the vapour is compared with the mass of the same volume of hydrogen under same condition; The ratio of these masses is called vapour density or Relative desity.

(iii) Molecular mass = 2 x Vapour density

Equivalent weight

(i) EM of an element

$= \frac{\text{Atomic mass}}{\text{Valency}}$

(ii) EM of an acid

$= \frac{\text{Molecular mass}}{\text{Basicity}}$

(Basicity of acid is the number of replaceable hydrogen atom in one molecule of the acid).

$= \frac{\text{Molecular mass}}{\text{Acidity}}$

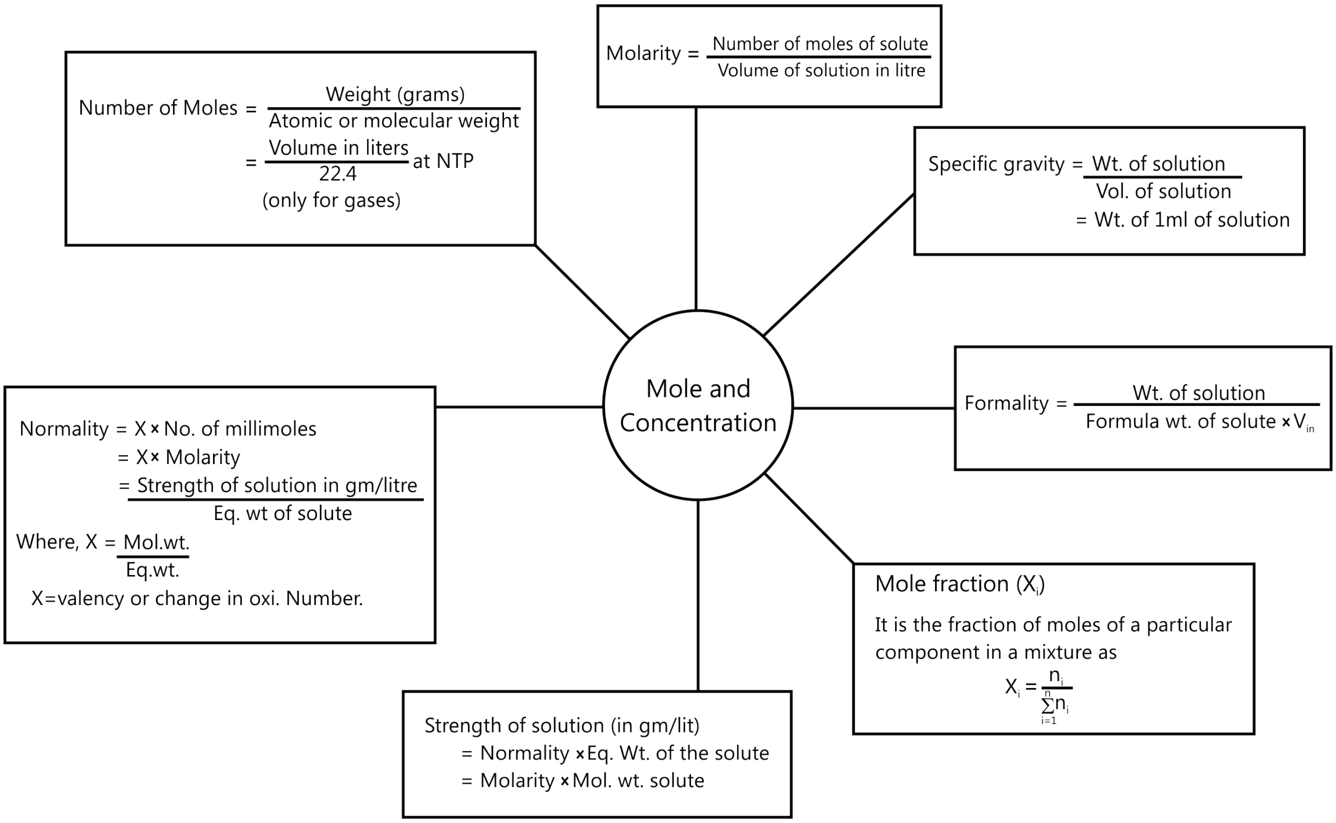
(Acidity of a base is the number of replaceable OH group in one molecule of the base).

(iv) EM of an salt = $\frac{\text{Formula mass}}{\text{Total positive or negative charge}}$

(v) EM of an oxidizing agent=

$\frac{\text{Formula mass}}{\text{Number of electrons gained per molecular or Total O.N.}}$

Equivalent mass of common oxidizing agent changes with the medium of the reaction.



Mole and Concentration

$$\text{Number of Moles} = \frac{\text{Weight (grams)}}{\text{Atomic or molecular weight}}$$

$$= \frac{\text{Volume in liters}}{22.4} \text{ at NTP}$$

(only for gases)

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$$

$$\text{Specific gravity} = \frac{\text{Wt. of solution}}{\text{Vol. of solution}}$$

= Wt. of 1ml of solution

$$\text{Formality} = \frac{\text{Wt. of solution}}{\text{Formula wt. of solute} \times V_{in}}$$

Mole fraction (X_i)

It is the fraction of moles of a particular component in a mixture as

$$X_i = \frac{n_i}{\sum_{i=1}^{n} n_i}$$

Strength of solution (in gm/lit)

= Normality × Eq. Wt. of the solute

= Molarity × Mol. wt. solute

Normality = X × No. of millimoles

= X × Molarity

$$= \frac{\text{Strength of solution in gm/litre}}{\text{Eq. wt of solute}}$$

$$\text{Where, } X = \frac{\text{Mol.wt.}}{\text{Eq.wt.}}$$

X=valency or change in oxi. Number.

RULES IN BRIEF

The following are the definitions of 'mole' represented in the form of equations:

(a) Number of moles of molecules $= \dfrac{\text{Weight in g}}{\text{Molecular weight}}$

(b) Number of moles of atoms $= \dfrac{\text{Weight in g}}{\text{Atomic weight}}$

(c) Number of moles of gases $= \dfrac{\text{Volume at NTP}}{\text{Standard molar volume}}$

(Standard molar volume is the volume occupied by 1 mole of any gas at NTP, which is equal to 22.4 litres.)

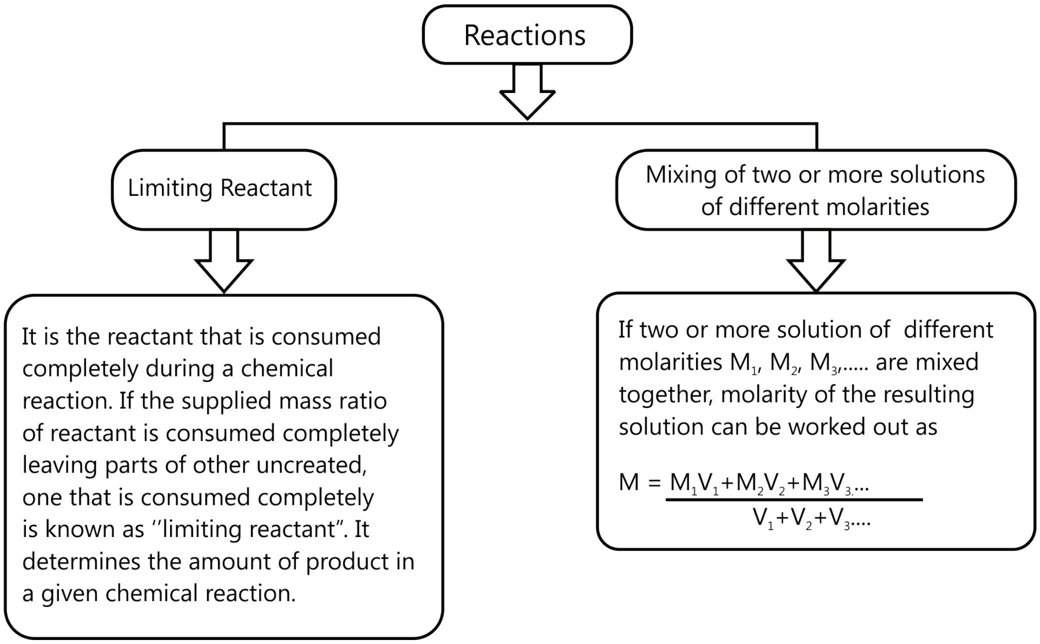
(d) Number of moles of atoms / molecules / ions / electrons $= \dfrac{\text{No. of atoms / molecules / ions / electrons}}{\text{Avogadro constant}}$

(e) Number of moles of solute = Molarity × Volume of solution in litres

Or No. of millimoles = Molarity × Volume in mL.

$$\frac{\text{Millimoles}}{1000} = \text{moles}$$

(f) For a compound M_x, N_y, x moles of N = y moles of M



It is the reactant that is consumed completely during a chemical reaction. If the supplied mass ratio of reactant is consumed completely leaving parts of other uncreated, one that is consumed completely is known as ''limiting reactant". It determines the amount of product in a given chemical reaction.

If two or more solution of different molarities M_1, M_2, M_3,..... are mixed together, molarity of the resulting solution can be worked out as

$$M = \frac{M_1V_1+M_2V_2+M_3V_3...}{V_1+V_2+V_3....}$$

Solved Examples

JEE Main/Boards

Example 1: Calculate the composition of 109% oleum.

Sol: Let the mass of SO_3 in the sample be 'w' g, then the mass of H_2SO_4 would be (100 – w)g. On dilution,

$$\underset{80g}{SO_3} + \underset{18g}{H_2O} \longrightarrow H_2SO_4$$

Moles of SO_3 in oleum = $\frac{w}{80}$ = Moles of H_2SO_4 formed after dilution.

$\therefore$ Mass of H_2SO_4 formed on dilution $= \frac{98w}{80}$

Total mass of H_2SO_4 present in oleum after dilution

$= \frac{98w}{80} + (100 - w) = 109$; w = 40

Thus oleum sample contains 40% SO_3 and 60% H_2SO_4.

Example 2: 20g of a sample of $Ba(OH)_2$ is dissolved in 10 mL. of 0.5 N HCl sol. The excess of HCl was titrated with 0.2 N NaOH. The volume of NaOH used was 10 cc. Calculate the percentage of $Ba(OH)_2$ in the sample.

Sol: The titration principle is applied wherein milli-equivalents of the neutralization reactions is calculated. Solving further, one gets the mass and % of the base.

Milli eq. of HCl initially = 10 × 0.5 = 5

Milli eq. of NaOH consumed

= Milli eq.of HCl in excess = 10 × 0.2 = 2

$\therefore$ Milli eq. of HCl consumed

= Milli eq. of $Ba(OH)_2$ = 5 – 2 = 3

$\therefore$ Eq. of $Ba(OH)_2$ = $3/1000 = 3 \times 10^{-3}$

Mass of $Ba(OH)_2$ = 3×10^{-3} (171/2) = 0.2565 g

% $Ba(OH)_2$ = (0.2565/20) × 100 = 1.28%

Example 3: One litre of mixture of CO and CO_2 is passed through red hot charcoal in tube. The new volume becomes 1.4 litre. Find out % composition of original mixture by volume. All measurements are made at same P and T.

Sol: Assuming the mixture contents as a and b, the reaction is framed and values are laid down.

Let the mixture contains

CO = a litre; CO_2 = b litre

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

On passing the mixture over charcoal only CO_2 reacts as:

$$\begin{array}{lccc} & CO_2 & +C\longrightarrow & 2CO \\ \text{Vol. before reaction} & b & & 0 \\ \text{Vol. after reaction} & 0 & & 2b \end{array}$$

$\therefore$ a + 2b = 1.4

By Eqs. (i) and (ii)

a = 0.6 litre or a = 60%

b = 0.4 litre or b = 40%

Example 4: 0.5 g sample containing is treated with HCl liberating Cl_2. The is passed into a Sol. of KI and 30.0 cm^3 of 0.1 M are required to titrate the liberated iodine. Calculate the percentage of in sample. (At. wt. of Mn = 55).

Sol: Principle of titration is involved in which equating the neutralization reactions is done and milliequivalents of each species is calculated. Thus, weight is calculated and the purity is found.

$$MnO_2 \xrightarrow{HCl} Cl_2 \xrightarrow{KI} I_2$$

$$\xrightarrow{Na_2S_2O_3} NaI + Na_2S_4O_6$$

Redox change are: $2e^- + I_2^0 \longrightarrow 2I$

$$2S_2^{2+} \longrightarrow S_4^{(5/2)^+} + 2e^-$$

$$2e^- + Mn^{4+} \rightarrow Mn^{2+}$$

The reactions suggest that,

Meq. of MnO_2 = Meq. of Cl_2 formed

= Meq.of I_2 liberated = Meq. of $Na_2S_2O_3$ used

$$\therefore \quad \frac{w}{M/2} \times 1000 = 0.1 \times 1 \times 30$$

[$\because$ $N_{Na_2S_2O_3} = M_{Na_2S_2O_3}$ since valency factor = 1, see redox changes for $Na_2S_2O_3$]

$$\text{Or } w_{MnO_2} = \frac{0.1 \times 1 \times 30 \times M}{2000} = \frac{0.1 \times 1 \times 30 \times 87}{2000}$$

$(\because M_{MnO_2} = 87)$; $w_{MnO_2} = 0.1305$

$$\therefore \text{Purity of } MnO_2 = \frac{0.1305}{0.5} \times 100 = 26.1\%$$

Example 5: 10 mL mixture of CH_4, C_2H_4 and C_3H_8 in the ratio 1: 1.5: 2.5 respectively is burnt in excess of air. Calculate the volume of air used and volume of CO_2 formed after combustion. All measurements are made at same P and T.

Sol: Using the given ratios, find the volumes of the hydrocarbons and frame the balanced combustion reactions. The calculated O_2 level is 1/5th of the air.Hence volume of CO_2 is found.

$$\text{Volume of } CH_4 = \frac{1 \times 10}{5} = 2 \text{ mL}$$

$$\text{Volume of } C_2H_4 = \frac{1.5 \times 10}{5} = 3 \text{ mL}$$

$$\text{Volume of } C_3H_8 = \frac{2.5 \times 10}{5} = 5 \text{ mL}$$

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

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$$

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

$\therefore$ Volume of O_2 needed

= 2 × 2 + 2 × 3 + 3 × 5 = 38 mL

Since, O_2 is 1/5th part of air

$$\therefore \quad V_{air} = \frac{25 \times 100}{20} = 125 \text{ mL}$$

Volume of CO_2 formed

= 2 × 1 + 2 × 3 + 3 × 5 = 23 mL

Example 6: Select the species acting as reductant and oxidant in the reaction given below:

(i) $PCl_3 + Cl_2 \longrightarrow PCl_5$

(ii) $AlCl_3 + 3K \longrightarrow Al + 3KCl$

(iii) $SO_2 + 2H_2S \longrightarrow 3S + H_2O$

(iv) $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

(v) $3I_2 + 6NaOH \longrightarrow NaIO_3 + 5NaI + 3H_2O$

Sol: Calculate the oxidation numbers, find the loss/gain of electrons and thus identify the respective oxidants and reductants.

In a conjugate pair oxidant has higher oxidation number.

(i) $P^{+3} \longrightarrow P^{+5} + 2e^-$

$$2e^- + Cl_2^0 \longrightarrow 2Cl^{-1}$$

$\therefore$ PCl_3 is reductant and Cl_2 is oxidant.

$\because$ In a conjugate pair of redox, the one having higher ox. no. is oxidant.

(ii) For $AlCl_3 : Al^{+3} + 3e^- \longrightarrow Al^0$;

For $K : K^0 \longrightarrow K^{+1} + e^-$

Oxidant is $AlCl_3$ and reductant is K.

(iii) For $SO_3 : S^{+4} + 4e^- \longrightarrow S^0$;

For $H_2S : S^{-2} \longrightarrow 2e^-$

∴ SO_2 is oxidant and H_2S is reductant.

(iv) No change in ox. no. of either of the conjugate pair.

∴ None is oxidant or reductant.

(v) For $I_2 : I_2^0 \longrightarrow 2I^{+3}$ and $I_2^0 + 2e^- \longrightarrow 2I^{-1}$ I_2 acts as oxidant and reductant both.

Example 7: Balance the following reaction

$NO_3^- + Al \longrightarrow Al^{3+} + NH_4^+$ in basic medium.

Sol: Here NO_3^- is undergoing reduction and Al is undergoing oxidation.

(i) $NO_3^- \longrightarrow NH_4^+$ (ii) $Al \longrightarrow Al^{3+}$

by balancing each half reaction, we get

(iii) $NO_3^- + 7H_2O + 8e^- \longrightarrow NH_4^+ + 10\ OH^-$

(iv) $Al \longrightarrow Al^{3+} + 3e^-$

by multiplying equation (iii) by 3 and equation (iv) by 8, we get

(v) $3NO_3^- + 7H_2O + 24e^- \longrightarrow 3NH_4^+ + 30\ OH^-$

(vi) $8Al \longrightarrow 8Al^{3+} + 24e^-$

by combining these equations, we get

$$8Al + 3NO_3^- + 21H_2O \longrightarrow 8Al^{3+} + 3NH_4^+ + 30\ OH^-$$

Example 8: The composition of a sample of wurtzite is $Fe_{0.93}O_{1.00}$. What percentage of iron is present in the form of Fe III?

Sol: Oxidation no. of Fe in wustite is $\frac{200}{93} = 2.15$

It is an intermediate value between two oxidation state of Fe as, Fe (II) and (III).

Let percentage of Fe (III) be a, then

2 × (100 – 0)+ 3 × a = 2.15 × 100 Or a = 15

∴ Percentage of Fe(III) = 15%

Example 9: A 5.0 cm^3 solution of H_2O_2 liberates 0.508g of iodine from an acidified KI solution. Calculate the strength of H_2O_2 solution in term of volume strength at STP.

Sol: Volume strength is the volume of oxygen released from 1 mL of hydrogen peroxide solution.

Meq. of H_2O_2 = Meq. of I_2

$$\frac{w}{17} \times 1000 = \left[\frac{0.508}{\frac{254}{2}}\right] \times 1000$$

∴ w = 0.068 g

$$H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$$

∵ 34 g H_2O_2 gives 11.2 litre O_2,

∴ 0.068 g gives $\frac{11.2 \times 0.068}{34} = 0.0224\ \text{litre} = 22.4\ \text{ml}\ O_2$

∴ Volume strength of $H_2O_2 = \frac{22.4}{5} = 4.48\%$

Example 10: A 1.100 g sample of copper ore is dissolved and the Cu^{2+} is treated with excess KI. The liberated I_2 requires 12.12 mL of 0.10 M $Na_2S_2O_3$ solution for titration. What is % copper by mass in the ore?

Sol: The titration reaction is framed to identify the loss/gain of electrons.The milliequivalents of the respective ions are equated and the amount is calculated. % can be found by dividing the whole weight.

$$Cu^{2+} + e^- \rightarrow Cu^+ ;\ 2I^- \longrightarrow I_2 + 2e^-$$

$$2S_2O_3^{2-} \longrightarrow S_4O_6^- + 2e^-$$

Meq. of Cu^{2+} = Meq. of liberated I_2 = Meq. of $Na_2S_2O_3$ = 12.12 × 0.1 × 1 = 1.212

∴ $\frac{w_{Cu^{2+}}}{63.6/1} \times 1000 = 1.212$

∴ $w_{Cu^{2+}} = 0.077\ g = w_{Cu}$ $(Cu \xrightarrow{H_2SO_4} CuSO_4)$

∴ $\%\ Cu = \frac{0.077}{1.10} \times 100 = 7\%$

JEE Advanced/Boards

Example 1: Chile salt petre, a source of $NaNO_3$ also contains $NaIO_3$. The $NaIO_3$ can be used as source of iodine, produced in the following reactions.

$IO_3^- + 3HSO_3^- \longrightarrow I^- + 3H^+ + 3SO_4^{2-}$ ...(i)

$5I^- + IO_3^- + 6H^+ \longrightarrow 3I_{2(g)} + 3H_2O$ ...(ii)

One litre of chile salt petre solution containing 5.80g $NaIO_3$ is treated with stoichiometric quantity of $NaHSO_3$. Now an additional amount of same solution is added to reaction mixture to bring about the second reaction.

How many grams of $NaHSO_3$ are required in step I and what additional volume of chile salt petre must be added in step II to bring in complete conversion of I^- to I_2?

Sol: The titration reaction is used to identify the loss/gain of electrons.The milliequivalents of the respective species are equated and the amount is calculated. Stepwise calculation gives the volume of $NaIO_3$.

Meq. of $NaHSO_3$ = Meq. of $NaIO_3$

$$= N \times V = \frac{5.8}{198/6} \times 1000$$

[Et. wt. of NaI = M/6 because $I^{3+} + 6e \longrightarrow I^-$]

Meq. of $NaHSO_3$ = 175.76

$$\therefore\ w_{NaHSO_3} = \frac{175.76 \times 104}{2000} = 9.14\ g$$

Also Meq. of formed in I step using valence factor 6 = 175.76

In II step valence factor of IO_3^- is 1 and valence factor of is 5.

Thus, Meq. of formed using valence factor $1 = \frac{175.76}{6}$

Also Meq. of $NaIO_3$ used in step II $= \frac{175.76}{6}$

$$\therefore\ N \times V = \frac{175.76}{6}; \Rightarrow \frac{5.8}{198/5} \times V = \frac{175.76}{6}$$

$$\therefore\ V_{NaIO_3} = 200\ mL$$

Example 2: What amount of substance containing 60% NaCl, 37% KCl should be weighed out for analysis so that after the action of 25 mL of 0.1 N $AgNO_3$ solution, excess of Ag^+ is back titrated with 5 mL of NH_4SCN. Given that 1 mL of NH_4SCN = 1.1 mL of $AgNO_3$.

Sol: Let a g of the given sample be weighed out for the purpose. The reaction of the chlorides with $AgNO_3$ will give AgCl. The unreacted Ag^+ ions will get consumed by NH_4SCN to give AgSCN. Proceeding accordingly, equate the milliequivalents and calculate a.

$$\therefore\ \text{Wt. of NaCl} = \frac{60}{100} \times a = 0.6\ a\ g$$

$$\therefore\ \text{Wt. of KCl} = \frac{37}{100} \times a = 0.37\ a\ g$$

Now this mixture reacts with $AgNO_3$, the excess of $AgNO_3$ is back titrated with NH_4SCN. Meq. of $AgNO_3$ added to mixture

= 25 × 0.1 = 2.5

Normality of NH_4SCN can be derived as

Meq. of NH_4SCN = Meq. of $AgNO_3$

$N \times 1 = 0.1 \times 1.1$

$N = 0.11$

Meq. of $AgNO_3$ left = Meq. of NH_4SCN

= 5 × N

∴ Meq. of $AgNO_3$ left = 5 × 0.11 = 0.55

∴ Meq. of $AgNO_3$ used for mixture = 2.5 – 0.55 = 1.95

Meq. of KCl + Meq. of NaCl is mixture

$$= 1.95;\ \frac{0.73a}{74.5} \times 1000 + \frac{0.6a}{58.5} \times 1000 = 1.95$$

∴ a = 0.128 g

Example 3: NaOH and Na_2CO_3 are dissolved in 200 mL aqueous solution In the presence of phenolphthalein indicator, 17.5 mL of 0.1 N HCl are used to titrate this solution. Now methyl orange is added in the same sol. titrated and it requires 2.5 mL of the same HCl. Calculate the normality of NaOH and Na_2CO_3 and their mass present in the solution.

Sol: The titration of a simple acid and a base using an indicator is seen over here. The milliequivalents of the acid is calculated and equated with that of the base. The volume and the mass is thus calculated.

Milli equivalent (a) of HCl used in the presence of phenolphthalein indicator.

= N × V (mL) = 0.1 × 17.5 = 1.75

1.75 (a) = milli. eq. of NaOH + 1/2 milli eq. of Na_2CO_3 ... (i)

Milli eq. (b) of HCl used in the presence of methyl orange indicator

= N × V (mL) = 0.1 × 2.5 = 0.25

0.25 (b) = 1/2 milli eq. of Na_2CO_3 ... (ii)

For Na_2CO_3 solution.; from equation (ii)

Milli eq. of acid used by Na_2CO_3 = 2b = 2 × 0.25 = 0.5

Volume of Na_2CO_3 solution = 200 mL

Suppose, Normality of Na_2CO_3 = N

Milli equivalents of = N × V (mL) =200 N

Putting equivalents of acid and Na_2CO_3 equal 200 N = 0.5

Or (Normality of Na_2CO_3 solution) N = $\frac{1}{400}$

Mass of Na_2CO_3 = N × E × V (litre)

(E for Na_2CO_3 = 53) $= \frac{1}{400} \times 5 \times 0.2$ = 0.0265 gram

For NaOH Sol.; from equation (i) and (ii)

Milli eq. acid used by NaOH = a – b = 1.75 – 0.25 = 1.50

Volume of NaOH solution = 200 mL

Suppose, Normality of NaOH solution = N

Milli eq. of NaOH = N × V (mL) = 200 N

Putting the milli eq. of NaOH and acid used equal 200 N = 1.5

(Normality of NaOH Sol.) $N = \frac{1.5}{200}$

Mass of NaOH = N × E × (V litres)

$= \frac{1.5}{200} \times 40 \times 0.2$ (E for NaOH = 40) = 0.06 g

Example 4: The molarity and molality of a solution are M and m respectively. If the molecular weight of the solute is M'. Calculate the density of the solution in terms of M, m and M'.

Sol: Let weight of solute be w g and weight of solvent be W g, volume of solution be V mL and density be D. Substitute as follows.

$$\therefore \quad M = \frac{w \times 1000}{M' \times V} \qquad \text{...(i)}$$

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

$$D = \frac{w + W}{V} \qquad \text{...(iii)}$$

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

By Eq. (ii) $W - \frac{w \times 1000}{M' \times m}$

By Eq. (iv) $W = \frac{MM'V \times 1000}{1000 \times M' \times m} = \frac{MV}{m}$ ...(v)

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

Example 5: 1.249 g of a sample of pure $BaCO_3$ and impure $CaCO_3$ containing some CaO was treated with dil. HCl and it evolved 168 mL of CO_3 at NTP. From this solution $BaCrO_3$ was precipitated, filtered and washed. The precipitate was dissolved in dilute sulphuric acid and diluted to 100 mL. 10 mL of this solution when treated with KI solution, liberated iodine which required exactly 20 mL of 0.05 N $Na_2S_2O_3$. Calculate the percentage of CaO in the sample.

Sol: An acid-base titration accompanied with iodine titration gives the following equation.

$$n_{CaCO_3} + n_{BaCO_3} = n_{CO_2}$$

Calculating the equivalents of the involved species gives their amount and the %.

$$= \frac{168}{22400} = 7.5 \times 10^{-3} \qquad \text{...(i)}$$

$$2BaCO_3 \longrightarrow 2BaCrO_4 \longrightarrow BaCr_2O_7 \xrightarrow{KI} I_2 + Na_2S_2O_3$$

Eq. of $Na_2S_2O_3$ = Eq. of I_2 = Eq. of $BaCr_2O_7$

$$= \frac{20 \times 10^{-3} \times 0.05 \times 100}{10} = 1 \times 10^{-2}$$

Moles of $BaCr_2O_7 = \frac{1}{6} \times 10^{-2}$,

Moles of $BaCrO_4 = \frac{2}{6}(1 \times 10^{-2})$

Moles of $BaCO_3 = \frac{1}{3} \times 10^{-2} = 3.33 \times 10^{-3}$ ...(ii)

Weight of $BaCO_3$ = 0.650 gm

From equation (i) and (ii) we get $\Rightarrow n_{CaCO_3} = 4.17 \times 10^{-3}$

Weight of $CaCO_3 = 100 \times 4.17 \times 10^{-3} = 0.417$ g

Weight of $CaO = 1.249 - 0.656 - 0.417 = 0.176$

% of $CaO = \frac{0.176}{1.249} \times 100 = 14.09\ \%$

Example 6: Find out the percentage of oxalate ion in a given sample of oxalate salt of which 0.3 g dissolved in 100 mL of water required 90 mL of N/20 $KMNO_4$ for complete oxidation.

Sol: Redox changes are

$$5e^- + Mn^{+7} \longrightarrow Mn^{+2}$$

$$C_2^{+3} \longrightarrow 2C^{+4} + 2e^-$$

$\therefore$ Meq. of oxalate ion = Meq. of $KMNO_4$

$$\frac{w}{E} \times 1000 = 90 \times \frac{1}{20};\ E_{C_2O_4^{-2}} = \frac{\text{Ionic wt.}}{2} \quad \frac{w}{\frac{88}{2}} \times 1000 = \frac{9}{2}$$

$\therefore\ w_{C_2O_4^{-2}} = 0.198$ g

$\therefore$ 0.3 g $C_2O_4^{-2}$ sample has oxalate ion = 0.198 g

$\therefore$ Percentage of $C_2O_4^{-2}$ in sample $= \frac{0.198 \times 100}{0.3} = 66\%$

Example 7: Balance the following redox equation, $AsO_3^{-3} + MnO_4^- \longrightarrow AsO_4^{-3} + MnO_2$ using ion-electron method (alkaline medium)

Sol: (i) Identify the oxidation and reduction halves.

Reduction half reaction: $MnO_4^- \longrightarrow MnO_2$

Oxidation half reaction: $AsO_3^{-3} \longrightarrow AsO^{-3}$

(ii) Atoms of the element undergoing oxidation and reduction are already balanced.

(iii) Balancing O atoms,

Reduction half reactions:

$$2H_2O + MnO_4^- \longrightarrow MnO_2 + 4OH^-$$

Oxidation half reactions:

$$2OH^- + AsO_3^{-3} \longrightarrow AsO_4^{-3} + H_2O$$

(iv) Balancing H atoms, H atoms are already balanced in both the half reactions.

(v) Balancing charge,

Reduction half reaction:

$$3e^- + 2H_2O + MnO_4^- \longrightarrow MnO_2 + 4OH^- \qquad \text{...(ii)}$$

Oxidation half reaction:

$$2OH^- + AsO_3^{-3} \longrightarrow AsO_4^{-3} + H_2O + 2e^- \qquad \text{...(i)}$$

(vi) Multiply equation (i) by 3 and equation (ii) by 2 and then add (i) and (ii).

$$3e^- + 2H_2O + MnO_4^- \longrightarrow MnO_3 + 4OH^-] \times 2$$

$$2OH^- + AsO_3^{-3} \longrightarrow AsO_4^{-3} + H_2O + 2e^-] \times 3$$

$$AsO_3^{-3} + 2MnO_4^- + H_2O$$
$$\longrightarrow 3AsO_4^{-3} + 2MnO_2 + 2OH^-$$

Example 8: 1 g sample of $AgNO_3$ is dissolved in 50 mL of water. It is titrated with 50 mL of KI solution. The AgI precipitated is filtered off. Excess of KI in filtrate is titrated with M/10 KIO_3 in presence of 6M HCl till all $\bar{I}$ converted into ICl. It requires 50 mL of M/10 KIO_3 solution. 20 mL of the same stock solution of KI requires 30 mL of M/10 KIO_3 under similar conditions. Calculate % of $AgNO_3$ in sample. The reaction is:

$$KIO_3 + 2KI + 6HCl \longrightarrow 3KCl + 3H_2O$$

Sol: Follow the reaction $AgNO_3 + KI \longrightarrow AgI + KNO_3$

1. Ag present in $AgNO_3$ is removed as AgI by adding 50 mL KI of which 20 mL requires 30 mL of M/10 KIO_3.
2. The solution contains KI unused. The unused KI is converted into ICl by KIO_3.

∴ Meq. of KI in 20 mL = Meq. of KIO_3

$$4e^- + I^{+5} \longrightarrow I^{+1}$$

$$= 30 \times \frac{1}{10} \times 4 \quad \Big| \quad I^- \longrightarrow I^{+1} + 2e^-$$

∴ Meq. of KI in 50 mL added to $AgNO_3$

$$\therefore \text{Eq. wt. of KI} = \frac{M}{2} = \frac{30 \times 4 \times 50}{10 \times 20} = 30$$

Now, Meq. of KI left unused by $AgNO_3$ = 30 – 20

∵ Mole ratio of $AgNO_3$ and KI

∴ Meq. of $AgNO_3$ = 10

Reaction is 1: 1 and thus if Eq.

$$\therefore \frac{w}{170/2} \times 1000 = 10 \quad \Big| \quad \text{Wt. of KI is } M/2,$$

w = 0.85 g then Eq. wt. of $AgNO_3$ = M/2

∴ Percentage of purity of $AgNO_3$ in sample

$$= \frac{0.85 \times 100}{1} = 85\%$$

Example 9: Selenium in a 10.0 gm soil sample is distilled as the tetrabromide, which is collected in an aqueous solution, where it is hydrolysed to SeO_3^{-2}. The SeO_3^{-2} is estimated iodometrically, requiring 4.5 mL of standard $Na_2S_2O_3$ solution for the titration. If 1 mL of $Na_2S_2O_3$ = 0.049 mg of $K_2Cr_2O_7$, what is the concentration of Se in the soil in ppm?

Sol: Follow the reaction

$$Se \longrightarrow SeBr_4 \longrightarrow SeO_3^{-2}$$

$$SeO_3^{-2} + 4I^- + 6H^+ \longrightarrow Se + 2I_2 + 3H_2O$$

$$I_2 + 2Na_2S_2O_3 \longrightarrow Na_2S_4O_6 + 2NaI$$

$$1\text{mL } Na_2S_2O_3 \equiv \frac{0.049 \times 10^{-3} \times 6}{294} \text{ eq. of } K_2Cr_2O_7$$

$$\equiv \frac{0.049 \times 10^{-3} \times 6 \times 10^3}{294} \text{ Meq. of } K_2Cr_2O_7$$

∴ 4.5 mL $Na_2S_2O_3$

$$= \frac{0.049 \times 10^{-3} \times 6 \times 10^3 \times 4.5}{294} \text{ Meq. of } K_2Cr_2O_7 = 4.5 \times 10^{-3}$$

Meq. of $K_2Cr_2O_7$ or Meq. of $Na_2S_2O_3$

Meq. of Se = Meq. of SeO_3^{-2} = Meq. of KI = Meq. of I_2 = Meq. of $Na_2S_2O_3$

$$\frac{w_{Se}}{79} \times 1000 \times 4 = 4.5 \times 10^{-3}$$

∴ $w_{Se} = 8.8875 \times 10^{-5}$ g

$$\therefore \text{ppm} = \frac{8.8875 \times 10^{-5} \times 10^6}{10} = 8.8875$$

JEE Main/Boards

Exercise 1

Mole Concept

Q.1 Express the following in S.I. units:

(i) 125 pounds, the average weight of an Indian boy (1ℓb = 545 g)

(ii) 14 ℓb/m^2 (atmospheric pressure)

(iii) 5'8", the average height of ramp models.

Q.2 The isotropic distribution of potassium is 93.2% ^{39}K and 6.8% ^{41}K. How many ^{41}K atoms are there in 2g-atoms?

Q.3 How many oxygen atoms are present in 6.025 g of Barium phosphate (at. mass of Ba=137.5, P= 31, O = 16 amu)

Q.4 The vapour density of a mixture containing NO_2 and N_2O_4 is 3.83 at 27ºC. Calculate the moles of NO_2 in 100 g mixture.

Q.5 Assume that the nucleus of the F atom is a sphere of radius 5×10^{-3} cm. Calculate the density of matter in F nucleus. (At. mass F = 19)

Q.6 20.0 mL of dil. HNO_3 is neutralised completely with 25 mL of 0.08 M NaOH. What is molarity of HNO_3?

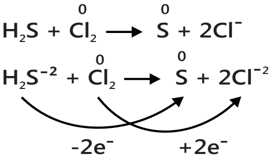
Q.7 Gastric juice containing 3.0 g of HCl per litre. If a person produces about 2.5 litres of gastric juice a per day, how many antacid tablets each containing 400 mg of $Al(OH)_3$ are needed to neutralise all the HCl produced in one day.

Q.8 10 mL of HCl solution produced 0.1435 g of AgCl when treated with excess of Silver nitrate solution. What is the Molarity of acid solution [At. mass Ag = 100].

Q.9 A certain compound containing only carbon and oxygen. Analysis show it has 36% carbon and 64% oxygen. If its molecular mass is 400 then what is the molecular formula of the compound.

Q.10 0.44 g of a hydrocarbon on complete combustion with oxygen gave 1.8 g water and 0.88 g carbon dixoide. Show that these results are in accordance with the law of conservation of mass.

Q.11 A chloride of phosphate contains 22.57% P. Phosphine contains 8.82% hydrogen and hydrogen chloride gas contain 97.26% chlorine. Show that the data illustrate law of reciprocal proportions.



Q.12 1.375 g of cupric oxide was reduced by heating in a current of hydrogen and the mass of copper that remained was 1.098 g. In another experiment, 1.179 g of copper was dissolved in the nitric acid and the resulting copper nitrate converted into cupric oxide by ignition. The mass of cupric oxide formed was 1.476 g. Show that these results illustrate the law of constant composition.

Q.13 1.020 g of metallic oxide contains 0.540 g of the metal. Calculate the equivalent mass of the metal and hence its atomic mass with the help of Dulong and Petit's law. Taking the symbol for the metal as M, find the molecular formula of the oxide. The specific heat of the metal is 0.216 cal deg^{-1} g^{-1}.

Q.14 Potassium per magnate is a dark green crystalline substance whose composition is 39.7% K, 29.9% Mn and rest O. Find the empirical formula?

Q.15 Calculate the molarity of pure water at 4ºC.

Q.16 (i) What is the mass in grams of one molecule of caffeine ($C_8H_{20}N_4O_2$)?

(ii) Determine the total number of electrons in 0.142 g Cl_2.

Q.17 Calculate the molarity of distilled water if its density is 10^3 kg/m^3.

Q.18 A plant virus if found to consist of uniform cylindrical particles of 150 Å in diameter and 5000 Å long. The specific volume of virus is 0.75 cm^3/g. If the virus is considered to be a simple particle, find the its molecular weight.

Q.19 Calculate the mass of two litre sample of water containing 25% heavy water D_2O in it by volume. Density of H_2O is 1.0 g cm^{-3} whereas that of D_2O is 1.06 g cm^{-3}.

Q.20 2.5 moles of sulphuryl chloride were dissolved in water to produce sulphuric acid and hydrochloric acid. How many moles of KOH will be required to completely neutralise the solution?

Q.21 100 g of a sample of common salt containing contamination of NH_4Cl and $MgCl_2$ to the extent of 2% each by mass is dissolved in water. How much volume of 5% by mass of $AgNO_3$ solution ($d = 1.04\ g\ cm^{-3}$) is required to precipitate all chloride ions?

Q.22 A mixture of formic acid and oxalic acid is heated with concentrated H_2SO_4. The gases produced are collected and on treatment with KOH solution, the volume of the gases decreased by 1.6th. Calculate the molar ratio of the two acids in the original mixture.

Q.23 The mean molecular mass of a mixture of methane (CH_4) and ethene (C_2H_4) in the molar ratio of x: y is found to be 20. What will be the mean molecular mass if the molar ratio of the gases is reversed?

Q.24 1 g sample of $KClO_3$ was heated under such conditions that a part of it decomposes a $2KClO_3 \longrightarrow 2KCl + 3O_2$ while the remaining part decomposes as

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

If net oxygen obtained is 146.8 mL at STP.

Calculate the mass of $KClO_4$ in the residue.

Q.25 A mixture of FeO and Fe_3O_4 was heated in air to constant mass and it was found to gain 5% in its mass. Find the composition of the initial mixture.

Q.26 Equal masses of zinc (at. mass 65) and iodine (at. mass 127) were allowed to react till completion of reaction to form ZnI_2. Which substance is left unreacted and to what fraction of its original mass?

Q.27 Two gram each of P_4 and O_2 are allowed to react till none of the reactant is left. If the products are P_4O_6 and P_4O_{10}. Calculate the mass of each of the product.

Q.28 A piece of aluminium weighing 2.7 g was heated with 100 mL of H_2SO_4 (25% by mass, $d = 1.18\ g\ cm^{-3}$). After complete dissolution of metal, the solution is diluted by adding water to 500 mL.

What is the molarity of free H_2SO_4 in resulting solution?

Q.29 Chemical reaction between ferrous oxalate and $KMnO_4$ has been given in the form of three partial equations. Write the complete balanced equation and thus find out the volume of 0.5 M $KMnO_4$ required to completely react with 1.5 mol of FeC_2O_4.

$$KMnO_4 + H_2SO_4 \longrightarrow$$

$$K_2SO_4 + MnSO_4 + H_2O + (O)$$

$$FeC_2O_4 + H_2SO_4 \longrightarrow FeSO_4 + H_2C_2O_4$$

$$FeSI_4 + H_2C_2O_4 + H_2SO_4 + O \longrightarrow Fe_2(SO_4)_3 + CO_2 + H_2$$

Redox Reactions

Q.1 Indicate the oxidation number of underlined in each case:

(i) $(\underline{N}_2H_5)_2SO_4$
(ii) $\underline{Mg}_3N_2$
(iii) $[\underline{Co}(NH_3)_5Cl]Cl_2$
(iv) $K_2\underline{Fe}O_4$
(v) $Ba(H_2\underline{P}O_2)_2$
(vi) $H_2\underline{S}O_4$
(vii) $C\underline{S}_2$
(viii) $\underline{S}^{-2}$
(ix) $Na_2\underline{S}_4O_6$
(x) $\underline{S}_2Cl_6$
(xi) $R\underline{N}O_2$
(xii) $\underline{Pb}_3O_4$
(xiii) $\underline{S}_2O_8^{-2}$
(xiv) $\underline{C}_6H_{12}O_6$
(xv) $Mg_2\underline{P}_2O_7$
(xvi) $K\underline{Cl}O_3$

Q.2 Write complete balanced equation for the following in acidic medium by ion-electron method:

(i) $Br^- + BrO_3^- + H^+ \longrightarrow Br_2 + H_2O$

(ii) $H_2S + Cr_3O_7^{-2} + H^+ \longrightarrow Cr_2O_3 + S_8 + H_2O$

(iii) $Au + NO_3^- + Cl^- + H^+ \rightarrow AuCl_4^- + NO_3 + H_2O$

(iv) $Cu_2O + H^+ + NO_3^- \longrightarrow Cu^{+2} + NO + H_2O$

(v) $MnO_4^{-2} \longrightarrow MnO_4^{-1} + MnO_2$

(vi) $Cu^{2+} + SO_2 \longrightarrow Cu^+ + SO_4^{-2}$

(vii) $Cl_2 + I_2 \longrightarrow IO_3^- + Cl^-$

(viii) $Fe(CN)_6^{-4} + MnO_4^- \rightarrow Fe^{+3} + CO_2 + NO_3^- + Mn^{+2}$

(ix) $Cu_3P + Cr_2O_7^{-2} \longrightarrow Cu^{+2} + H_3PO_4 + Cr^{+3}$

Q.3 Write complete balanced equation for the following in basic medium by ion-electron method:

(i) $Cu^{+2} + I^- \longrightarrow Cu^+ + I_2$

(ii) $Fe_3O_4 + MnO_4^- \longrightarrow Fe_2O_3 + MnO_2$

(iii) $C_2H_5OH + MnO_4^- \longrightarrow C_2H_3O^- + MnO_2(s) + H_2O$

(iv) $CrI_3 + H_2O_2 + OH^- \longrightarrow CrO_4^{-2} + IO_4^- + H_2O$

(v) $KOH + K_4Fe(CN)_6 + Ce(NO_3)_4 \longrightarrow$

$Fe(OH)_3 + Ce(OH)_3 + K_2CO_3 + KNO_3 + H_2O$

Q.4 Balance the following equations by oxidation method:

(i) $I^- + H_2O_2 \longrightarrow H_2O + I_2$ (Acid medium)

(ii) $Cu^{+2} + I^- \longrightarrow Cu^+ + I_2$

(iii) $CuO + NH_3 \longrightarrow Cu + N_2 + H_2O$

(iv) $H_2SO_3 + Cr_2O_7^{-2} \longrightarrow H_2SO_4 + Cr^{+3} + H_2O$ (Acid medium)

(v) $Cr_2O_7^{-2} + C_2H_4O + H^+ \longrightarrow C_2H_4O_2 + Cr^{+3}$ (Acid medium)

(vi) $SbCl_3 + KIO_3 + HCl \longrightarrow SbCl_3 + ICl + H_2O + KCl$ (Acid medium)

Q.5 Define disproportionation? Give one example.

Q.6 Define difference between ion electron method and oxidation method?

Q.7 What is the most essential conditions that must be satisfied in a redox reaction?

Q.8 Does the oxidation number of an element in any molecule or any poly atomic ion represents the actual charge on it?

Q.9 What is redox couple?

Q.10 Calculate the standard e.m.f. of the cells formed by different combinations of the following half cells.

$Zn(g)\ /\ Zn^{2+}(aq)$

$Cu(s)\ /\ Cu^{2+}(aq)$

$Ni(s)\ /\ Ni^{2+}(aq)$

$Ag(s)\ /\ Ag^{2+}(aq)$

Q.11 Balance the following equations in acidic medium by both oxidation number and ion electron methods & identify the oxidants and the reductants.

(i) $MnO_4^-(aq) + C_2H_2O_4(aq) \longrightarrow Mn^{2+}(aq) + CO_2(g) + H_2O(l)$

(ii) $H_2S(aq) + Cl_2(g) \longrightarrow S(s) + Cl(aq)$

Q.12 Write the half reactions for the following redox reactions:

(i) $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+} + (aq) + I_2(aq)$

(ii) $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

(iii) $Al(s) + 3Ag^+(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$

Q.13 Define oxidation & reduction in term of oxidation number.

Q.14 Discuss the following redox reactions?

(i) Combination reactions

(ii) Decomposition reactions

(iii) Displacement reactions

(iv) Disproportionation reaction

Q.15 What is the difference between valence and oxidation number?

Q.16 H_2S acts only as reducing agent while SO_2 can act both as a reducing agent and oxidising agent. Explain.

Q.17 What are half reactions? Explain with examples?

Q.18 Explain the term:

(i) Oxidation (ii) Reduction

(iii) Oxidizing agent (iv) Reducing agent

Exercise 2

Mole Concept

Single Correct Choice Type

Q.1 If 'x' gms of an element A reacts with 16 gms of oxygen then the equivalent weight of element A is

(A) $\frac{x}{4}$ (B) $\frac{x}{2}$ (C) x (D) 2x

Q.2 The mass of CO containing the same amount of oxygen as in 88 gms of CO_2 is

(A) 56 gms (B) 28 gms (C) 112 gms (D) 14 gms

Q.3 When 8 gms of oxygen reacts with magnesium then the amount of MgO formed is

(A) 18 gm (B) 20 gm (C) 24 gm (D) 32 gm

Q.4 One gram of the silver salt of an organic dibasic acid yields, on strong heating 0.5934 g of silver. If the weight percentage of carbon in it 8 times the weight percentage of hydrogen and one half the weight percentage of oxygen, determine the molecular formula of the acid. [Atomic weight of Ag = 108]

(A) $C_4H_6O_4$ (B) $C_4H_6O_6$ (C) $C_2H_6O_2$ (D) $C_5H_{10}O_5$

Q.5 Mass of sucrose $C_{12}H_{22}O_{11}$ produced by mixing 84 gm of carbon, 12 gm of hydrogen and 56 liter O_2 at 1 atm and 273 K according to given reaction, is

$$C(s) + H_2(g) + O_2(g) \longrightarrow C_{12}H_{22}O_{11}(s)$$

(A) 138.5 (B) 155.5 (C) 172.5 (D) 199.5

Q.6 40 gm of carbonate of an alkali metal or alkaline earth metal containing some inert impurities was made to react with excess HCl solution. The liberated CO_2 occupied 12.315 lit. at 1 atm and 300 K. The correct option is

(A) Mass of impurity is 1 gm and metal is Be

(B) Mass of impurity is 3 gm and metal is Li

(C) Mass of impurity is 5 gm and metal is Be

(D) Mass of impurity is 2 gm and metal is Mg

Q.7 An hydride of nitrogen decomposes to give nitrogen and hydrogen. It was formed that one volume of the hydride gave one volume of N_2 and 2 volume of H_2 at STP. The hydride of nitrogen is

(A) NH_3 (B) N_2H_6 (C) NH_2 (D) N_2H_4

Q.8 5 volumes of a hydrocarbon on complete consumed 10 volumes of oxygen giving 5 volumes of CO_2 at STP. The hydrocarbon is

(A) C_2H_6 (B) C_2H_4 (C) CH_4 (D) C_2H_4

Q.9 The percentage by mole of NO_2 in a mixture of $NO_2(g)$ and NO(g) having average molecular mass 34 is

(A) 25% (B) 20% (C) 40% (D) 75%

Q.10 The minimum mass of mixture of A_2 and B_4 required to produce at least 1 kg of each product is (Given At. mass of 'A' = 10; At. mass of 'B' = 120)

$$5A_2 + 2B_4 \longrightarrow 2AB_2 + 4A_2B$$

(A) 2120 gm (B) 1060 gm (C) 560 gm (D) 1660 gm

Q.11 74 gm of a sample on complete combustion given 132 gm CO_2 and 54 gm of H_2O. The molecular formula of the compound may be

(A) C_5H_{12} (B) $C_4H_{10}O$ (C) $C_3H_{10}O_2$ (D) $C_3H_7O_2$

Q.12 The volume of oxygen used when x gms of Zn is converted to ZnO is

(A) $\frac{2x}{65} \times 5.6$ litres (B) $\frac{x}{65} \times 5.6$ litres

(C) $\frac{4x}{65} \times 5.6$ litres (D) None of these

Q.13 A sample of clay was partially dried and then contained 50% silica and 7% water. The original clay contained 12% water. The silica is original sample is

(A) 51.69 (B) 47.31

(C) 63.31 (D) None of these

Q.14 The mass of CO_2 produced from 620 mixture of $C_2H_4O_2$ and O_2, prepared produce maximum energy is (combustion reaction is exothermic)

(A) 413.33 gm (B) 593.04 gm

(C) 440 gm (D) 320 gm

Q.15 In the quantitative determination of nitrogen, N_2 gas liberated from 0.42 gm of a sample of organic compound was collected over water. If the volume of N_2 gas collected was 100/11 mL at total pressure 860 mm Hg at 250 K, % by mass of nitrogen in the organic compound is

[Aq. tension at 250 K is 24 mm Hg and R = 0.08 L atm mol^{-1} K^{-1}]

(A) $\frac{10}{3}\%$ (B) $\frac{5}{3}\%$ (C) $\frac{20}{3}\%$ (D) $\frac{100}{3}\%$

Q.16 300 mL of 0.1 M HCl and 200 mL of 0.3 M H_2SO_4 are mixed. The normality of the resulting mixture is

(A) 0.4 N (B) 0.1 N (C) 0.3 N (D) 0.2 N

Q.17 The volume of water which should be added to 300 mL of 0.5 M NaOH solution so as to get a solution of 0.2 M is

(A) 550 mL (B) 350 mL (C) 750 mL (D) 450 mL

Q.18 The mole fraction of a solution containing 3.0 gms of urea per 250 gms of water would be

(A) 0.00357 (B) 0.99643

(C) 0.00643 (D) None of these

Q.19 The mass of P_4O_{10} produced if 440 gm of P_4S_3 is mixed with 384 gm of O_2 is $P_4S_3 + O_2 \longrightarrow P_4O_{10} + SO_2$

(A) 568 gm (B) 426 gm

(C) 284 gm (D) 396 gm

Q.20 Calculate percentage change in M_{avg} of the mixture, if PCl_5 undergo 50% decomposition. $PCl_5 \longrightarrow PCl_3 + Cl_2$

(A) 50% (B) 66.66%

(C) 33.33% (D) Zero

Q.21 The mass of Mg_3N_2 produced if 48 gm of Mg metal is reacted with 34 gm NH_3 gas is $Mg + NH_3 \longrightarrow Mg_3N_2 + H_2$

(A) $\frac{200}{3}$ (B) $\frac{100}{3}$ (C) $\frac{400}{3}$ (D) $\frac{150}{3}$

Q.22 The molarity of a solution of conc. HCl containing 36.5% by weight of HCl would be

(A) 16.75 (B) 17.75 (C) 15.75 (D) 14.75

Q.23 0.35 gms of a sample of $Na_2CO_3.xH_2O$ were dissolved in water and the volume was made to 50 mL of this solution required 9.9 mL of $\frac{N}{10}$ HCl for complete neutralization. Calculate the value of x.

(A) 1 (B) 2 (C) 3 (D) None of these

Q.24 1.2 gms of a sample of washing soda was dissolved in water and volume was made upto 250 cc. 25 cc of this solution when titrated against N/10 HCl for required 17 mL. The percentage of carbonate is given sample is

(A) Approximately 70% (B) Approximately 66%

(C) Approximately 76% (D) None of these

Q.25 The number of carbon atoms present in a signature, if a signature written by carbon pencil weights 1.2×10^{-3} g is

(A) 12.40×10^{20} (B) 6.02×10^{19}

(C) 3.01×10^{19} (D) 6.02×10^{20}

Q.26 The average atomic mass of a mixture containing 79 mole % of ^{24}Mg is 24.31. % mole of ^{26}Mg is

(A) 5 (B) 20 (C) 10 (D) 15

Q.27 25 cc of solution containing NaOH and Na_2CO_3 when titrated against N/10 HCl. Using phenolphthalein as indicator required 40 cc. of HCl. The same volume of mixture when titrated against N/10 HCl using methyl orange required 45cc of this HCl. The amount of NaOH and Na_2CO_3 in one mixture is

(A) NaOH = 28 gm/L ; Na_2CO_3 = 10.6 gm/L

(B) NaOH = 10.6 gm/L ; Na_2CO_3 = 28 gm/L

(C) NaOH = 14 gm/L ; Na_2CO_3 = 5.3 gm/L

(D) None of these

Q.28 0.5 gms of a mixture of K_2CO_3 and Li_2CO_3 requires 30 mL of 0.25 NHCl solution for neutralization. The percentage composition of mixture would be

(A) K_2CO_3 = 96%; Li_2CO_3 = 4%

(B) K_2CO_3 = 4%; Li_2CO_3 = 96%

(C) K_2CO_3 = 50%; Li_2CO_3 = 25%

(D) K_2CO_3 = 50%; Li_2CO_3 = 74%

Q.29 How many mL of a 0.05 M $KMnO_4$ solution are required to oxidise 2.0 g of $FeSO_4$ in a dilute acid solution?

(A) 5.263 (B) 0.5263

(C) 52.63 (D) None of these

Redox Reaction

Single Correct Choice Type

Q.1 The equivalent weight of $FeSO_4$ when it is oxidised by acidified $KMnO_4$ will be equal to

(A) M_0 of $FeSO_4$ (B) $\frac{M_0 FeSO_4}{2}$

(C) $2M_0$ $FeSO_4$ (D) $\frac{M_0 FeSO_4}{4}$

Q.2 The equivalent weight of $K_2Cr_2O_7$ when it is converted Cr^{3+} will be equal to

(A) $M_{K_2Cr_2O_7}$ (B) $\frac{M_{K_2Cr_2O_7}}{3}$

(C) $\frac{M_{K_2Cr_2O_7}}{4}$ (D) $\frac{M_{K_2Cr_2O_7}}{6}$

Q.3 The amount of H_2S that can be oxidised to sulfur on oxidation using 1.58 gm of $KMnO_4$ as oxidising agent in acidic medium will be

(A) 0.85 gms (B) 1.7 gms

(C) 0.425 gms (D) None of these

Q.4 The amount of nitric acid required to oxidise 127 gms of I_2 to I_2O_5 will be ______. Assume that during the reaction HNO_3 gets converted to NO_2.

(A) 12.7 (B) 3.15 (C) 315 (D) 31.5

Q.5 10 mL of oxalic acid was completely oxidised by 20 mL of 0.02 M $KMnO_4$. The normality of oxalic acid solution is

(A) 0.05 N (B) 0.1 N (C) 0.2 N (D) 0.025 N

Q.6 0.2 g of a sample of H_2O_2 required 10 mL of 1N $KMnO_4$ in a titration in the presence of H_2SO_4. Purity of H_2O_2 is

(A) 25% (B) 65% (C) 85% (D) None of these

Q.7 The number of moles of $KMnO_4$ that will be needed to react completely with one mole of ferrous oxalate in acidic solution is

(A) $\frac{2}{5}$ (B) $\frac{3}{5}$ (C) $\frac{4}{5}$ (D) 1

Q.8 A metal oxide is reduced by heating it in a stream of hydrogen. It is found that after complete reduction, 3.15 g of the oxide has yielded 1.05 g of the metal. We may deduce that

(A) The atomic weight of the metal is 8
(B) The atomic weight of the metal is 4
(C) The equivalent weight of the metal is 4
(D) The equivalent weight of the metal is 8

Q.9 Oxidation involves

(A) Gain of electrons
(B) Loss of electrons
(C) Increase in the valency of negative part
(D) Decrease in the valency of positive part

Q.10 The oxidation number of Cr in $K_2Cr_2O_7$

(A) +2 (B) –2 (C) +6 (D) –6

Q.11 When $K_2Cr_2O_7$ is converted into $K_2Cr_2O_4$ the change in oxidation number of Cr is

(A) 0 (B) 6 (C) 4 (D) 3

Q.12 White P reacts with caustic soda. The products are PH_3 and NaH_2PO_2. This reaction is an example of

(A) Oxidation (B) Reduction
(C) Oxidation and reduction (D) Neutralization

Q.13 The oxidation number of carbon in CH_2O is

(A) –2 (B) +2 (C) 0 (D) +4

Q.14 The oxidation number of C in CH_4, CH_3Cl, CH_2Cl_2, $CHCl_3$, and CCl_4 are respectively

(A) $0, 2, -2, 4, -4$ (B) $-4, -2, 0, +2, +4$
(C) $2, 4, 0, -2, -4$ (D) $4, 2, 0, -2, -4$

Q.15 Which of the following reactions is not redox type

(A) $2BaO + O_2 \longrightarrow 2BaO_2$
(B) $4KClO_3 \longrightarrow 2KClO_4 + KCl$
(C) $BaO_2 + H_2SO_4 \longrightarrow BaSO_4 + H_2O_2$
(D) $SO_2 + 2H_2S \longrightarrow 2H_2O + 3S$

Q.16 In which of the following compounds iron has lowest oxidation state

(A) $K_4Fe(CN)_6$ (B) K_2FeO_4
(C) Fe_2O (D) $Fe(CO)_5$

Q.17 Select the compound in which chlorine is assigned the oxidation number +5

(A) HClO (B) $HClO_2$ (C) $HClO_3$ (D) $HClO_4$

Q.18 If three electrons are lost by a metal iron M^{3+} its final oxidation number would be

(A) 0 (B) +2 (C) +5 (D) +6

Q.19 The oxidation number of Mn in MnO_4^- is

(A) +7 (B) –5 (C) –7 (D) +5

Q.20 The oxidation number of carbon in $CHCl_3$ is

(A) +2 (B) +4 (C) +4 (D) –3

Q.21 Pb^{2+} loses two electrons in a reaction. What will be the oxidation number of lead after the reaction?

(A) +2 (B) 0 (C) +4 (D) –2

Q.22 The oxidation number of carbon in $C_{12}H_{22}O_{11}$ is

(A) 0 (B) –6 (C) +2 (D) +6

Q.23 The oxidation state of sulphur in SO_4^{2-} is

(A) +2 (B) +4 (C) +5 (D) +6

Q.24 If the following reaction 'X' is

$MnO_2 + 4H^+ + X \longrightarrow Mn^{2+} + H_2O$

(A) $1e^-$ (B) $2e^-$ (C) $3e^-$ (D) $4e^-$

Q.25 In the following reaction the value of 'X' is

$H_2O + SO_3^{-2} \longrightarrow SO_4^{-2} + 2H^+ + X$

(A) $4e^-$ (B) $3e^-$ (C) $2e^-$ (D) $1e^-$

Q.26 The oxidation state of sulphur is $S_2O_7^{2-}$ is

(A) +6 (B) –6 (C) –2 (D) +2

Q.27 The oxidation number and covalency of sulphur in S_8 are respectively

(A) 0 & 2 (B) 0 & 8 (C) 6 & 8 (D) 6 & 2

Q.28 The oxidation state of nitrogen in N_3H is

(A) 1/3 (B) +3 (C) –1 (D) –1/3

Q.29 The oxidation number of iron in potassium ferricyanide is

(A) +1 (B) +2 (C) +3 (D) +4

Q.30 Oxidation number of hydrogen in MH_2 is

(A) +1 (B) –1 (C) +2 (D) –2

Q.31 The oxidation state of phosphorus varies from

(A) –1 to +1 (B) –3 to +3 (C) –3 to +5 (D) –5 to +1

Q.32 Select the compound in which chlorine is assigned the oxidation number +5

(A) $HClO_4$ (B) $HClO_2$ (C) $HClO_3$ (D) HCl

Previous Years' Questions

Mole Concept

Q.1 If we consider that 1/6, in place of 1/12, mass of carbon atom is taken to be the relative atomic mass unit, the mass of one mole of a substance will ***(2002)***

(A) Decrease twice

(B) Increase two fold

(C) Remain unchanged

(D) Be a function of the molecular mass of the substance

Q.2 A molar solution is one that contains one mole of a solute in ***(1986)***

(A) 1000 g of the solvent (B) One litre of the solvent

(C) One litre of the solution (D) 22.4 litres of the solution

Q.3 In the reaction,

$2Al(s)+6HCl(S)\longrightarrow 2Al^{3+}(aq)+6Cl^{-}(aq)+3H_2(g)$ ***(2007)***

(A) 6 l HCl (aq) is consumed for every 3L $H_2(g)$ produced

(B) 33.6 l $H_2(g)$ is produced regardless of temperature and pressure for every mole Al that reacts

(C) 67.2 l $H_2(g)$ at STP is produced for every mole Al that racts

(D) 11.2 $H_2(g)$ at STP is produced for every mole HCl (aq) consumed

Q.4 How many moles of magnesium phosphate, $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms ***(2006)***

(A) 0.02 (B) 3.125×10^{-2}

(C) 1.25×10^{-2} (D) 2.5×10^{-2}

Q.5 If 10^{21} molecules are removed from 200 mg of CO_2, then the number of moles of CO_2 left are ***(1983)***

(A) 2.85×10^{-3} (B) 28.8×10^{-3}

(C) 0.288×10^{-3} (D) 1.68×10^{-2}

Q.6 In standardization of $NA_2S_2O_3$ using $K_2Cr_2O_7$ by iodometry, the equivalent weight of $K_2Cr_2O_7$ is ***(2000)***

(A) $\frac{MW}{2}$ (B) $\frac{MW}{3}$ (C) $\frac{MW}{6}$ (D) $\frac{MW}{1}$

Q.7 The molarity of a solution obtained by mixing 750 mL of 0.5(M) HCl with 250 mL of 2(M) HCl will be: ***(2013)***

(A) 0.875 M (B) 1.00 M (C) 1.75 M (D) 0.975 M

Q.8 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: ***(2013)***

(A) C_2H_4 (B) C_3H_4 (C) C_6H_5 (D) C_7H_8

Q.9 Experimentally it was found that a metal oxide has formula $M_{0.98}$ O. Metal M, present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be: ***(2013)***

(A) 7.01 % (B) 4.08 % (C) 6.05 % (D) 5.08 %

Q.10 The ratio of masses of oxygen and nitrogen in a particular gaseous mixture is 1 : 4. The ratio of number of their molecule is 3 ***(2014)***

(A) 1 : 4 (B) 7 : 32 (C) 1 : 8 (D) 3 : 16

Q.11 The molecular formula of a commercial resin used for exchanging ions in water softening is $C_6H_7SO_3Na$ (Mol. Wt. 206). What would be the maximum uptake of Ca^{2+} ions by the resin when expressed in mole per gram resin? ***(2015)***

(A) $\frac{1}{103}$ (B) $\frac{1}{206}$ (C) $\frac{2}{309}$ (D) $\frac{1}{412}$

Q.12 At 300 K and 1 atm, 15 mL of a gaseous hydrocarbon requires 375 mL air containing 20% O_2 by volume for complete combustion. After combustion the gases occupy 330 mL. Assuming that the water formed is in liquid form and the volumes were measured at the same temperature and pressure, the formula of the hydrocarbon is: ***(2016)***

(A) C_2H_{12} (B) C_4H_8 (C) C_4H_{10} (D) C_3H_6

Redox Reactions

Q.13 Several blocks of magnesium are fixed to the bottom of a ship to ***(2003)***

(A) Keep away the sharks

(B) Make the ship lighter

(C) Prevent action of water and salt

(D) Prevent puncturing by under-sea rocks

Q.14 Which of the following chemical reactions depicts the oxidizing behaviour of H_2SO_4? ***(2006)***

(A) $2HI + H_2SO_4 \rightarrow I_2 + SO_2 + 2H_2O$

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

(C) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

(D) $2PCl_5 + H_2SO_4 \rightarrow 2POCl_3 + 2HCl + SO_2Cl_2$

Q.15 The oxidation number of carbon in CH_2O is ***(1982)***

(A) –2 (B) +2 (C) 0 (D) 4

Q.16 The oxidation state of chromium in the final product formed by the reaction between KI and acidified potassium dichromate solution is ***(2005)***

(A) +4 (B) +6 (C) +2 (D) +3

Q.17 When $KMnO_4$ acts as an oxidising agent and ultimately forms $[MnO_4]^{-2}$, MnO_2, Mn_2O_3, Mn^{+2} then the number of electrons transferred in each case respectively is ***(2002)***

(A) 4, 3, 1, 5 (B) 1, 5, 3, 7

(C) 1, 3, 4, 5 (D) 3, 5, 7, 1

Q.18 Which of the following is a redox reaction ***(2002)***

(A) $NaCl + KNO_3 \rightarrow NaNO_3 + KCl$

(B) $CaC_2O_4 + 2HCl \rightarrow CaCl_2 + H_2C_2O_4$

(C) $Mg(OH)_2 + 2NH_4Cl \longrightarrow MgCl_2 + 2NH_4OH$

(D) $Zn + 2AgCN \rightarrow 2Ag + Zn(CN)_2$

Q.19 The product of oxidation of I^- and MnO_4^- in alkaline medium is ***(2004)***

(A) IO_3^- (B) I_2 (C) IO^- (D) IO_4^-

Q.20 For H_3PO_3 and H_3PO_4 the correct choice is ***(2003)***

(A) H_3PO_3 is dibasic and reducing

(B) H_3PO_3 is dibasic and non-reducing

(C) H_3PO_4 is tribasic and reducing

(D) H_3PO_3 is tribasic and non-reducing

Q.21 Consider the following reaction:

$$XMnO_4^- + YC_2O_4^{2-} + ZH^+ \rightarrow xMn^{2+} + 2yCO_2 + \frac{z}{2}H_2O$$

The values of X, Y and Z in the reaction are, respectively: ***(2013)***

(A) 5, 2 and 16 (B) 2, 5 and 8

(C) 2, 5 and 16 (D) 5, 2 and 8

Q.22 In which of the following reaction H_2O_2 acts as a reducing agent? ***(2014)***

(A) $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$

(B) $H_2O_2 - 2e^- \rightarrow O_2 + 2H^+$

(C) $H_2O_2 - 2e^- \rightarrow 2OH^-$

(D) $H_2O_2 + 2OH^- - 2e^- \rightarrow O_2 + 2H_2O$

(A) (a), (b) (B) (c), (d) (C) (a), (c) (D) (b), (d)

Q.23 The equation which is balanced and represents the correct product(s) is ***(2014)***

(A) $Li_2O + 2KCl \rightarrow 2LiCl + K_2O$

(B) $\left[CoCl(NH_3)_5\right]^+ + 5H^+ \rightarrow Co^{2+} + 5NH_4^+ + Cl^-$

(C) $\left[Mg(H_2O)_6\right]^{2+}(EDTA)^{4-} \xrightarrow{\text{excess NaOH}} \left[Mg(EDTA)\right]^{2+} + 6H_2O$

(D) $CuSO_4 + 4KCN \rightarrow K_2\left[Cu(CN)_4\right] + K_2SO_4$

Q.24 From the following statements regarding H_2O_2, choose the incorrect statement: ***(2015)***

(A) It can act only as an oxidizing agent

(B) It decomposed on exposure to light

(C) It has to be stored in plastic or wax lined glass bottles in dark

(D) It has to be kept away from dust

JEE Advanced/Boards

Exercise 1

Mole Concept

Q.1 How many gm of HCl is needed for complete reaction with 69.6 gm MnO_2?

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

Q.2 Titanium, which is used to make air plane engines and frames, can be obtained from titanium tetrachloride, which in turn is obtained from titanium oxide by the following process:

$$3TiO_2(s) + 4C(s) + 6Cl_2(g) \rightarrow 3TiCl_4(g) + 2CO_2(g) + 2CO(g)$$

A vessel contains 4.32 g TiO_2 5.76 g C and 6.82 g Cl_2, suppose the reaction goes to completion as written, how many gram of $TiCl_4$ can be produced? (Ti = 48).

Q.3 Sulphuric acid is produced when sulphur dioxide reacts with oxygen and water in the presence of a catalyst:

$$2SO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4.$$

If 5.6 mol of SO_2 reacts with 4.8 mole of O_2 and a large excess of water, what is the maximum number of moles of H_2SO_4 that can be obtained?

Q.4 What weight of Na_2CO_3 of 95% purity would be required to neutralize 45.6 mL of 0.235 N acid?

Q.5 How much $BaCl_2.2H_2O$ and pure water to be mixed to prepare 50g of 12.0% (by wt.) $BaCl_2$ solution.

Q.6 To 50 litre of 0.2 N NaOH, 5 litre of 1N HCl and 15 litre of 0.1 N $FeCl_3$ solution are added. What weight of Fe_2O_3 can be obtained from the precipitate? Also report the normality of NaOH left in the resultant solution.

Q.7 0.5 g fuming H_2SO_4 (oleum) is diluted with water. The solution requires 26.7 mL of 0.4 N NaOH for complete neutralization. Find the percentage of free SO_3 in the sample of oleum.

Q.8 200 mL of a solution of mixture of NaOH and Na_2CO_3 was first titrated with phenolphthalein and N/10 HCl. 17.5 mL of HCl was required for the end point. After this methyl orange was added and 2.5 mL of same HCl was again required for next end point. Find out amount of NaOH and Na_2CO_3 in mixture.

Q.9 Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen:

$$KO_2(s) + H_2O(l) \rightarrow KOH(s) + O_2(g)$$

If a reaction vessel contains 0.158 mol KO_2 and 0.10 mol H_2O, how many moles of O_2 can be produced?

Q.10 A sample of mixture of $CaCl_2$ and NaCl weighing 4.22 gm was treated to precipitate all the Ca as $CaCO_3$ which was then heated and quantitatively converted to 0.959 gm of CaO. Calculate the percentage of $CaCl_2$ in the mixture.

Q.11 Cyclohexanol is dehyrated to cyclohexene on heating with conc. H_2SO_4. If the yield of this reaction is 75%, how much cyclohexene will be obtained from 100 g of cyclohexanol? $C_6H_{12}O \xrightarrow{\text{con. } H_2SO_4} C_6H_{10}$

Q.12 How many grams of 90% pure Na_2SO_4 can be produced from 250 gm of 95% pure NaCl?

Q.13 A precipitate of AgCl and AgBr weighs 0.4066 g. On heating in a current of chlorine, the AgBr is converted to AgCl and the mixture loses 0.0725 g in weight. Find the percentage of Cl in original mixture.

Q.14 How many milli-litre of 0.5 M H_2SO_4 are needed to dissolve 0.5 g of copper II carbonate?

Q.15 What is the strength in g per litre of a solution of H_2SO_4, 12 mL of which neutralized 15 mL of N/10 NaOH solution.

Q.16 n-butane is produced by the monobromination of ethane followed by Wurtz reaction. Calculate the volume of ethane at NTP required to produce 55 g n-butane if the bromination takes place with 90% yield and the Wurtz reaction with 85% yield.

Q.17 0.50 g of a mixture of K_2CO_3 and Li_2CO_3 required 30 mL of 0.25 N HCl solution for neutralization. What is percentage composition of mixture?

Q.18 Sodium chlorate, $NaClO_3$, can be prepared by the following series of reactions:

$$2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$$

$$6Cl_2 + 6Ca(OH)_2 \rightarrow Ca(ClO_3)_2 + 5CaCl_2 + 6H_2O$$

$$Ca(ClO_3)_2 + Na_2SO_4 \rightarrow CaSO_4 + 2NaClO_3$$

What mass of $NaClO_3$ can be prepared from 100 mL of concentrated HCl (density 1.18 gm/mL and 36% by mass)? Assume all other substance are present in excess amounts.

Q.19 In a determination of P an aqueous solution of NaH_2PO_4 is treated with a mixture of ammonium and magnesium ions to precipitate magnesium ammonium phosphate $Mg(NH_4)PO_4.6H_2O$. This is heated and decomposed to magnesium pyrophosphate, $Mg_2P_2O_7$ which is weighed. A solution of NaH_2PO_4 yielded 1.054g of $Mg_2P_2O_7$. What weight of NaH_2PO_4 was present originally?

Q.20 5 mL of 8 N HNO_3, 4.8 mL of 5 N HCl and a certain volume of 17 M H_2SO_4 are mixed together and made upto 2 litre. 30 mL of this acid mixture exactly neutralizes 42.9 mL of Na_2CO_3 solution containing 1 g $Na_2CO_3.10H_2O$ in 100 mL of water. Calculate the amount of sulphate ions in g present in solution.

Q.21 A sample of Mg was burnt in air to give a mixture of MgO and Mg_3N_2. The ash was dissolved in 60 Meq of HCl and the resulting solution was back titrated with NaOH. 12 Meq of NaOH were required to reach the end point. As excess of NaOH was then added and the solution distilled. The ammonia released was then trapped in 10 Meq of second acid solution. Back titration of this solution required 6 Meq of the base. Calculate the percentage of Mg burnt to the nitride.

Q.22 A mixture of ethane (C_2H_6) and ethene occupies 40 litre at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of O_2 to produce CO_2 and H_2O. Assuming ideal gas behaviour, calculate the mole fractions of C_2H_4 and C_2H_6 in the mixture.

Q.23 A solid mixture 5 g consists of lead nitrate and sodium nitrate was heated below 600°C until weight of residue was constant. If the loss in weight is 28%, find the amount of lead nitrate and sodium nitrate in mixture.

Q.24 Upon mixing 45.0 mL of 0.25 M lead nitrate solution with 25 mL of 0.10 M chromic sulphate, precipitation of lead sulphate takes place. How many moles of lead sulphate are formed? Also calculate the molar concentration of the species left behind in final solution. Assume that lead sulphate is completely insoluble.

Q.25 A 10 g sample of a mixture of calcium chloride and sodium chloride is treated with Na_2CO_3 to precipitate calcium as calcium carbonate. This $CaCO_3$ is heated to convert all the calcium to CaO and the final mass of CaO is 1.12 gm. Calculate % by mass of NaCl in the original mixture.

Q.26 A mixture of Ferric oxide (Fe_2O_3) and Al is used as solid rocket fuel which reacts to give Al_2O_3 and Fe. No other reactants and products are involved. On complete reaction of 1 mole of Fe_2O_3, 200 units of energy is released?

(i) Write a balance reaction representing the above change.

(ii) What should be the ratio of masses of Fe_2O_3 and Al taken so that maximum energy per unit mass of fuel is released.

(iii) What would be energy released if 16 kg of Fe_2O_3 reacts with 2.7 kg of Al.

Q.27 A mixture of nitrogen and hydrogen. In the ratio of one mole of nitrogen to three moles of hydrogen, was partially converted into so that the final product was a mixture of all these three gases. The mixture was to have a density of 0.497 g per litre at 25°C and 1.00 atm. What would be the mass of gas in 22.4 litres at 1 atm and 273 K? Calculate the % composition of this gaseous mixture by volume.

Q.28 In one process for waterproofing, a fabric is exposed to $(CH_2)_3SiCl_2$ vapour. The vapour reacts with hydroxyl groups on the surface of the fabric or with traces of water to form the waterproofing film $[(CH_3)_2SiO]_n$ by the reaction

$$n(CH_3)_2SiCl_2 + 2nOH^- \rightarrow 2nCl^- + nH_2O + [(CH_3)_2SiO]_n$$

where n stands for a large integer. The waterproofing film is deposited on the fabric layer upon layer. Each layer is 6.0 Å thick [the thickness of the $(CH_3)_2SiO$ group]. How much $(CH_2)_3SiCl_2$ is needed to waterproof one side of a piece of fabric, 1.00 m by 3.00 m, with a film 300 layers thick? The density of the film is 1.0 g/cm³.

Q.29 Two substance P_4 and O_2 are allowed to react completely to form mixture of P_4O_6 and P_4O_{10} leaving none of the reactants. Using this information calculate the composition of final mixture when mentioned amount of P_4 and O_2 are taken.

$$P_4 + 3O_2 \longrightarrow P_4O_6$$

$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

(i) If 1 mole P_4 & 4 mole of O_2

(ii) If 3 mole P_4 & 11 mole of O_2

(iii) If 3 mole P_4 & 13 mole of O_2

Q.30 Chloride samples are prepared for analysis by using NaCl, KCl and NH_4Cl seperately or as a mixture. What minimum volume of 5% by weight $AgNO_3$ solution (sp. gr., 1.04 g mL^{-1}) must be added to a sample of 0.3 g in order to ensure complete precipitation of chloride in every possible case?

Q.31 124 gm of mixture containing $NaHCO_3$, $AlCl_3$, and KNO_3 requires 500 mL, 8% w/w NaOH solution [d_{NaOH} = 1.8 gm/mL] for complete neutralisation. On heating same amount of mixture, it known loss in weight of 18.6 gm. Calculate % composition of mixture by moles. Weak base formed doesn't interfere in reaction. Assume KNO_3 does not decompose under given conditions.

Q.32 If the yield of chloroform obtainable from acetone and bleaching powder is 75%. What is the weight of acetone required for producing 30 gm of chloroform?

Q.33 A sample of impure Cu_2O contains 66.67% of Cu. What is the percentage of pure Cu_2O in the sample?

Q.34 Equal weights of mercury and iodine are allowed to react completely to form a mixture of mercurous and mercuric iodide leaving none of the reactants. Calculate the ratio by weight of Hg_2I_2 and HgI_2 and formed. (Hg = 200, I = 127)

Redox Reactions

Q.1 Indicate the oxidation state of underlined in each case:

(i) $Na\underline{N}O_2$ (b) $\underline{H}_2$ (c) $\underline{Cl}_2O_7$

(ii) $K\underline{Cr}O_3Cl$ (e) $\underline{Ba}Cl_2$ (f) $\underline{I}Cl_3$

(iii) $K_2\underline{Cr}_2O_7$ (h) $\underline{C}H_2O$ (i) $\underline{Ni}(CO)_4$

(iv) $\underline{N}H_2OH$

Q.2 Indicate the each reaction which of the reactant is oxidized or reduced if any:

(i) $CuSO_4 + 4KI \longrightarrow 2CuI + I_2 + 2K_2SO_4$

(ii) $2Na_2S + 4HCl + SO_2 \longrightarrow 4NaCl + 3S + 2H_2O$

(iii) $NH_4NO_2 \xrightarrow{\Delta} N_2 + 2H_2O$

Q.3 Calculate the number of electrons lost or gained during the changes:

(i) $3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$

(ii) $AlCl_3 + 3K \longrightarrow Al + 3KCl$

Q.4 Explain, why?

(i) H_2S acts as reductant whereas, SO_2 acts as reductant and oxidant both.

(ii) H_2O_2 acts as reductant and oxidant both.

Q.5 MnO_4^- can oxidize NO_2^- to NO_3^- in basic medium. How many mol of NO_2^- are oxidized by 1 mol of MnO_4^-?

Q.6 Which is stronger base in each pair?

(i) HSO_4^-; HSO; (ii) NO_2^-; NO_3^-;

(iii) Cl^-; ClO^-

Q.7 Fill in the blanks and balance the following equations:

(i) Zn +HNO_3 → .... + N_2O + ...

(ii) HI + HNO_3→ .... + NO + H_2O ....

Q.8 What volume of 0.20 M H_2SO_4 is required to produce 34.0 g of H_2S by the reaction:

$$8KI + 5H_2SO_4 \longrightarrow 4K_2SO_4 + 4I_2 + H_2S + 4H_2O$$

Q.9 20 mL of 0.2 M $MnSO_4$ are completely oxidized by 16 mL of $KMnO_4$ of unknown normality, each forming Mn^{4+} oxidation state. Find out the normality and molarity of $KMnO_4$ solution.

Q.10 $KMnO_4$ solution is to be standardized by titration against As_2O_3(s). A 0.1097 g sample of As_2O_3 requires 26.10 mL of the $KMnO_4$ solution for its titration. What are the molarity and normality of the $KMnO_4$ solution?

Q.11 0.518 g sample of limestone is dissolved and then Ca is precipitated as CaC_2O_4. After filtering and washing the precipitate, it requires 40 mL of 0.25 N $KMnO_4$ solution to equivalence point. What is percentage of CaO in limestone?

Q.12 20 mL of a solution containing 0.2 g of impure sample of H_2O_2 reacts with 0.316 g of $KMnO_4$ (acidic). Calculate:

(i) Purity of H_2O_2,

(ii) Volume of dry O_2 evolved at 27ºC and 750 mm P.

Q.13 5.7 g of bleaching powder was suspended in 500 mL of water. 25 mL of this suspended on treatment with KI and HCl liberated iodine which reacted with 24.35 mL of N/10 $Na_2S_2O_3$. Calculate percentage of available Cl_2 in bleaching powder.

Q.14 Balance the following equation:

(i) $C_2H_5OH + K_2Cr_2O_7 + H_2SO_4 \longrightarrow$

$$C_2H_4O_2 + Cr_2(SO_4)_3 + K_2SO_4 + H_2O$$

(ii) $As_2S_5 + HNO_3 \longrightarrow$

$$NO_2 + H_2O + H_3AsO_4 + H_2SO_4$$

(iii) $CrI_3 + Cl_3 + KOH \longrightarrow$

$$KIO_4 + K_2CrO_4 + KCl + H_2O$$

(iv) $As_2S_3 + HClO_3 + H_2O \longrightarrow$

$$HCl + H_3AsO_4 + H_2SO_4$$

Q.15 Balance the following equations:

(i) $As_2S_3 + OH^- + H_2O_2 \longrightarrow AsO_4^{2-} + SO_4^{2-} + H_2O$

(ii) $CrI_3 + H_2O_2 + OH^- \longrightarrow CrO_4^{2-} + 3IO_4^- + H_2O$

(iii) $P_4 + OH^- + H_2O_2 \longrightarrow H_2PO_2^- + PH_3$

(iv) $As_2S_3 + NO_3^- + H^+ \xrightarrow{+H_2O} H_3AsO_4 + NO + S$

Q.16 Mg can reduce NO_3^- to NH_3 in basic solution:

$NO_3^- + Mg(s) + H_2O \longrightarrow$

$Mg(OH)_2(s) + OH^-(aq) + NH_3(g)$

A 25.0 mL sample of NO_3^- solution was treated with Mg. The NH_3(g) was passed into 50 mL of 0.15 N HCl. The excess HCl required 32.10 mL of 0.10 M NaOH for its neutralization. What was the molarity of NO_3^- ions in the original sample?

Q.17 An acid solution of $KReO_4$ sample containing 26.83 mg of combined rhenium was reduced by passage through a column of granulated zinc. The effluent solution including the washing from the column, was then titrated with 0.05 N $KMnO_4$. 11.45 mL of the standard $KMnO_4$ was required for the reoxidation of all the rhenium to the perrhenate ion ReO_4^-. Assuming that rhenium was the only element reduced, what is the oxidation state to which rhenium was reduced by the zinc column.

Q.18 100 mL solution of FeC_2O_4 and $FeSO_4$ is completely oxidized by 60 mL of 0.02 M in acid medium. The resulting solution is then reduced by Zn and dil.HCl. The reduced solution is again oxidized completely by 40 mL of 0.02 M $KMnO_4$. Calculate normality of FeC_2O_4 and $FeSO_4$ in mixture.

Q.19 1 g of most sample of KCl and $KClO_3$ was dissolved in water to make 250 mL solution, 25 mL of this solution was treated with SO_2 to reduce chlorate to chloride and excess of SO_2 was removed by boiling. The total chloride was precipitated as silver chloride. The weight of precipitate was 0.1435 g. In another experiment, 25 mL of original solution was heated with 30 mL of 0.2 N ferrous sulphate solution and unreacted ferrous sulphate required 37.5 mL of 0.08 N solution of an oxidant for complete oxidation. Calculate the molar ratio of chlorate to chloride in the given mixture. Fe^{2+} reacts with ClO_3^- according to equation.

$ClO_3^- + 6Fe^{2+} + 6H^+ \longrightarrow Cl^- + 6Fe^{3+} + 3H_2O$

Q.20 (i) $CuSO_4$ reacts with KI in acidic medium to liberate I_2

$2CuSO_4 + 4KI \longrightarrow Cu_2I_2 + 2K_2SO_4 + I_2$

(ii) Mercuric per iodiate $Hg_5(IO_6)_2$ reacts with a mixture of KI and HCl following the equation:

$Hg_5(IO_6)_2 + 34KI + 24HCl \longrightarrow$

$$5K_2HgI_4 + 8I_2 + 24KCl + 12H_2O$$

(iii) The liberated iodine is titrated against $Na_2S_2O_3$ solution. One mL of which is equivalent to 0.0499 g of $CuSO_4.5H_2O$. What volume in mL of $Na_2S_2O_3$ solution will be required to react with I_2 liberated from 0.7245 g of $Hg_5(IO_6)_2$? M. wt. of $Hg_5(IO_6)_2$ = 1448.5 and M. wt. of $CuSO_4.5H_2O$ = 249.5.

Q.21 1.249 g of a sample of pure $BaCO_3$ and impure $CaCO_3$ containing some CaO was treated with dil. HCl and it evolved 168 mL of CO_2 at NTP. From this solution $BaCrO_4$ was precipitated, filtered an washed. The dry precipitate was dissolved in dilute H_2SO_4 and dilute to 100 mL. 10 mL of this solution when treated with KI solution liberated iodine which required exactly 20 mL of 0.05 N $Na_2S_2O_3$. Calculate percentage of CaO in the sample.

Q.22 A 10 g mixture of Cu_2S and CuS was treated with 200 mL of 0.75 M MnO_4^- in acid solution producing SO_2, Cu^{2+} and Mn^{2+}. The SO_2 was boiled off and the excess of MnO_4^- was treated with 175 mL of 1 M Fe^{2+} solution. Calculate percentage of CuS in original mixture.

Q.23 For estimating ozone in the air, a certain volume of air is passed through an acidified or neutral KI solution when oxygen is evolved and iodide is oxidised to give iodine. When such a solution is acidified, free iodine is evolved which can be titrated with standard $Na_2S_2O_3$ solution. In an experiment 10 litre of air at 1 atm and 27°C were passed through an alkaline KI solution, at the end, the iodine entrapped in a solution on titration as above required 1.5 mL of 0.01 N $Na_2S_2O_3$ solution. Calculate volume percentage of O_3 in sample.

Q.24 30 mL of an acidified solution of 1.5 N MnO_4^- ions, 15 mL of 0.5 N oxalic acid and 15 mL of 0.4 N ferrous salt solution are added together. Find the molarities of MnO_4^- and Fe_3^+ ions in the final solution?

Q.25 (i) 25 mL of H_2O_2 solution were added to excess of acidified solution of KI. The iodine so liberated required 20 mL of 0.1 N $Na_2S_2O_3$ for titration. Calculate the strength of H_2O_2 in terms of normality, percentage and volume.

(ii) To a 25 mL H_2O_2 solution, excess of acidified solution of KI was added. The iodine liberated required 20 mL of 0.3 N sodium thiosulphate solution. Calculate the volume strength of H_2O_2 solution.

Q.26 An aqueous solution containing 0.10 g KIO_3 (formula weight = 214.0) was treated with an excess of KI solution. The solution was acidified with HCl. The liberated I_2 consumed 45 mL of thiosulphate solution to decolorise the blue starch-iodine complex. Calculate the molarity of the sodium thiosulphate solution.

Q.27 A sample of $MnSO_4.4H_2O$ is strongly heated in air. The residue (Mn_3O_4) left was dissolved in 100 mL of 0.1 N $FeSO_4$ containing dil. H_2SO_4. This solution was completely reacted with 50 mL of $KMnO_4$ solution. 25 mL of this $KMnO_4$ solution was completely reduced by 30 mL of 0.1 N $FeSO_4$ solution. Calculate the amount of $MnSO_4.4H_2O$ in sample.

Q.28 Write complete balanced equation for the following in acidic medium by ion-electron method:

(i) $ClO_3^- + Fe^{2+} \rightarrow Cl^- + Fe^{+3} + H_2O$

(ii) $CuS + NO_3^- \rightarrow Cu^{+2} + S_8 + NO + H_2O$

(iii) $S_2O_3^{-2} + Sb_2O_3 \rightarrow SbO + H_2SO_3$

(iv) $HCl + KMnO_4 \longrightarrow Cl_2 + KCl + MnCl_2 + H_2O$

(v) $KClO_3 + H_2SO_4 \longrightarrow KHSO_4 + HClO_4 + ClO_3 + H_2O$

(vi) $HNO_3 + HBr \longrightarrow NO + Br_2 + H_2O$

(vii) $IO_4^- + I^- + H^+ \longrightarrow I_2 + H_2O$

Q.29 Balance the following equations by oxidation method:

(i) $Cu + NO_3^- + ... \longrightarrow Cu^{+2} + NO_2 + ...$

(Acid medium)

(ii) $Cl_2 + IO_3^- + OH^- \longrightarrow IO_4^- + ... + H_2O$

(Basic medium)

(iii) $H_2S + K_2CrO_4 + H_2SO_4 \longrightarrow ......$

(Acid medium)

(iv) $Fe^{+2} + MnO_4^- \longrightarrow Fe^{+3} + Mn^{+2} + ...$

(Acid medium)

(v) $KMnO_4 + H_2SO_4 + H_2O_2 \longrightarrow$

$K_2SO_4 + MnSO_4 + H_2O + ...$

(Acid medium)

(vi) $MnO_2 + H_2O_2 \longrightarrow MnO_4^- + H_2O$

(Basic medium)

Q.30 Write complete balance equation for the following in basic medium by ion-electron method:

(i) $S_2O_4^{-2} + Ag_2O \rightarrow Ag + SO_3^{-2}$

(ii) $Cl_2 + OH^- \rightarrow Cl^- + ClO^-$

(iii) $H_2 + ReO_4^- \rightarrow ClO_2^- + Sb(OH)_6^-$

(iv) $I_2 + OH^- \rightarrow I^- + IO_3^-$

(v) $MnO_4^- + Fe^{+2} \rightarrow Mn^{+2} + Fe^{+3}$

Exercise 2

Mole Concept

Single Correct Choice Type

Q.1 'x' gms of an element 'A' on heating in a jar of chlorine give 'y' gms of ACl_2 the atomic weight of element A is

(A) $\left(\frac{x}{y-71}\right)\times\frac{35.5}{2}$ (B) $\frac{71x}{y-71}$

(C) $\frac{35.5x}{y-71}$ (D) None of these

Q.2 The amount of H_2SO_4 present in 1200 mL of 0.2 N solution is

(A) 10.76 gms (B) 11.76 gms

(C) 12.76 gms (D) 14.76 gms

Q.3 An iodized salt contains 0.5% of NaI. A person consumes 3 gm of salt everyday. The number of iodide ions going into his body everyday is

(A) 10^{-4} (B) 6.02×10^{-4}

(C) 6.02×10^{19} (D) 6.02×10^{23}

Assertion Reasoning Type

(A) If both statement-I and statement-II are true and statement-II is the correct explanation of statement-I, the mark (A).

(B) If both statement-I and statement-II are true and statement-II is not the correct explanation of statement -I, the mark (B).

(C) If statement-I is true but statement-II is false, then mark (C).

(D) If both statement-I and statement-II are false, then mark (D).

Q.4 Statement-I: 0.28 g of N_2 has equal volume as 0.44 g of another gas at same conditions of temperature and pressure.

Statement-II: Molecular mass of another gas is 44 g mol^{-1}.

Q.5 Statement-I: Boron has relative atomic mass 10.81.

Statement-II: Borons two isotopes, ${}^{10}_{5}B$ and ${}^{11}_{5}B$ and their relative abundance is 19% and 81%.

Q.6 Statement-I: The percentage of nitrogen in urea is 46%.

Statement-II: Urea is ionic compound.

Q.7 Statement-I: The oxidation state of central sulfur of $Na_2S_2O_3$ is +6.

Statement-II: Oxidation state of an element should be determined form structure.

Q.8 Statement-I: Molarity of a solution and molality of a solution both change with density.

Statement-II: Density of the solution changes when percentage by mass of solution changes.

Q.9 Statement-I: $2A + 3B \rightarrow C$, 4/3 moles of 'C' are always produced when 3 moles of 'A' and 4 moles of 'B' are added.

Statement-II: 'B' is the liming reactant for the given data.

Multiple Correct Choice Type

Q.10 Given following series of reactions:

(i) $NH_3 + O_2 \rightarrow NO + H_2O$

(ii) $NO + O_2 \rightarrow NO_2$

(iii) $NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

(iv) $HNO_2 \rightarrow HNO_3 + NO + H_2O$

Select the correct option(s):

(A) Moles of HNO_3 obtained is half of moles of Ammonia used if HNO_2 is not used to produce HNO_3 by equation (iv)

(B) 100/6% more HNO_3 will be produced if HNO_2 is used to produce HNO_3 by reaction (iv) than if HNO_2 is not used to produce HNO_3 by reaction (iv)

(C) If HNO_2 is used to produce HNO_3 then 1/4th of total is produced by reaction (iv)

(D) Moles of NO produced in reaction (iv) is 50% of moles of total HNO_3 produced.

Comprehension Type

Paragraph 1: 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 mill equivalents of reactants as well as products are always equal.

Q.11 On heating a litre of a $\frac{N}{2}$ 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

Q.12 The volume of 0.1 M Ca(OH) required to neutralize 10 mL of 0.1 N HCl will be

(A) 10 mL (B) 20 mL (C) 5 mL (D) 40 mL

Q.13 Molarity of 0.5 N Na_2CO_3 is

(A) 0.25 (B) 1.0 (C) 0.5 (D) 0.125

Q.14 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

Q.15 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

Paragraph 2: A 4.925 g sample of a mixture of $CuCl_2$ and $CuBr_2$ was dissolved in water and mixed thoroughly with a 5.74 g portion of AgCl. After the reaction and solid, a mixture of AgCl and AgBr, was filtered, washed, and dried. Its mass was found to be 6.63 g.

Q.16

(1) % By mass of $CuBr_2$ in original mixture is

(A) 2.24 (B) 74.5 (C) 45.3 (D) None

(2) % By mass of Cu in original mixture is

(A) 38.68 (B) 19.05 (C) 3.86 (D) None

(3) % by mole of AgBr in dried precipitate is

(A) 25 (B) 50 (C) 75 (D) 60

(4) No. of moles of Cl^- ion present in the solution after precipitate ion are

(A) 0.06 (B) 0.02 (C) 0.04 (D) None

Paragraph 3: Water is added to 3.52 grams of UF_6. The products are 3.08 grams of a solid [containing only U, O and F] and 0.8 gram of a gas only. The gas [containing fluorine and hydrogen only], contains 95% by mass fluorine.

[Assume that the empirical formula is same as molecular formula.]

Q.17

(1) The empirical formula of the gas is

(A) HF_2 (B) H_2F (C) HF (D) HF_3

(2) The empirical formula of the solid product is

(A) UF_2O_2 (B) UFO_2 (C) UF_2O (D) UFO

(3) The percentage of fluorine of the original compound which is converted into gaseous compound is

(A) 66.66% (B) 33.33% (C) 50% (D) 89.9%

Match the Columns

Q.18 One type of artificial diamond (commonly called YAG for yttrium aluminium garnet) can be represented by the formula $Y_3Al_5O_{12}$. [Y = 89, Al = 27]

Column I	Column II
(A) Y	(p) 22.73%
(B) Al	(q) 32.32%
(C) O	(r) 44.95%

Q.19 The recommended daily does is 17.6 milligrams of vitamin C (ascorbic acid) having formula $C_6H_8O_6$. Match the following. Given: $N_A = 6 \times 10^{23}$

Column I	Column II
(A) O-atoms present	(p) 10^{-4} mole
(B) Moles of vitamin C in 1 gm of vitamin C	(q) 5.68×10^{-3}
(C) Moles of vitamin C in 1 gm should be consumed daily	(r) 3.6×10^{20}

Q.20 If volume strength of H_2O_2 solution is 'X-V' then its

Column I	Column II
(i) Strength in g/L	(p) $\frac{X}{11.2}$
(ii) Volume strength X	(q) $\frac{X}{5.6}$
(iii) Molarity	(r) $\frac{17X}{5.6}$
(iv) Normality	(s) $5.6 \times N$

(A) (i) - r, (ii) - p, (iii) - s, (iv) - q

(B) (i) - s, (ii) - p, (iii) - q, (iv) - p

(C) (i) - r, (ii) - s, (iii) - p, (iv) - q

(D) (i) - r, (ii) - q, (iii) - s, (iv) - p

Q.21 Match the entries in column I with entries in column II and then pick out correct options:

Column I	Column II
(i) M_R on mixing two acidic solutions	(p) $\frac{x \times d \times 10}{M_{solute}}$
(ii) M_R on mixing two basic solutions	(q) $n \times M \times V$ mL
(iii) M_R on mixing two acidic and basic solutions	(r) $\frac{M_1V_1 - M_2V_2}{V_1 + V_2}$
(iv) Milliequivalent	(s) $\frac{M_1V_1}{V_2}$
(v) Molarity	(t) $\frac{M_1V_1 + M_2V_2}{V_1 + V_2}$

(A) (i) - p, (ii) - r, (ii) - p, (iv) - q, (v) - s

(B) (i) - t, (ii) - t, (ii) -r, (iv) -q, (v) - p, s

(C) (i) - q, (ii) - p, (ii) -q, (iv) - r, (v) -q

(D) (i) - p, (ii) - q, (ii) - q, (iv) - r, (v) - r

Redox Reactions

Single Correct Choice Type

Q.1 One mole of N_2H_4 loses ten moles of electrons to form a new compound Y. Assuming that all the nitrogen appears in the new compound, what is the oxidation state of nitrogen in Y? (There is no change in the oxidation state of hydrogen)

(A) –1 (B) –3 (C) +3 (D) +5

Q.2 Which is best reducing agent

(A) F^- (B) Cl^- (C) Br^- (D) I^-

Q.3 In the alumino thermite process, aluminium acts as

(A) An oxidizing agent (B) A flux

(C) Reducing agent (D) A solder

Q.4 Zinc-copper couple that can be used as a reducing agent is obtained by

(A) Mixing zinc dust and copper gas

(B) Zinc coated with copper

(C) Copper coated with zinc

(D) Zinc and copper wires welded together

Q.5 In the following equations value of X is

$$ClO_3^- + 6H^+ + X \rightarrow Cl^- + 3H_2O$$

(A) $4e^-$ (B) $5e^-$ (C) $6e^-$ (D) $7e^-$

Q.6 The brown ring complex compound is formulated as $[Fe(H_2O)_5(NO)^+]SO_4$. The oxidation state of iron is

(A) 1 (B) 2 (C) 3 (D) 0

Q.7 Oxidation state of oxygen atom in potassium superoxide is

(A) –1/2 (B) –1 (C) –2 (D) 0

Q.8 In the following reaction

$$3Br_2 + 6CO_3^{-2} + 3H_2O \rightarrow 5Br^- + 6HCO_3^- + BrO_3^-$$

(A) Bromine is both reduced and oxidised

(B) Bromine is neither reduced nor oxidised

(C) Bromine is oxidised and carbonate is reduced

(D) Bromine is reduced and water is oxidised

Comprehension Type

Paragraph 1: The redox titration involve the chemical reaction between the oxidising agent and reducing agent in aqueous solutions under suitable conditions. Titrations involve the direct use of iodine as oxidising agent are known as iodimetric titrations while those titrations involving indirect use of iodine are known as iodometric titrations. These titrations are used for the estimation of oxidising agents like $KMnO_4$, $K_2Cr_2O_7$, $CuSO_4$ etc.

Q.9 50 mL of an aqueous solution of H_2O_2 was treated with excess of KI solution and the iodine so liberated quantitatively required 20 mL of 0.1 N solution of hypo. This titration is known as:

(A) Iodometric titration (B) Iodimetric titration

(C) Potassium iodide titration (D) All of these

Q.10 In the above problem, concentration of H_2O_2 in gm/litre is:

(A) 6.8 (B) 0.68 (C) 0.068 (D) 0.34

Q.11 0.5 gm sample of pyrolusite (MnO_2) is treated with HCl, the Cl_2 gas evolved is treated with KI, the violet vapours evolved are absorbed in 30 mL 0.1 N $Na_2S_2O_3$ solution percentage purity of pyrolusite sample is

(A) 30% (B) 50% (C) 36% (D) 26.1%

Q.12 Arsenite gets converted into arsenate by using iodine, valency factor for Arsenite and Iodine are respectively

(A) 2 and 2 (B) 2 and 1 (C) 1 and 2 (D) 5 and 2

Paragraph 2: Oxidation and reduction process involves the transaction of electrons. Loss of electrons is oxidation and the gain of electrons is reduction. It is thus obvious that in a redox reaction, the oxidant is reduced by accepting the electrons and the reductant is oxidised by losing electrons. The reactions in which a species disproportionate into two oxidation states (lower and higher) are called disproportionation reactions. In electrochemical cells, redox reaction is involved, i.e., oxidation takes place at anode and reduction at cathode.

Q.13 The reaction: $Cl_2 \rightarrow Cl^- + ClO^-_3$ is

(A) Oxidation

(B) Reduction

(C) Disproportionation

(D) Neither oxidation nor reduction

Q.14 In the reaction: $I_2 + 2S_2O_3^{-2} \rightarrow 2I^- + S_4O_6^{-2}$

(A) I_2 is reducing agent

(B) I_2 is oxidising agent

(C) $S_2O_3^{-2}$ is reducing agent

(D) $S_2O_3^{-2}$ is oxidising agent

Q.15 Determine the change in oxidation number of sulphur is H_2S and SO_2 respectively in the following reaction: $2H_2S + SO_2 \rightarrow 2H_2O + 3S$

(A) 0, +2 (B) +2, –4 (C) –2, +2 (D) +4, 0

Multiple Correct Choice Type

Q.16 Which of the following reactions is/are correctly indicated?

Oxidant Reductant

(A) $HNO_3 + Cu \longrightarrow Cu^{2+} + NO_2$

(B) $2Zn + O_2 \longrightarrow ZnO$

(C) $Cl_2 + 2Br^- \longrightarrow 2Cl^- + Br_2$

(D) $4Cl_2 + CH_4 \longrightarrow CCl_4 + 4HCl$

Assertion and Reasoning Type

Each of the questions given below consist of statement-I and statement-II. Use the following Key to choose the appropriate answer.

(A) If both statement-I and statement-II are true, and statement-II is the correct explanation of statement-I.

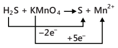
(B) If both statement-I and statement-II are true, and statement-II is not the correct explanation of statement-I.

(C) If statement-I is true but statement-II is false.

(D) If statement-I is false but statement-II is true.

Q.17 Statement-I: In CrO_5 oxidation number of Cr is +6.

Statement-II: CrO_5 has butterfly structure in which peroxide bonds are present.



Q.18 Statement-I: In PbO_4 all Pb has +8/3 oxidation number.

Statement-II: PbO_4 is mixed oxide of PbO and PbO_2

Q.19 Statement-I: $HClO_4$ is only oxidising agent.

Statement-II: Cl is most electro-negative element in H, Cl and O.

Q.20 Statement-I: In FeS_2 oxidation number of iron is +4.

Statement-II: In FeS_2 $(S^- – S^-)$ linkage is present.

Q.21 Statement-I: In given reaction H_2O_2 is oxidising & reducing agent

$$H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$$

Statement-II: In H_2O_2 is a bleaching reagent.

Q.22 Statement-I: In basic medium colour of $K_2Cr_2O_7$ is changed from orange to yellow.

Statement-II: In basic medium $K_2Cr_2O_7$ is changed in chromate ion.

Q.23 Statement-I: $I_2 \longrightarrow IO_3^- + I^-$.

This reaction is disproportionate reaction.

Statement-II: Oxidation number of I can vary from –1 to +7.

Match the Columns

Q.24 Match the entries in column I with entries in column II and then pick out correct options:

Column I	Column II
(A) Increase in oxidation number	(p) Loss of electrons
(B) Decrease in oxidation number	(q) Redox reaction
(C) Oxidising agent	(r) Fractional oxidation number
(D) Reducing agent	(s) Zero oxidation number
(E) $2Cu^+ \rightarrow Cu^{2+} + Cu$	(t) Simple neutralisation reaction
(F) $MnO_2 + 4HCl \rightarrow MnCl_2$	(u) Gain of electrons + $Cl_2 + 2H_2O$
(G) $\underline{Mn}_3O_4$	(v) Disproportion-ation
(H) $\underline{C}H_2Cl_2$	(w) Oxidation
(I) $NaOH + HCl \rightarrow NaCl + H_2O$	(x) Reduction

Q.25 Match the reactions in column I with nature of the reactions/type of the products in Column II.

Column I	Column II
(A) $O_2^- \rightarrow O_2 + O_2^{-2}$	(p) Redox reaction
(B) $CrO_4^{-2} + H^+ \rightarrow$	(q) One of the products has trigonal planar structure
(C) $MnO_4^- + NO_2^- + H^+ \rightarrow$	(r) Dimeric bridged tetrahedral metal ion
(D) $NO_3^- + H_2SO_4 + Fe^{2+} \rightarrow$	(s) Disproportionation

Previous Years' Questions

Mole Concept

Q.1 Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of natural boron is 10.81. Calculate the percentage of each isotope in natural boron. ***(1978)***

Q.2 The vapour density (hydrogen = 1) of a mixture consisting of NO_2 and N_2O_4 is 38.3 at 26.7ºC. Calculate the number of moles of NO_2 in 100 g of the mixture. ***(1979)***

Q.3 A solid mixture (5.0 g) consisting of lead nitrate and sodium nitrate was heated below 600ºC until the weight of the residue was constant. If the loss in weight is 28.0 percent, find the amount of lead nitrate and sodium nitrate in the mixture. ***(1990)***

Q.4 'A' is a binary compound of a univalent metal. 1.422 g of A reacts completely with 0.321 g of sulphur in an evacuated and sealed tube to give 1.743 g of a white crystalline solid B, that forms a hydrated double salt, C with $Al_2(SO_4)_3$ Identify A, B and C. ***(1994)***

Q.5 Calculate the molality of 1.0 L solution of 93% H_2SO_4, (weight/volume). The density of the solution is 1.84 g/mL. ***(1990)***

Q.6 20% surface sites have adsorbed N_2. On heating N_2 gas evolved from sites and were collected at 0.001 atm and 298 K in a container of volume is 2.46 cm^3. Density of surface sites is 6.023×10^{14} /cm^2 and surface area is 1000 cm^2, find out the number of surface sites occupied per molecule of N_2. ***(2005)***

Q.7 If 0.50 mole of $BaCl_2$ is mixed with 0.20 mole of Na_3PO_4 the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is ***(1981)***

(A) 0.70 (B) 0.50 (C) 0.20 (D) 0.10

Q.8 In the standardization of $Na_2S_2O_3$ using $K_2Cr_2O_7$ is ***(2001)***

(A) $\left(\frac{\text{Molecular Weight}}{2}\right)$

(B) $\left(\frac{\text{Molecular Weight}}{6}\right)$

(C) $\left(\frac{\text{Molecular Weight}}{3}\right)$

(D) Same as molecular weight

Q.9 The difference in the oxidation numbers of the two types of sulphur atoms in $Na_2S_4O_6$ is. ***(2011)***

Read the following questions and answer as per the direction given below:

(A) Statement-I is true; statement-II is true; statement-II is the correct explanation of statement-I.

(B) Statement-I is true; statement-II is true; statement-II is not the correct explanation of statement-I.

(C) Statement-I is true; statement-II is false.

(D) Statement-I is false; statement-II is true.

Q.10 Statement-I: In the titration of Na_2CO_3 with HCl using methyl orange indicator, the volume required at the equivalent point is twice that of the acid required using phenolphthalein indicator.

Statement-II: Two moles of HCl are required for the complete neutralization of one mole of Na_2CO_3. ***(1991)***

Q.11 2.68×10^{-3} moles of a solution containing an ion A^{n+} require 1.61×10^{-3} moles of MnO_4^- for the oxidation of A^{n+} to AO_3^- in acidic medium. What is the value of n? ***(1984)***

Q.12 A 5.0 cm^3 solution of H_2O_2 liberates 0.508 g of iodine from an acidified KI solution. Calculate the strength of H_2O_2 solution in terms of volume strength at STP. ***(1995)***

Q.13 A solution of 0.2 g of a compound containing Cu^{2+} and $C_2O_4^{2-}$ ions on titration with 0.02 M $KMnO_4$ in presence of H_2SO_4 consumes 22.6 mL of the oxidant. The resultant solution is neutralized with $NaCO_3$, acidified with dilute acetic acid and treated with excess KI. The liberated iodine requires 11.3 mL of 0.05 M $Na_2S_2O_3$ solution for complete reduction. Find out the mole ratio of Cu^{2+} to $C_2O_4^{-2}$ in the compound. Write down the balanced redox reactions involved in the above titrations. ***(1991)***

Q.14 A mixture of $H_2C_2O_4$ (oxalic acid) and $NaHC_2O_4$ weighing 2.02 g was dissolved in water and the solution made up to one litre. Ten millilitres of the solution required 3.0 mL of 0.1 N sodium hydroxide solution for complete neutralization. In another experiment, 10.0 mL of the same solution, in hot dilute sulphuric acid medium, required 4.0 mL of 0.1 N potassium permanganate solution for complete reaction. Calculate the amount of $H_2C_2O_4$ and $NaHC_2O_4$ in the mixture. ***(1990)***

Q.15 The unbalanced chemical reactions given in list I show missing or condition which are provided in list II. Match list I with list II and select the correct answer using the code given below the lists: ***(2013)***

	List I		**List II**
(i)	$PbO_2 + H_2SO_4 \xrightarrow{?}$ $PbSO_4 + O_2 + \text{other product}$	(p)	NO
(ii)	$Na_2S_2O_3 + H_2O \xrightarrow{?}$ $NaHSO_4 + \text{other product}$	(q)	I_2
(iii)	$N_2H_4 \xrightarrow{?}$ $N_4 + \text{other product}$	(r)	Warm
(iv)	$XeF_2 \xrightarrow{?}$ $Xe + \text{other product}$	(s)	Cl_2

Codes:

	(i)	(ii)	(iii)	(iv)
(p)	4	2	3	1
(q)	3	2	1	4
(r)	1	4	2	3
(s)	3	4	2	1

Q.16 For the reaction $I^- + ClO_3^- + H_2SO_4 \rightarrow Cl^- + HSO_4^- + I_2$ The correct statement(s) in the balanced equation is/are: ***(2014)***

(A) Stoichiometric coefficient of HSO_4^- is 6.

(B) Iodide is oxidized.

(C) Sulphur is reduced.

(D) H_2O is one of the products

Q.17 Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a ***(2014)***

(A) Reducing agent, oxidising agent

(B) Reducing agent, reducing agent

(C) Oxidising agent, oxidising agent

(D) Oxidising agent, reducing agent

PlancEssential Questions

JEE Main/Boards

Exercise 1

Mole Concept

Q.1
Q.3
Q.7
Q.11
Q.13
Q.18
Q.21
Q.29

Redox

Q.3 (C)
Q.4 (F)

Exercise 2

Mole Concept

Q.1
Q.6
Q.10
Q.15
Q.19
Q.23
Q.29
Q.33

Redox

Q.1
Q.8
Q.15
Q.24
Q.25

Previous Years' Questions

Mole Concept and Redox

Q.1
Q.5
Q.14

JEE Advanced/Boards

Exercise 1

Mole Concept

Q.3
Q.7
Q.14
Q.15
Q.22
Q.26
Q.28

Redox

Q.2
Q.5
Q.13
Q.23
Q.17

Exercise 2

Mole Concept

Q.2
Q.7
Q.13
Q.16

Redox

Q.1
Q.6
Q.9
Q.16
Q.19
Q.21

Previous Years' Questions

Mole Concept and Redox

Q.3
Q.14

Answer Key

JEE Main/Boards

Exercise 1

Mole Concept

Q.1 (i) 68.125 Kg (ii) 7.63 Kg/m^2 (iii) 1.72 m

Q.2 7.818×10^{22} atoms

Q.3 4.82×10^{22} atoms

Q.4 0.437

Q.5 6.02×10^{10} g / cm^3

Q.6 0.1 M HNO_3

Q.7 14.0 tablets

Q.8 0.1 M

Q.9 $(C_3O_4) = C_{12}O_{16}$

Q.10 0.44 g

Q.11 35.5: 1, 35.5: 1, 1: 1

Q.12 0.7985, 0.798

Q.13 M_2O_3

Q.14 K_2MnO_4

Q.15 (i) 55.5 M

Q.16 (i) 3.24×10^{-22} g/molecule

(ii) 4.09×10^{22}

Q.17 55.56 moles

Q.18 7.098×10^{7} g mol^{-1}

Q.29 2.03 kg

Q.20 10 mol

Q.21 260 mL

Q.22 $\frac{x}{y} = 5$

Q.23 24

Q.24 0.394 g

Q.25 79.714 gm

Q.26 0.744

Q.27 1.125, 1.99, 2.00

Q.28 0.302 M

Q.29 1800 mL

Redox Reaction

Q.1 (i) 5/2 (ii) +2 (iii) +3 (iv) +6 (v) +2 (vi) +6
(vii) +2 (viii) –2 (ix) +5/2 (x) +1 (xi) +3 (xii) +8/3
(xiii) +7 (xiv) 0 (xv) +5 (xvi) +5

Q.2 (i) $5Br^- + BrO_3^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$,

(ii) $8Cr_2O_7^{2-} + 24H_2S + 16H^+ \longrightarrow 8Cr_2O_3 + 3S_8 + 32H_2O$

(iii) $Au + 2NO_3^- + 4Cl^- + 4H^+ \longrightarrow AuCl_4^- + 2NO_2 + 2H_2O$

(iv) $3Cu_2O + 14H^+ + 2NO_3^- \longrightarrow 6Cu^{+2} + 2NO + 7H_2O$

(v) $3MnO_4^- + 4H^+ \longrightarrow 2MnO_4^{-1} + MnO_2 + 2H_2O$

(vi) $2Cu^{+2} + SO_2 + 2H_2O \longrightarrow 2Cu^+ + 4H^+ + SO_4^{-2}$

(vii) $5Cl_2 + I_2 + 3H_2O \longrightarrow 2IO_3^- + 10Cl^- + 6H^+$

(viii) $5Fe(CN)_6^{-4} + 188H^+ + 61MnO_4^- \longrightarrow 5Fe^{3+} + 30CO_2 + 30NO_3^- + 61Mn^{+2} + 94H_2O$

(ix) $6Cu_3P + 124H^+ + 11Cr_2O_7^{-2} \longrightarrow 18Cu^{+2} + 6H_3PO_4 + 22Cr^{+3} + 53H_2O$

Q.3 (a) $2Cu^{+2} + 2I^{-} \longrightarrow 2Cu^{+} + I_2$

(i) $6Fe_3O_4 + 2MnO_4^{-1} + 8H_2O \longrightarrow 9Fe_2O_3 + 2MnO_3 + 16OH^{-}$

(ii) $3C_2H_5OH + 2MnO_4^{-} + OH^{-} \longrightarrow 3C_2H_3O^{-} + 2MnO_2(s) + 5H_2O$

(iii) $2CrI_3 + 27H_2O_2 + 10OH^{-} \longrightarrow 2CrO_4^{-2} + 6IO_4^{-} + 32H_2O$

(iv) $258KOH + K_4Fe(CN)_6 + 61Ce(NO_3)_4 \longrightarrow 61Ce(OH)_3 + Fe(OH)_3 + 36H_2O + 6K_2CO_3 + 250KNO_3$

Q.4 (i) $H_2O_2 + 2I^{-} + 2H^{+} \longrightarrow 2H_2O + I_2$

(ii) $2Cu^{+2} + 2HI \longrightarrow 2Cu^{+} + I_2 + H_2O$

(iii) $3CuO + 2NH_3 \longrightarrow 3Cu + N_2 + 3H_2O$

(iv) $3H_2SO_3 + Cr_2O_7^{-2} + 8H^{+} \longrightarrow 3H_2SO_4 + 2Cr^{+3} + 4H_2O$

(v) $\therefore\ 2Cr_2O_7^{2-} + 9C_2H_4O + 16H^{\oplus} \longrightarrow 9C_2H_4O_2 + 4Cr^{+3} + 8H_2O$

(vi) $2SbCl_3 + KIO_3 + 6HCl \longrightarrow 2SbCl_5 + ICl + 3H_2O + KCl$

(vii) $As_2S_5 + 2HNO_3 \longrightarrow 5H_2SO_4 + 40NO_3 + 2H_5AsO_4 + 12H_2O$

Exercise 2

Mole Concept

Single Correct Choice Type

Q.1 B	**Q.2** C	**Q.3** B	**Q.4** B	**Q.5** B	**Q.6** B	**Q.7** D
Q.8 C	**Q.9** A	**Q.10** A	**Q.11** C	**Q.12** A	**Q.13** B	**Q.14** C
Q.15 A	**Q.16** C	**Q.17** D	**Q.18** A	**Q.19** B	**Q.20** C	**Q.21** A
Q.22 C	**Q.23** B	**Q.24** C	**Q.25** B	**Q.26** C	**Q.27** D	**Q.28** A
Q.29 C						

Redox Reaction

Single Correct Choice Type

Q.1 A	**Q.2** D	**Q.3** A	**Q.4** C	**Q.5** C	**Q.6** C	**Q.7** B
Q.8 C	**Q.9** B	**Q.10** C	**Q.11** D	**Q.12** C	**Q.13** C	**Q.14** B
Q.15 C	**Q.16** D	**Q.17** C	**Q.18** D	**Q.19** A	**Q.20** A	**Q.21** C
Q.22 A	**Q.23** D	**Q.24** B	**Q.25** C	**Q.26** A	**Q.27** A	**Q.28** D
Q.29 C	**Q.30** D	**Q.31** C	**Q.32** C			

Previous Year's Questions

Q.1 A	**Q.2** C	**Q.3** D	**Q.4** B	**Q.5** A	**Q.6** C	**Q.7** A
Q.8 D	**Q.9** B	**Q.10** B	**Q.11** D	**Q.12** A	**Q.13** C	**Q.14** A
Q.15 C	**Q.16** D	**Q.17** C	**Q.18** D	**Q.19** A	**Q.20** A	**Q21.** C
Q.22 D	**Q.23** B	**Q.24** A				

JEE Advanced/Boards

Exercise 1

Mole Concept

Q.1 116.8 gm

Q.2 9.12

Q.3 5.6

Q.4 0.597 g

Q.5 $BaCl_2.2H_2O$ = 7.038 g, H_2O = 42.962 g

Q.6 120 g

Q.7 20.78%

Q.8 NaOH = 0.06 g per 200 mL, Na_2CO_3 = 0.0265 g per 200 mL

Q.9 0.1185

Q.10 45%

Q.11 61.5 gm

Q.12 320.3 gm

Q.13 6%

Q.14 8.097 mL

Q.15 6.125 g/litre

Q.16 55.53 litre

Q.17 K_2CO_3 = 96%, Li_2CO_3 = 4%

Q.18 12.9 gm

Q.19 1.14 gm

Q.20 SO_4^{-2} ion concentration = 6.528

Q.21 27.27%

Q.22 C_2H_6 = 0.66, C_2H_4 = 0.34

Q.23 $Pb(NO_3)_2$ = 3.32 g, $NaNO_3$ = 1.68 g

Q.24 0.0075, $[Pb^{2+}]$ = 0.0536 M, $[NO_3^-]$ = 0.32 M, $[Cr^{3+}]$ = 0.0714 M

Q.25 %NaCl = 77.8%

Q.26 (i) $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$; (ii) 80: 27; (iii) 10,000 units

Q.27 12.15 gm, N_2 = 14.28%, H_2 = 42.86%, NH_3 = 42.86%

Q.28 0.9413 gram

Q.29 (i) 0.5, 0.5; (ii) 0.66, 0.33; (iii) 1, 2

Q.30 13.4 mL

Q.31 $AlCl_3$ = 33.33%; $NaHCO_3$ = 50; KNO_3 = 16.67

Q.32 9.4 gm

Q.33 75%

Q.34 0.532: 1.00

Redox Reaction

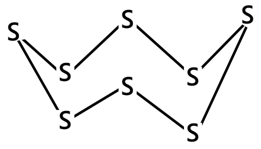
Q.1 (i) +3 (ii) 0 (iii) +7 (iv) +6 (v) +2 (vi) +3 (vii) +6 (viii) 0 (ix) 0 (x) –1

Q.2 Oxidized: KI, Na_2S, NH_4^+; Reduced: $CuSO_4$, SO_2, NO_2^-

Q.3 (i) 8 electrons, (ii) electrons

Q.4 (i) Oxidation number of sulphur in H_2S and SO_2 are respectively –2 and +4.

Q.5 NO_2^- is oxidized to NO_3^- by MnO_4^- (in basic medium) which is reduced to MnO_2.



Thus, $MnO_4^- \longrightarrow MnO_3$ oxidation number decreases by 3-units

$NO_2^- \longrightarrow NO_3^-$ oxidation number increases by 2 units

Thus, $2MnO_4^- \equiv 3NO_2^-$ $\quad MnO_4^- \equiv \frac{3}{2}NO_2^- = 1.5\,\text{mol}\,NO_2^-$

Q.6 (i) HSO_3^-; (ii) NO_2^-; (ii) Cl^-

Q.7 (i) $4Zn + 10HNO_3 \longrightarrow 4Zn(NO_3)_2 + N_2O + 5H_2O$ (ii) $6HI + 2HNO_3 \longrightarrow 3I_2 + 2NO + 4H_2O$

Q.8 25 litre **Q.9** 0.5 N, 0.167 M **Q.10** 0.085 M, 0.042 N

Q.11 54% **Q.12** (i) 85%; (ii) 124.79 mL **Q.13** 30.33%

Q.14

(i)	3	2	8	3	1	2	11
(ii)	1	40	40	12	2	5	
(iii)	2	27	64	6	2	54	32
(iv)	3	14	18	14	6	9	

Q.15 (i) $As_2S_3 + 12OH^- + 14H_2O \longrightarrow 2As^{3-}O_4 + 3S^{2-}O_4 + 20H_2O$

(ii) $2CrI_3 + 10OH^- + 27H_2O_2 \longrightarrow 2Cr^{2-}O_4 + 6IO_4^- + 32H_2O$

(iii) $P_4 + 3OH^- + 3H_2O \longrightarrow 3H_2PO_2^- + PH_3$

(iv) $3As_2S_3 + 4H_2O + 10NO_3^- + 10^+ \longrightarrow 6H_3AsO_4 + 9S + 10NO$

Q.16 0.1716 **Q.17** +3 **Q.18** FeC_2O_4 = 0.03 N, $FeSO_4$ = 0.03 N

Q.19 Molar ratio = 1: 1 **Q.20** 40 mL **Q.21** 14% **Q.22** 57.4%

Q.23 $1.847 \times 10^{-3}\%$ **Q.24** $[Fe^{3+}] = 0.1M, [MnO_4^-] = 0.105M$

Q.25 (i) 0.08 N, 0.136%, 0.448 volume; (ii) 1.344 **Q.26** 0.062 M **Q.27** 1.338 g

Q.28 (i) $6H^+ + ClO_3^- + 5Fe^{+2} \longrightarrow Cl^- + 5Fe^{+3} + 3H_2O$

(ii) $24CuS + 16NO_3^- + 64H^+ \longrightarrow 24Cu^{+2} + 3S_8 + 16NO + 32H_2O$

(iii) $S_2O_3^{-2} + Sb_2O_5 + 4H^+ \longrightarrow 2SbO + 2H_2SO_3$

(iv) $16HCl + 2KMnO_4 \longrightarrow 5Cl_2 + 2KCl + 2MnCl_2 + 8H_2O$

(v) $3KClO_3 + 3H_2SO_4 \longrightarrow 3KHSO_4 + HClO_4 + 2ClO_2 + H_2O$

(vi) $2HNO_3 + 6HBr \longrightarrow 2NO + 3Br_2 + 4H_2O$

(vii) $IO_4^- + 7I^- + 8H^+ \longrightarrow 4I_2 + 4H_2O$

Q.29 (i) $Cu + 4H^+ + 2NO_3^- \longrightarrow Cu^{+2} + 2NO_2 + 2H_2O$

(ii) $Cl_2 + IO_3^- + 2OH \longrightarrow IO_4^- + 2Cl^- + 2H_2O$

(iii) $3H_2S + 2K_2CrO_4 + 5H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + 2K_2SO_4 + 8H_2O + 3S$

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

(v) $2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

(vi) $2H_2O_2 + 2MnO_2 + 2OH^- \longrightarrow 2MnO_4^- + 4H_2O$

Q.30 (i) $S_2O_4^{-2} + Ag_2O + 2OH^- \longrightarrow 2Ag + 2SO_3^{-2} + H_2O$

(ii) $Cl_2 + 2OH^- \longrightarrow Cl^- + ClO^- + H_2O$

(iii) $3H_2 + 2ReO_4^- \longrightarrow 2ReO_2 + 2H_2O + 2OH^-$

(iv) $2ClO_2 + SbO_2^- + 2OH^- + 2H_2O \longrightarrow 2ClO_2^- + Sb(OH)_6^{-1}$

(v) $6I_2 + 12OH^- \longrightarrow 10I^- + 2IO_2^- + 6H_2O$

(vi) $MnO_4^- + 5Fe^{+2} + 4H_2O \longrightarrow Mn^{+2} + 5Fe^{+3} + 8OH^-$

Exercise 2

Mole Concept

Single Correct Choice Type

Q.1 D **Q.2** B **Q.3** C

Assertion Reasoning Type

Q.4 B **Q.5** A **Q.6** C **Q.7** B **Q.8** A **Q.9** C

Multiple Correct Choice Type

Q.10 A, C, D

Comprehension Type

Paragraph 1: **Q.11** A **Q.12** C **Q.13** A **Q.14** A **Q.15** C

Paragraph 2: **Q.16** (1) C; (2) A; (3) B; (4) A

Paragraph 3: **Q.17** (1) C; (2) A; (3) A

Match the Columns

Q.18 A → r; B → p; C → q **Q.19** A → r; B → q; C → p **Q.20** C **Q.21** B

Redox Reaction

Single Correct Choice Type

Q.1 C **Q.2** D **Q.3** C **Q.4** D **Q.5** C **Q.6** A **Q.7** A
Q.8 B

Comprehension Type

Paragraph 1: **Q.9** D **Q.10** D **Q.11** D **Q.12** D

Paragraph 2: **Q.13** C **Q.14** B, C **Q.15** B **Q.16** A, B, D

Assertion Reasoning Type

Q.17 A **Q.18** D **Q.19** C **Q.20** D **Q.21** B **Q.22** A **Q.23** B

Match the Columns

Q.24 A → w; B → x; C → u; D → p; E → v; F → q; G → r; H → s; I → t

Q.25 A → p, s; B → r; C → p, q; D → p

Previous Year's Questions

Q.1 20% **Q.2** 0.437 **Q.3** 1.7 g **Q.4** A = KO_2 **Q.5** 10.43 **Q.6** 2 **Q.7** D

Q.8 B **Q.9** 5 **Q.10** B **Q.11** 2 **Q.12** 4.48 V

Q.13 Moles of Cu^{2+}; Moles of $C_2O_4^{-2}$ = 1:2 **Q.14** 0.9 g, 1.12 g **Q.15** D **Q.16** A, B, D

Q.17 A

Solutions

JEE Main/Boards

Exercise 1

Mole Concept

Sol 1: (i) 125 pound

1 pound = lb = 545 gm

125 pound = 125 × 545 gm

= 125 × 545 × 10^{-3} kg = 68. 125 kg

(ii) 14 lb/m^2

1lb = 545 gm

In SI units = 14 × 545 × 10^{-3} kg/m^2

= 7. 63 kg/m^2

(iii) 5′8″

(1′ = 12″)

5′8″ = (12″ × 5) + 8″ = 68″

= 68 × 2. 54 cm = 1. 72 m

Sol 2: $M_{avg.}$ = (0. 932) 39 + (0. 068)41 = 39. 136

Mass of 2g-atoms = 2 ×39. 136 gm

Mass of ''41K'' in 2g-atoms

= 2 × 39. 136 × (0. 068)

Number of atoms = $\frac{2\times39.136}{41}\times(0.068)\times6.023\times10^{23}$

= 7.818 × 10^{22}

Sol 3: Barium phosphate = $Ba_3(PO_4)_2$

No. of oxygen atoms = $\frac{6.025}{602.5}\times8\times6.023\times10^{23}$

= 4.82 × 10^{22} atoms

Sol 4: Molecular weight = Vapour density × 2 = 76. 6

Let's suppose x % mole of NO_2 is there

76. 6 = x (46) + (1 – x) 92

46x = 15. 4

x = 0.3347=33. 47% = mole fraction of NO_2

Total mole = $\frac{100}{76.6}$ = 1. 305 mole

Mole of NO_2 = (0. 3347) × (1. 305) = 0.437 mole.

Sol 5: Correction: radius of fluorine

$= 5 \times 10^{-3}$ Å

Mass of nucleous $= 19 \times 1.67 \times 10^{-27}$ kg

Volume of nucleous

$$= \frac{4}{3} \times \pi \times (5 \times 10–3)^3 \text{ cm}^3$$

Density

$$= \frac{3 \times 19 \times 1.67 \times 10^{-27} \times 10^3}{4 \times \pi \times (5 \times 10^{-3})^3 \times (10^{-10})^3} \frac{\text{gm}}{\text{cm}^3}$$

$$= \frac{95.19 \times 10^{-27} \times 10^{30}}{1570.79 \times 10^{-9}} \text{ gm/cm}^3$$

$= 6.02 \times 10^{13}$ gm/cm^3

Sol 6: mole $= M_1V_1$

For neutralisation $H_{HNO_3} = H_{NaOH}$

$M_1V_1 = M_2V_2$

$20 \times M_1 = 0.08M \times 25$

$$M_1 = \frac{0.08 \times 25}{20} = 0.1M$$

Sol 7: HCl produced perday

$= 3.0 \text{ gm} \times 2.5 = 7.5 \text{ gm} = \frac{7.5}{36.5}$mole

Moles of $Al(OH)_3$ in an antacid tablet

$$= \frac{400 \times 10^{-3}}{(27+51)} = \frac{0.4}{78} \text{ mole}$$

$3 \times$ mole of $Al(OH)_3$ = moles of HCl

$$3 \times n \times \frac{0.4}{78} = \frac{7.5}{36.5}$$

$n \approx 14$

Sol 8: $HCl + AgNO_3 \rightarrow AgCl + HNO_3$

$$M \times 10 \times 10^{-3} = \frac{0.1435}{108 + 35.5}$$

M = 0. 1 M.

Sol 9: Lets it is C_xO_y

$x(12) + y(16) = 400$

$$\frac{x(12)}{400} = 0.36$$

x = 12; y = 16

the formula is $C_{12}O_{16} = (C_3O_4)_4$

Sol 10: $C_xH_y + O_2 \rightarrow H_2O \quad + \quad CO_2$

0. 1 mole   0. 2 mole

$$\text{Mole of } H_2O = \frac{0.18}{18} = 0.1 \text{ mole}$$

Mole of CO_2 = 0.02 mole

$$\text{Mole of } O_2 \text{ required} = \frac{1}{2}(0.1) + 0.02 = 0.07 \text{ mole}$$

y = Mole of H = (0. 1)2 = 0.2 mole

x = Mole of C = 0.02 mole

Mass of hydro is = (0.02)12 + (0.2)1

= 0.24 + 0.2 = 0.44 gm.

Sol 11: PCl_3 and PH_3

2257%   91. 18%

Mass of Cl in $PCl_3 = 3 \times 35.5 = 106.5$

Mass of H in $PH_3 = 3 \times 1 = 3$

$$\left.\begin{array}{l} \text{ratio} = \dfrac{106.5}{3} = 35.5 \\ \\ \text{Ratio of Cl : H} = 35.5 \end{array}\right\} \text{equal.}$$

Hence prove.

Sol 12: Exp. (I) $CuO \rightarrow Cu + X$

Ratio of mass of

$$\text{Cu : CuO} = \frac{1.098}{1.375} = 0.7985$$

$$\text{Exp. (II)} \underset{1.179\text{ gm}}{Cu} \xrightarrow{HNO_3} Cu(NO_3)_2 \longrightarrow \underset{1.476\text{ gm}}{CuO}$$

$$\text{Ratio of mass of Cu : CuO} = \frac{1.179}{1.479} = 0.798$$

both ratio are same. Hence prove.

Sol 13: M_xO_y

x × atomic mass of M = 0. 540 .... (i)

y × 16 = 1. 020 – 0. 540

y = 0. 03

Dulong-Petit law (atomic mass of M)

× 0. 216 = 5. 83

Atomic mass of M ≅ 27 .... (ii)

Petit x × (27) = 0. 540

x = 0. 02

Formula of metal oxide = M_2O_3.

Sol 14: Let's say substance is 100 gm

Moles of K = $\frac{39.7}{39} = 1.017$

Moles of Mn = $\frac{29.9}{55} = 0.5436$

Moles of O = $\frac{100 - 39.7 - 29.9}{16} = 1.9$

so by seeing on ratio of K : Mn : O

empirical formula is K_2MnO_4.

Sol 15: Molarity = $\frac{\text{no. of moles}}{\text{volume (in litre)}}$

No. of moles = $\frac{\text{mass}}{18} = \frac{1000 \times 0.997}{18}$ per litre.

Molarity = 55. 38 M

Sol 16: (a) Mass = (8 × 12) + (10 × 1) +(4 × 14) + (2 × 16)
= 96 + 10 + 56 + 32
Mass = 194 amu
= $194 \times 1.66 \times 10^{-24}$ gm/molecule
= 3.24×10^{-22} gm/molecule

(b) Molecular mass of Cl_2 = 71
Total no. of electrons in one molecule of Cl_2 = 34

So no. of electrons = $\frac{0.142}{71} \times 34 \times 6.023 \times 10^{23}$
= 4.029×10^{22}

Sol 17: Molarity = moles per litre

$$= \frac{\text{Mass}}{18 \times V} = \frac{\text{Density} \times \text{Volume}}{18 \times \text{Volume}} = \frac{1000}{18} = 55.55\text{M}$$

Sol 18: Volume of plant virus = $(\pi r^2 h)$
= $\pi \times (75 \times 10^{-10})^2 \times (5000 \times 10^{-10})$
= 8.835×10^{-23} m^3
= $8.835 \times 10^{-23} \times (10^{+2})^3$ cm^3
= 8.835×10^{-17} cm^3

Mass = $\frac{8.835 \times 10^{-17}}{0.75}$ gm

= 11.78×10^{-17} gm
= $11.78 \times 6.023 \times 10^{+23} \times 10^{-17}$
= 7.098×10^{7} g mol^{-1}

Sol 19: 25% of heavy water = 0.5 litre.
Mass of heavy water
= $0.5 \times 10^3 \times 1.06$ gm/cm^3 = 530 gm
Mass of normal water
= $1.5 \times 10^3 \times 1$ gm/cm^3 = 1500 gm
Total mass = 2030 gm = 2. 030 kg

Sol 20 $SO_2Cl_2 + 2H_2O \rightarrow H_2SO_4 + 2HCl$

Initially 2. 5 0 0

after 0 2. 5 5

For 2. 5 moles of H_2SO_4, KOH = 5 mole

For 5 mole of HCl, KOH = 5 mole

Total KOH = 5 + 5 = 10 mole

Sol 21: $\underbrace{NH_4Cl + MgCl_2}_{\text{2 \% by mass}} + \underbrace{AgNO_3}_{\text{5\% by mass}} \rightarrow$

$AgCl + NH_4NO_3 + Mg(NO_3)_2$

d = 1040 gm/lit.

Moles of Cl^- in

$NH_4Cl = \frac{2}{(14 + 4 + 35.5)}$ = 0. 0373 mole

Moles of Cl^- in

$MgCl_2 = 2 \times \frac{2}{(24 + 71)}$ = 0. 0421 mole

Total mole of Cl^-

= Total mole of $AgNO_3$ required

= 0.0421 + 0.0373 = 0.07940 mole

Mass of $AgNO_3$ = 0.07940 × 170 = 13.49 gm

Mass of solution of

$AgNO_3 \times 13.49 \times \frac{100}{5} = 269.97\,\text{gm}$

Volume required = $\frac{269.97}{1.04}\text{cm}^3$ = 259. 59 cm^3

Sol 22: Oxalic acid = $H_2C_2O_4$

Formic acid = HCOOH

$H_2C_2O_4 + H_2SO_4 \rightarrow SO_4^{2-} + H_4C_2O_4^{2+}$

$HCOOH + H_2SO_4 \xrightarrow{\Delta} SO_4^{2-} + 2H^+ + HCOOH$

$H_4C_2O_4^{2+} + KOH \rightarrow C_2O_4^{2-}$

Sol 23: $CH_4 \rightarrow$ x mole $\rightarrow$ Molecular weight = 16

$(C_2H_4) \rightarrow$ y mole $\rightarrow$ Molecular weight = 28

Mean molecular weight

$$= 20 = \frac{x(16)+y(28)}{x+y}$$

$$20 = 16 + \frac{12y}{x+y}$$

$$0.33 = \frac{y}{x+y}$$

$$\frac{x}{x+y} = 0.66$$

x : y = 2 : 1

If x : y = 1 : 2

Then, mean molecular weight $= \dfrac{1(16)+2(28)}{3} = 24$

Sol 24:

$2KClO_3 \rightarrow 2KCl + 3O_2$

4.369×10^{-3} $\quad$ 6.55×10^{-3}

$4KClO_3 \rightarrow 3KClO_4 + KCl$

3.794×10^{-3} $\quad$ 2.845×10^{-3}

Moles of oxygen produced

$$= \frac{146.8 \times 10^{-3}}{22.4} = 6.55 \times 10^{-3} \text{ mole}$$

Total mole of $KClO_3 = \dfrac{1}{39+35.5+48}$

$= 8.163 \times 10^{-3}$ mole

Moles of $KClO_3$ in IInd reaction = 3.794×10^{-3} moles

Moles of $KClO_4$ produced in IInd reaction

$= 2.8496 \times 10^{-3}$ mole

Mass of $KClO_4 = 2.8456 \times 10^{-3} \times (39 + 35.5 + 64)$

= 0.394 gm

Sol 25: Let's say we have 100 gm mix.

$Fe_3O_4 = FeO.Fe_2O_3 \rightarrow FeO + Fe_2O_3$

x gram $\quad$ 0.310 gram $\quad$ 0.680x gram

Initially FeO $\rightarrow$ (100 – x) gram

Total (FeO) $\rightarrow$ (100 – x + 0.310 x) gm

= (100 – 0.690 x) gm

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

(105 – 0. 690x)gm

$$2 \times \left(\frac{100-0.690x}{72}\right) = \frac{(105-0.690x)}{160}$$

$$(100 \times 0.690x) \times \frac{160}{36} = 105 - 0.690x$$

4000 – 27.6 x = 945 – 6.21 x 3055 = 21.39 x

x = oxygen external = 5gm $= \dfrac{5}{32}$mole

So moles of FeO that was present

$$\frac{(100-0.690x)}{56+16} = \frac{4\times 5}{32}$$

Fe_3O_4 + x = 79.71 gm

FeO = 100 – x = 20.29 gm

Sol 26: $Zn + 2I \rightarrow ZnI_2$

m $\quad$ m

2x moles of Zn = moles of I

(to complete reaction)

$2 \times \dfrac{m}{65}$ = 2x moles of Zn

$\dfrac{m}{127}$ = moles of I

Since moles of I < 2x moles of Zn

So Zn will be left unreacted

Zn unreacted $= \dfrac{m}{65} - \dfrac{m}{127\times 2}$ mole

Mass Zn unreacted $= m - \dfrac{65}{254}m = 0.744$ m

Sol 27: Mole of $P_4 = \dfrac{2}{4\times 31} = \dfrac{1}{62}$ mole

Moles of $O_2 = \dfrac{2}{2\times 16} = \dfrac{1}{16}$ mole

$$\begin{array}{llllll} P_4 & + & 3O_2 & \rightarrow & P_4O_6 & \\ x & & 3x & & 0 & \text{Initial} \\ 0 & & 0 & & x & \text{After} \end{array}$$

$$\begin{array}{llllll} P_4 & + & 5O_2 & \rightarrow & P_4O_{10} & \\ y & & 5y & & 0 & \text{Initial} \\ 0 & & 0 & & y & \text{After} \end{array}$$

$$\left.\begin{aligned} x + y &= \frac{1}{62} = 0.0161 \\ 3x + 5y &= \frac{1}{16} = 0.0625 \end{aligned}\right\} \text{by solving}$$

$y = 7.056 \times 10^{-3}$

$x = 9.0435 \times 10^{-3}$

Mass of $P_4O_6 = 9.0435 \times 10^{-3}$

$[(4 \times 31) + (6 \times 16)] = 1.9895$ gm

Mass of $P_4O10 = 7.056 \times 10^{-3}$

$[(4 \times 31) + (10 \times 16)] = 2.003$ gm

Sol 28: Moles of aluminium = $\frac{2.7}{27} = 0.1$ mole

Moles of H_2SO_4 in solution

$= \frac{(1.18 \times 100) \times 0.25}{98} = 0.\ 3010$ mole

$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

For consumption of Al, required mole of

$H_2SO_4 = (0.10) \times \frac{3}{2} = 0.\ 15$ mole

remaining mole of $H_2SO_4 = 0.3010 - 0.15 = 0.151$ mole

Molarity = $\frac{0.151}{500} \times 1000 = 0.302M$

Sol 29: $KMnO_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + (O)$ .... (1)

$FeC_2O_4 + H_2SO_4 \rightarrow FeSO_4 + H_2C_2O_4$ .... (2)

$FeSI_4 + H_2C_2O_4 + H_2SO_4 + O \rightarrow Fe_2(SO_4)_3 + CO_2 + H_2$ .... (3)

$3KMnO_4 + 5FeC_2O_4 \rightarrow Fe^{3+} + 2CO_2 + Mn^{2+}$

$(0.\ 5)V = \frac{(1.5)}{5} \times 3$

V = 1. 8 lit. = 1800 mL

Redox Reactions

Sol 1: (a) $(N_2H_5)_2\ \underbrace{SO_4}_{2}$

$2(N_2H_5)^+ + SO_4^{2-}$

$\downarrow$

$2N^{x-} + 5H^+$

$\therefore$ Oxidation number of N = $-\frac{5}{2}$

$-2x + 5 = 0;\ x = \frac{5}{2}$

(b) $Mg_3N_2 \rightarrow 3Mg^{x+} + 2N^{3-}$

$3x - 6 = 0$

$x = 2$ Mg^{2+}

(c) $\underbrace{\left[Co\left(NH_3\right)_5 Cl\right]}Cl_2$

$\left[Co\left(NH_3\right)_5 Cl\right]^{+2} + 2Cl^-$

$Co^{2+} + (NH_3)_5\ \ Cl^-$

$\therefore x - 1 = +2$ $x = +3$

Co^{+3}

(d) K_2FeO_4

$2K^+\ Fe^{x+}\ 4O^{2-}$

$+2 + x - 8 = 0;\ x = +6$

Fe^{+6}

(e) $Ba(H_2PO_2)_2$

$Ba^{2+}\ (H_2PO_2)^-$

$2H^+ + Px^+ + 2O^{2-}$

$2 + x - 4 = 0;\ x = +2$

$\therefore P^{+2}$

(f) H_2SO_4

$+ 2 + x - 8 = 0;\ x = +6$

S^{+6}

(g) CS_2

$- 4 + 2x = 0;\ x = +2$

S^{+2}

(h) S^{-2}

(i) $Na_2S_4O_6$

$+2 + 4x - 12 = 0$

$S^{+5/2}$

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

(j) S_2Cl_2

$+2x - 2 = 0;\ x = +1$

S^{+1}

(k) RNO_2

$+1 + x - 4 = 0; x = 3$

N^{+3}

(l) Pb_3O_4

$+3x - 8 = 0$

$x = +\frac{8}{3} \quad Pb^{+8/3}$

(m) $\underline{S_2}O_8^{2-}$

$2x - 16 = -2$

$2x = 14; x = +7$

S^{+7}

(n) $\underline{C_6}H_{12}O_6$

$+6x + 12 - 12 = 0; x = 0$

C^0

(o) $Mg_2P_2O_7$

$+2(2) + 2x - 14 = 0$

$x = +5$

P^{+5}

(p) $KClO_3$

$+1 + x - 6 = 0; x = +5$

Cl^{+5}

Sol 2: (a) $\overset{-1}{Br} + \overset{+5}{BrO_3^-} + H^+ \to \overset{0}{Br_2} + H_2O$

$Br^{-1} \to \frac{1}{2} Br_2 + e^-$ ......(1)

$5e^- + BrO_3^- + 6H^+ \to \frac{1}{2} Br_2 + 3H_2O$ ......(2)

((1) × 5) + (2)

$5Br^- + BrO_3^- + 6H^+ \to 3Br_2 + 3H_2O$

(b) $\overset{-2}{H_2S} + \overset{-2}{Cr_2O_7^{2-}} + H^+ \longrightarrow$

$\overset{+3}{Cr_2O_3} + \overset{0}{S_8} + H_2O$

$H_2S \to \frac{1}{8} S_8 + 2e^- + 2H^+$ ......(1)

$8H^+ + Cr_2O_7^{2-} + 6e^- \to Cr_2O_3 + 4H_2O$ ......(2)

((1) × 3) + (2)

$3H_2S + Cr_2O_7^{2-} + 2H+ \to \frac{3}{8} S_8 + 6H^+ + Cr_2O_3 + 4H_2O$

$8Cr_2O_7^{2-} + 24H_2S + 16H^+ \to 8Cr_2O_3 + 3S_8 + 32H_2O$

(c) $Au + 4Cl^- \to AuCl_4^- + 3e^-$ ......(1)

$NO_3^- + e^- + 2H^+ \to NO_2 + H_2O$ ......(2)

(1) + (2 × (2))

$Au + 4Cl– + 2NO_3^- + 4H^+ \to AuCl_4^- + 2NO_2 + 2H_2O$

(d) $Cu_2O + 2H^+ \to 2Cu^{+2} + 2e^- + H_2O$ ......(1)

$H^+ + NO_3^- + 3e^- \to NO + 2H_2O$ ......(2)

(3 × (1)) + (2 × (2))

$3Cu_2O + 6H^+ + 8H^+ + 2NO_3^- \to 6Cu^{2+} + 3H_2O + 2NO + 4H_2O$

$3Cu_2O + 2NO_3^- + 14H^+ \to 6Cu^{2+} + 2NO + 7H_2O$

(e) $\overset{+6}{MnO_4^{2-}} \longrightarrow \overset{+7}{MnO_4^-} + \overset{+2}{MnO_2}$

$4H^+ + \overset{+6}{MnO_4^{2-}} + 2e^- \to MnO_2 + 2H_2O$ ......(1)

$MnO_4^{2-} \longrightarrow MnO_4^- + e^-$ ......(2) × 2

$3MnO_4^{2-} + 4H^+ \to MnO_2 + 2MnO_4^- + 2H_2O$

(f) $Cu^{2+} + SO_2 \to Cu^+ + SO_4^{2-}$

$Cu^{2+} + e^- \to Cu^+ \times (2)$

$H_2O + SO_2 \to SO_4^{2-} + 2e^- + 4H^+$

$2Cu^{2+} + SO_2 + 2H_2O \to 2Cu^+ + SO_4^{2-} + 4H^+$

(g) $\overset{0}{Cl_2} + \overset{0}{I_2} \longrightarrow \overset{0}{IO_3^-} + Cl^-$

$2e^- + Cl_2 \to 2Cl^- \times (5)$

$3H_2O + I_2 \to 2IO_3^- + 10e^- + 6H^+$

$3H_2O + 5Cl_2 + I_2 \to 2IO_3^- + 10Cl^- + 6H^+$

(h) $Fe^{+2} \to Fe^{+3} + e^-$

$2H_2O + 6C^{+2} \to 6CO_2^{+4} + 6(2e^-) + 24H^+$

$8H_2O + 6N^{3-} \to \overset{+5}{6NO_3^-} + 6(8e^-) + 36H^+$

$5e^- + \overset{+7}{MnO_4^-} + 8H^+ \to Mn^{2+} + 4H_2O \times (6H^+)$

$Fe(CN)_6^{4-} + 30H^2O \to Fe^{3+} + 6CO_2$

$6NO_3^- + 60H^+ + 61e^- \times (5)$

$5Fe(CN)_6^{4-} + 61MnO_4^- + 188H^+ \to 5Fe^{+3}$

$+30CO_2 + 30NO_3^- + 61Mn^{2+} + 94H_2O$

(i) $Cu^{+1} \rightarrow Cu^{+2} + e^- \times (3)$

$P^{3-} + 4H_2O \rightarrow \overset{+5}{H_3PO_4} + 8e^- + 5H^+$

$Cu_3P + 4H_2O \rightarrow 3Cu^{2+} + H_3PO_4 + 5H^+ + 11e^-$

$\overset{+6}{Cr_2O_7^{2-}} + 3e^- + 14H^+ \rightarrow Cr^{+3} + 7H_2O$

$6Cu_3P + 124H^+ + 11Cr_2O_7^{2-} \rightarrow 18Cu^{2+}$
$+ 6H_3PO_4 + 22Cr^{+3} + 53H_2O$

Sol 3: (a) $2Cu^{2+} + 2I^- \rightarrow 2Cu + I_2$

(b) $\overset{+8/3}{Fe_3O_4} + 4H_2O \rightarrow \overset{+3}{Fe_2O_3} +$
$8OH^- + 2e^- \times (3)$

$3OH^- + \overset{+7}{MnO_4^-} + 3e^- \rightarrow$
$MnO_2 + 2H_2O \times (2)$

$3Fe_3O_4 + 12H_2O + 8OH^- + 2MnO_4^- \rightarrow$
$3Fe_2O_3 + 24OH^- + 4H_2O$

$6Fe_3O_4 + 2MnO_4^- + 8H_2O \rightarrow 9Fe_2O_3 + 16OH^- + 2MnO_3$

(c) $\overset{2}{C_2H_5OH} + OH^- \rightarrow \overset{-1}{C_2H_3O^-} + H2O\ Re^-$

$3e^- + \overset{+7}{MnO_4^-} + 4H2O \rightarrow \overset{+4}{MnO_2} + 8OH^-$

$3C_2H_5OH + 2MnO_4^- + OH- \rightarrow 3C_3H_3O^- + 2MnO_2 + 5H_2O$

(d) $Cr+^{3+}\ 8OH^- \rightarrow \overset{+6}{CrO_4^{2-}} + 4H_2O + 3e^-$

$3I^- + 8OH^- \rightarrow \overset{+7}{3IO_4} + 24e^- + 4H_2O$

$e^- + H_2O_2^{-1} + H_2O \rightarrow H_2O^{-2} + 2OH^-$

$2CrI_3 + 27H_2O_2 + 10OH^- \rightarrow$
$2CrO_4^{2-} + 6IO_4^- + 32H_2O$

(e) $258KOH + K4Fe(CN)_6 + 61Ce(NO_3)_4 \rightarrow 61Ce(OH)_3 + Fe(OH)_3 + 36H_2O + 6K_2CO_3 + 250KNO_3$

Sol 4: (a) $I^\ominus + H_2O_2 \rightarrow H_2O + I_2$
(acidic medium)

$(\overset{-1}{I^\ominus} \xrightarrow{1e^-} \overset{0}{I_2}) \times 2$

$\overset{+1\ -1}{H_2O_2} \xrightarrow{2\times1e} H_2O^{-2}$

$2I^\ominus + H_2O_2 \rightarrow H_2O + I_2 + 2H^+ + OH^\ominus$

$\therefore 2HI + H_2O_2 \rightarrow 2H_2O + I_2 + H^+$

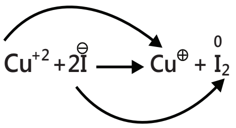
(b) $Cu^{+2} + I^\ominus \rightarrow Cu^+ + I_2$

$(Cu^{+2} \xrightarrow{1e^-} Cu^+) \times 2$

$(I^\ominus \xrightarrow{1e^-} I) \times 2$

$2Cu^{+2} + 2I^\ominus \rightarrow 2Cu^+ + I_2$

By the oxidation number method,



$\therefore$ To balance the electrons transferred,

$2Cu^{+2} + 2I^\ominus \rightarrow 2Cu^+ + I_2$

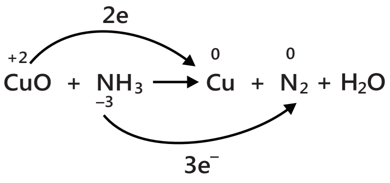
To balance charges on both sides,

$2Cu^{+2} + 2I^\ominus + 2H^+ \rightarrow 2Cu^+ + I_2 + H_2O$

$\therefore 2Cu^{+2} + 2HI \rightarrow 2Cu^+ + I_2 + H_2O$

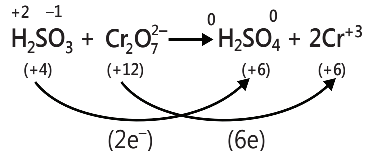
(c) $CuO + NH_3 \rightarrow Cu + N_2 + H_2O$

To balance the electrons transferred to balance oxygen



$3CuO + 2NH_3 \longrightarrow 3Cu + N_2 + 3H_2O$

(d)



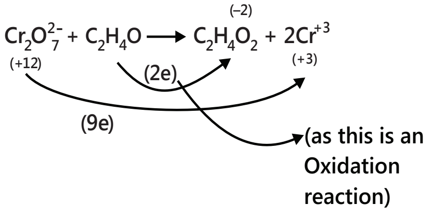
To balance the number of electrons transferred,

$9H_2SO_3 + Cr_2O_7^{2-} \rightarrow 9H_2SO_4 + 2Cr^{+3}$

To balance charges on both sides,

$3H_2SO_3 + Cr_2O_7^{2-} + 8H^+ \rightarrow 3H_2SO_4 + 2Cr^{+3} + 4H_2O$

We observe that the number of oxygen atoms are simultaneously balanced

(e) 

$\therefore\ Cr_2O_7^{2-} + C_2H_4O \rightarrow 9C_2H_4O_2 + 4Cr^{+3}$

To balance charges on both sides,

$\therefore\ 2Cr_2O_7^{2-} + 9C_2H_4O + 16H^+ \rightarrow 9C_2H_4O_2 + 4Cr^{+3} + 8H_2O$

(f) $3Cl^- + \overset{+3}{SbCl_3} \rightarrow \overset{+5}{SbCl_5} + 2e^- \times (2)$

$6e^- + \overset{+5}{KIO_3} + 6H^+ \rightarrow \overset{+1}{I} + 3H_2O + K^+$

$2SbCl_3 + KIO_3 + 8HCl \rightarrow 2SbCl_5 +$

$ICl + 4H_2O + KCl$

(g) $\overset{+5}{As_2}S_5^{-2}$

$As^{+5} \rightarrow \overset{+5}{H_3AsO_4}$ √ No redox charge

$5S^{2-} + 4H_2O \rightarrow 5\overset{+6}{H_2SO_4} + 40e^-$

$e^- + \overset{+5}{HNO_3} + H^+ \rightarrow \overset{+4}{NO_2} + H_2O$

$As_2S_5 + 2HNO_3 \rightarrow 5H_2SO_4 + 40NO_2 + 2H_3ASO_4 + 12H_2O$

Sol 5: Disproportionation is a specific type of redox reaction in which a species is simultaneously reduced and oxidized to form two different product.

Eg. $\underset{+6}{MnO_4^{2-}} \longrightarrow \underset{+7}{MnO_4^-} + \underset{+4}{MnO_2}$

Sol 6: Ion-electron method :-

(I) Divide the complete equations into two half reaction.

(II) Balance the atoms in each half reaction separately according to the following steps :-

(a) Balance all atoms other then O and H.

(b) For O and H.

1. Acidic Medium:

(i) Add H_2O to the side which is oxygen deficient.

(ii) Add H^+ to the side which is hydrogen deficient.

2. Basic Medium:

(i) Add OH^- to the side which has less -ve charge.

(ii) Add H_2O to the side which is oxygen deficient.

(iii) Add H^+ to the side which is hydrogen deficient.

3. Oxidation State Method: This method is based on the fact that the number of electrons gained during reduction must be equal to the number of e^-s lost during oxidation.

Sol 7: Definition of Redox Reaction: Reaction which involves change in oxidation state of their atom, generally involve the transfer of electron between species. So, the most essential conditions that must be satisfied is the exchange of electron change in oxidation state.

Sol 8: No, oxidation state term is just introduced to easily calculate the exchange of electron in redox reaction.

So, oxidation no. of an element in a particular compound represents the no. of e^-s lost or gained by an element during its change from free state into that compound or it represent the extent of oxidation or reduction of an element during its charge from free state into that compound.

Sol 9: Redox Couple: Oxidation half reaction and reduction half reaction contributes to redox couple

$$\begin{array}{ll} M \longrightarrow M^{+n} + ne^- & \text{Oxidation} \\ \underline{A + ne^- \longrightarrow A^{-n}} & \text{Reduction} \\ M + A \longrightarrow M^{+n} + A^{-n} & \end{array}$$

Sol 10: (1) Combination of half cells (a) and (b)

$$\underset{\text{Anode}}{Zn(s)/Zn^{2+}(aq)}\,||\,Cu(s)/\underset{\text{Cathode}}{Cu^{2+}}(aq)$$

E.M.F. of the cell, E

$= E_{right} - E_{left} = 0.34 - (-0.76)$

= 1.10 V

(2) Combination of half cells (b) and (d)

$$\underset{\text{Anode}}{Cu(s)/Cu^{2+}(aq)}\,||\,Ag(s)/\underset{\text{Cathode}}{Ag^{2+}}(aq)$$

E.M.F. of the cell, E

$= E_{right} - E_{left} = 0.80 - (+0.34)$

= 0.46 V

Sol 11: (a)

$$\underset{(aq.)}{MnO_4^-} + \underset{(aq.)}{C_2H_2O_4} \rightarrow Mn^{2+}_{(aq.)} + CO_{2(g)} + H_2O_{(\ell)}$$

Oxidant Reductant Reductant Oxidant

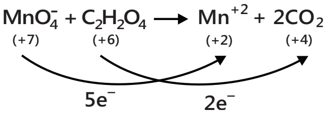
(i) Ion-electron method :-

$\overset{+7}{MnO_4^-} \longrightarrow Mn^{+7}$ —— $5e^-$) × 2

$\overset{+3}{C_2}\overset{+2}{H_2}\overset{-8}{O_4} \xrightarrow{2e^-} \overset{+4}{CO_2}$ —— $2e^-$) × 5

$2MnO_4^- + 5C_2H_2O_4 \rightarrow 2Mn^{+2} + 10CO_2$

(ii) Oxidation number method :-

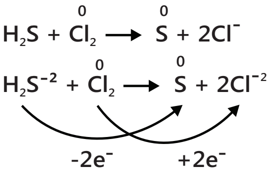


(b) $H_2\overset{-2}{S}_{(aq.)} + Cl_{2(aq)} \longrightarrow \overset{0}{S}_{(S)} + Cl^-_{(aq.)}$

Reductant Oxidant

$H_2S^{-2} \longrightarrow S + 2e^- + 2H^+$

$Cl_2 + 2e^- \longrightarrow 2Cl^-$



So, no need to multiply this equation with any co-efficients.

Sol 12 (a) $Fe^{3+} + e^- \rightarrow Fe^{2+}$

$2I^- - 2e^- \rightarrow I_2$

(b) $Zn \rightarrow Zn^{2+} + 2e^-$

$2H^+ + 2e^- \rightarrow H_2(g)$

(c) $Al^{3+} + 3e^- \rightarrow Al(s)$

$Ag^+ + e \rightarrow Ag(s)$

Sol 13: Oxidation: Increase in oxidation number

$2Cl^- \longrightarrow Cl_2$

Reduction: Decrease in oxidation number

$KMnO_4 \longrightarrow Mn^{2+}$

Sol 14: (a) Combination reaction: Reaction in which two or more elements on compounds combine together to form a single compound

$2Mg + O_2 \longrightarrow 2MgO$ + heat

(b) Decomposition reaction: Reaction is the separation of a chemical compound into elements or simpler compounds

$2H_2O_2 \longrightarrow 2H_2O + O_2$

(c) Displacement reaction:

Reaction in which on element or ion moves out of ore compound and into another

Eg. $Fe + CuSO_4 \longrightarrow Cu + FeSO_4$

Sol 15: Oxidation No.: No. of e^-s lost or gained by an element during its change from free state into compound or represent the extent of oxidation or reduction of an element during its change from free state into that compound.

Valence: Number of valence bonds a given atom has formed or can form with one or more than one with other atoms.

Sol 16: S in SO_2 has oxidation state +4. It lies between the minimum oxidation state (-2) and maximum oxidation state (+6) of S. Thus, S in SO_2 can show an increase in its ox. no. (i.e., act as reducant) or can show a decrease in its ox. no. (i.e. acts as oxidant). On the other hand in H_2S, S is in - 2 oxidation state and can only increase its oxidation state to act as reducant.

Sol 17: Half Reaction: This is either the oxidation or reduction reaction component of a redox reaction. This is obtained by considering the change in oxidation states of individual substances involved in the redox reaction

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

$Zn \longrightarrow Zn^{2+} + 2e^-$

oxidation half reaction

$e^- + CuSO_4 \longrightarrow Cu + SO_4^{2-}$

Reduction half reaction.

Sol 18: (i) Oxidation-Oxidation is the loss of electrons or an increase in oxidation state by a molecule, atom, or ion.

(ii) Reduction-Reduction is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion.

(iii) Oxidizing agent an oxidizing agent is a chemical species that removes an electron from another species.

(iv) Reducing agent-Reducing agent is an element or compound that loses an electron to another chemical species in a redox chemical reaction.

Exercise 2

Mole Concept

Single Correct Choice Type

Sol 1: (B) $A + O_2 \rightarrow$

$M_1V_1 = N_2V_2$

Equivalent of A = Equivalent of O_2

$$\frac{x}{\text{Equivalent weight of A}} = \left(\frac{16}{16}\right)\times 2$$

$$\frac{x}{2} = \text{equivalent weight of A}$$

Sol 2: (C) Mass O_2 in 88 gm

$$CO_2 = \frac{88\times 32}{44} = 64\text{gm}$$

$$\text{Mole of O} = \frac{64}{16} = 4 \text{ mole}$$

So, mass of CO is = 4 × (12 + 16) = 112 gm

Sol 3: (B) $Mg + \frac{1}{2}O_2 \rightarrow MgO$

0.25 mole

$\downarrow$

0.5 mole

Mass of MgO = 0. 5 × (24 + 16) = 20 gm

Sol 4: (B) Let's diabasic acid is $C_xH_yO_z$

$$\text{Weight of C} = \frac{x(12)}{M}$$

$$\text{Weight} = H = \frac{y}{M}$$

$$\text{Weight of O} = \frac{z(16)}{M}$$

$x(12) = 8 \times y \Rightarrow 3x = 2y$

$x(12) = \frac{1}{2} \times 16(z) \Rightarrow 3x = 2z$

$y = z = \frac{3}{2}x$

$\Rightarrow$ Empirical formula $C_2H_3O_3$

$$Ag_2(C_xH_yO_z) \xrightarrow{\Delta} 2Ag$$

$$\frac{0.5934}{108}$$

$$\text{Mole of salt} = \frac{0.5934}{2\times 108} = \frac{1}{[216+(24+3+48)x]}$$

216 + 75x = 364

x ~ z

So the formula would be = $C_4H_6O_6$

Sol 5: (B) $12C(s) + 11H_2(g) + \frac{11}{2}O_2(g) \rightarrow C_{12}H_{22}O_{11}(s)$

$\frac{84}{12}$	$\frac{12}{1}$	$\frac{56}{22.4}$
7	12	2. 5

Here O_2 is limiting reagent

$$\text{Moles of } C_{12}H_{22}O_{11} \text{ formed} = \frac{2.5}{11}\times 2 = \frac{5}{11} \text{ mole}$$

$$\text{Mass} = \frac{5}{11}\times[(12\times 12)+22+(11\times 16)] = 155.45 \text{ gm}$$

Sol 6: (B) $M(CO_3) \rightarrow CO_2 + MO$

or

$M_2(CO_3) \rightarrow CO_2 + M_2O$

Mass of CO_3 = 12 + 48 = 60

$$\text{Mole of } CO_2 = \frac{12.315}{(PV)}(RT) = \frac{12.315}{1\times(12.315)} \times 0.0821 \times$$

300 = 0.5 mole

Mole of $M(CO_3)$ or M_2CO_3 = 0.5 mole

So, mass of CO_3 in carbonate = 0.5 × 60 = 30 gram

Checking all options one by one

(B) is correct.

Sol 7: (D) Empirical formula would be NH_2 because ratio of N and H is given 1 : 2. By stability we see N_2H_4 is correct answer.

Sol 8: (C) $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

5V 10V 5V ↓

10V

By oxygen atom balance $H_2O = 10V$

By hydrogen atom balance $y(5) = 2(10) \quad \therefore\ y = 4$

By carbon balance $= x(5) = 5$

the molecule is CH_4

Sol 9: (A) Molecular weight of $NO_2 = 32 + 14 = 46$

Molecular weight of $NO = 16 + 14 = 30$

let's $x = NO \quad 1 - x = NO_2$

$34 = x(30) + (1 - x)\,46$

$16x = 12$

$x = \frac{3}{4}$ so NO_2 % = 25%

Sol 10: (A) $5A_2 + 2B_4 \rightarrow 2AB_2 + 4A_2B$

4 mole

Molecular mass of $AB_2 = 250$

Molecular mass of $A_2B = 140$

$B_4 = 480$

$A_2 = 20$

Moles of AB_2 to be produced $= \frac{1000}{250} = 4$ mole

Moles of A_2B to be produced $= \frac{1000}{140} = 7.14$ mole

So, mass of A_2, B_4 would to according to AB_2

So, mass of A_2 required $= \frac{5}{2} \times 4 \times 20 = 10 \times 20 = 200$ gm

Mass of B_4 required = 4 × 480 = 2 × 960 gm = 1920 gm

Total mass = 1920 + 200 = 2120 gm

Sol 11: (C) $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$

132 gm 54 gm

⇓ ⇓

3 mole 3 mole

y = 6 mole

x = 3 mole

Sol 12: (A) $Zn + \frac{1}{2}O_2 \rightarrow ZnO$

x gm

$$\frac{1}{2} \times \frac{x}{65} = \frac{v}{22.4}$$

$$v = \frac{x}{65} \times 11.2 = \frac{2x}{65} \times 5.6 \text{ lit.}$$

Sol 13: (B) Let's say 100 gm of clay is given initially

12 gm water

x gm silica

y gm other

After that (100 – A)gm of clay

$(12 - A)$ gm water $\left(\frac{100 - A}{2}\right)$ silica

$$(12 - A) = \frac{(100 - A) \times 7}{100}$$

$1200 - 100A = 700 - 7A$

$93A = 500$

$$A = \frac{500}{93}$$

By conservation of silica

$$\frac{100 - \frac{500}{93}}{2} = x$$

x = 47. 31

Sol 14: (C) $C_2H_4O_2 + 2O_2 \rightarrow 2CO_2 + 2H_2O$

x gm 620–x gm

11 11

$\frac{x}{60}$ mole $\frac{620 - x}{32}$

To produce maximum energy $C_2H_4O_2$ and O_2 will be fully consumed.

$$x\frac{x}{60} = \frac{620 - x}{32} \times \frac{1}{2}$$

$64x = 37200 - 60x$

x = 300 gm

Weight of $CO_2 = 2 \times \frac{300 \times 44}{60} = 440$ gm

Sol 15: (A) (Organic compound) + $H_2O \rightarrow N_2$

0.42 gm

Moles of N_2 = $\frac{PV}{RT} = \frac{860}{760} \times \frac{100}{11} \times \frac{10^{-3}}{0.08 \times 250}$

$$= \frac{86}{167200} = 5.143 \times 10^{-4}$$

Mass of N_2 = $5.143 \times 10^{-4} \times 28$ = 0.0144 gm

Fraction = $\frac{0.0144}{0.42} = 0.034 = \frac{10}{3}\%$

Sol 16: (C) Moles of H^+ = (0. 1) (0. 3) + (0. 2) (0. 3) × 2 = 0. 15 mole

Normality = $\frac{0.15}{500} \times 1000 = 0.3N$

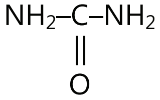
Sol 17: (D) Moles of NaOH = (0. 300) (0. 5) = 0. 15 moles

For molarity = 0. 2 M = $\frac{0.15}{V}$

V = 750 mL

Volume to be added = 750 – 300 = 450 mL

Sol 18: (A) Moles of water = $\frac{250}{18} = 13.888$ mole

urea = 

$$NH_2-\underset{\underset{O}{\|}}{C}-NH_2$$

Moles urea = $\frac{3}{60}$ = 0. 05 mole

Mole fraction = 0.0036

Sol 19: (B) $P4S_3 + 8O_2 \rightarrow P_4O_{10} + 3SO_2$

Moles of O_2 = $\frac{384}{32} = 12$mole

Moles of P_4S_3 = $\frac{440}{124+96} = 2$ mole

L. R. = O_2

So mass of P_4O_{10} produced

$= \frac{12}{8} \times [124+160]$ = 426 gm

Sol 20: (C) $PCl_5 \rightarrow PCl_3 + Cl_2$

Initially 1 mole

After $\frac{1}{2}$mole $\frac{1}{2}$mole $\frac{1}{2}$mole

Initially $M_{avg.}$ = M_{PCl_5} = 31 + 5(35. 5) = 208. 5

After $M_{avg.}$ = $\frac{M}{3/2} = \frac{208.5}{3} \times 2 = 208.5 \times \frac{2}{3}$

So change in $M_{avg.}$ = 33. 33%

Sol 21: (A) $3Mg + 2NH_3 \rightarrow Mg_3N_2 + 3H_2$

2 mole 2 mole

L. R. = Mg

Mass of Mg_3N_2 produced = $\frac{2}{3} \times (72+28)$ = $\frac{200}{3}$gm

Sol 22: (C) Let's say solution is in 100 gm.

HCl mole = 1 mole

Molality = $\frac{\text{moles of solute}}{\text{mass of solvent (in kg)}}$

Molality = $\frac{1}{(100-36.5)}$ × 1000 = 15. 75

Sol 23: (B) Weight of $Na_2CO_3.xH_2O$ in 10 mL solution

$= \frac{0.025}{5} = 0.07$

$$2 \times \frac{0.07}{46+12+48+x(18)} = \frac{9.9}{10} \times 10^{-3}$$

$$\frac{0.14}{106+18x} = 0.99 \times 10^{-3}$$

0.07 = [104.94 + 17.82 x] × 10^{-3}

35.06 = 17.82 x

x ~ 2

Sol 24: (C) Washing soda (Na_2CO_3) in 25 cc = 0. 12 gm

$$2 \times \frac{0.12}{106+18x} = 1.7 \times 10^{-3}$$

240 = 180. 2 + 30. 6 x

x ~ 2

Percentage of carbonate = $\frac{106}{106+36}$ ~ 76%

Sol 25: (B) No. of carbon atoms

$= \frac{1.2 \times 10^{-3}}{12} \times 6.023 \times 10^{23}$ = 6. 02 × 10^{19}

Sol 26: (C) 21.31 = (0. 79) (24) + (0. 21 – x) (25) + (x) (26)

24. 31 = 18. 96 + 5. 25 + x

x = 0. 1 = 10%

Sol 27: (D) Using HPh

$$Na_2CO_3 \xrightarrow{HCl} NaHCO_3^- + H^+$$

$$NaOH \xrightarrow{HCl} NaCl + H^+$$

Using

MeOH

$Na_2CO_3 \xrightarrow{HCl} H_2CO_3$ + NaCl

$NaOH \xrightarrow{HCl}$ NaCl + H^+

Moles of HCl used in HPh = 4m mole

Moles of HCl used in MeOH = 4. 5 m mole

It means that for $NaHCO_3 \rightarrow H_2CO_3$ required mole of HCl 0. 5 m mole

Moles of Na_2CO_3 = 0. 5 m mole

= 0. 5 × 10^{-3} × 106 gm/250 mL

= 5. 3 mg/25 mL

= 2. 12 g/L

NaOH moles = 3. 5 m mole

Mass of NaOH = 40 × 3. 5

= 140 mg/25 mL

= 5. 6 g/L

None of these

Sol 28: (A) Moles of HCl = 0. 25 × 30 m mole = 7. 5 m mole

$$\frac{7.5}{2} = 10^{-3} = \frac{x(0.5)}{138} + \frac{(1-x)0.5}{74}$$

7. 5 × 10^{-3}

Solving this x ~ 96%

K_2CO_3 ~ 96%

Li_2CO_3 ~ 4%

Sol 29: (C) $KMnO_4 + 5FeSO_4 \rightarrow Mn^{2+} + Fe^{3+}$

$\frac{2.0}{152}$ moles of $KMnO_4$

$= \frac{2.0}{5 \times 152}$ = 2.631 × 10^{-3}

Volume × molarity = moles

Volume = $\frac{2.631 \times 10^{-3}}{0.05}$ = 52. 63 mL

Redox Reactions

Single Correct Choice Type

Sol 1: (A) Equivalent weight = Molecular weight × n_{factor}

$= (M_0)_{FeSO_4} \times 1$

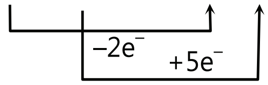
$Fe^{+2} \rightarrow Fe^{+3}$

Sol 2: (D) Equivalent weight = Molecular weight × n_{factor}

$= (M)_{K_2Cr_2O_7} \times 6$

$Cr_2O_7 \rightarrow Cr^{+3}$

Sol 3: (A) $H_2S + KMnO_4 \rightarrow S + Mn^{2+}$



$$\frac{m}{34} \times 2 = \frac{1.58}{158} \times 5 = 0.85$$

Sol 4: (C) $\overset{+5}{HNO_3} + \overset{0}{I_2} \rightarrow \overset{+5}{I_2O_5} + \overset{+4}{NO_2}$

$$\frac{m}{63} \times 1 = \frac{127}{127 \times 2} \times 10 = 315$$

Sol 5: (C) N_1V_1 = N_2V_2

Oxalic acid $KMnO_4$

10 × 10^{-3} × N = 20 × 10^{-3} × 0.02 × (5)

n-factor =0.2N

Sol 6: (C) $\frac{m}{34} \times 2$ = 10 × 10^{-3} × 1; m = 0. 17

$\therefore$ Purity = $\frac{0.17}{0.2} \times 100 = 85\%$

Sol 7: (B) $KMnO_4 + FeC_2O_4 \rightarrow Mn^{2+} + Fe^{3+} + CO_2$

$$n_{KMnO_4} \times 5 = 1 \times (1+2) = \frac{3}{5}$$

Sol 8: (C) $M_2x_2 + xH_2 \rightarrow 2M + xH_2O$

1 mole M_2x_2 gives 2 moles M

$\therefore \frac{3.15g}{(MW)} \rightarrow \frac{1.05}{M}$

$\therefore$ 6M = 2M + x(16)

$\therefore$ 4M = x(16)

$\therefore$ M = 4x

Now, $(EW)_M = \frac{(MW)_M}{x} = \frac{M}{X}$

$\therefore (EW)_M = \frac{M}{X} = 4.$

Sol 9: (B) Oxidation means increase of oxidation number

$\therefore$ So, there is loss of electrons.

Sol 10: (C) $K_2Cr_2O_7$

$2K^+ \quad 2Cr^{x+} \quad 7O^{2-}$

+ 2 + 2x – 14 = 0

x = +6

Sol 11: (D) $K_2\overset{+6}{Cr_2}O_7 \rightarrow K_2\overset{+3}{Cr_2}O_7$

+6 → +3

$\therefore$ Change in oxidation No. = [3].

Sol 12: (C) P + NaOH → $\overset{-3}{P}H_3 + NaH_2\overset{+1}{P}O_2$

P is getting oxidised and also reduced

$\therefore$ It is oxidation and reduction

(D is proportionation)

Sol 13: (C) CH_2O

$C^{x+} \quad 2H^+ \quad O^{2-}$

x + 2 – 2 = 0

x = 0

Sol 14: (B) $CH_4 \rightarrow \quad C^{x+} + 4H^+ \quad x = -4$

$CH_3Cl \quad C^{x+} + 3H^+ + Cl^- \quad x = -2$

$CH_2Cl_2 \quad x + 2 - 2 = 0 \quad x = 0$

$CHCl_3 \quad x + 1 - 3 = 0 \quad x = 2$

$CCl_4 \quad x - 4 = 0 \quad x = +4$

Sol 15: (C) Redox: Exchange of electrons

$\therefore$ Change in oxidation state.

(c) $Ba^{2+}\ O_2^{2-} + H_2\overset{+6}{S}O_4 \rightarrow Ba^{2+}\ \overset{+6}{S}O_4^{2-} + H_2\overset{-1}{O_2}$

No change in oxidation

Sol 16: (D) (a) +4 – 6 + x = 0; x = +2

(b) + 2 + x – 8 = 0; x = +6

(c) +2x – 2 = 0; x = +1

(d) x + 5(0) = 0; x = 0

Sol 17 (C) (a) $H\overset{+1}{Cl}O^{-2}$ + 1 + x – 2 = 0; x = +1

(b) $HClO_2$ + 1 + x – 4 = 0; x = +3

(c) $HClO_3$ + 1 + x – 6 = 0; x = 5

(d) $HClO_4$ + 1 + x – 8 = 0; x = +7

Sol 18: (D) $M^{3+} \rightarrow M^{6+} + 3e^-$

Sol 19: (A) $\overset{+x}{Mn}O_4^-$ + x – 8 = –1; x = +7

Sol 20: (A) The oxidation number of carbon in $CHCl_3$ is +4

Sol 21: (C) $Pb^{2+} \rightarrow Pb^{4+} + 2e^-$

Sol 22: (A) $C_{12}\ H_{22}\ O_{11}$

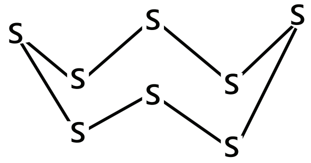
12x + 22 + 11(–2) = 0; x = 0

Sol 23: (D) SO_4^{2-}

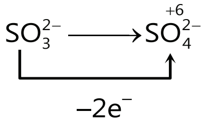
$S^{x+} + 4O^{2-}$

x – 8 = –2; x = +6

Sol 24: (B)



Sol 25: (C)



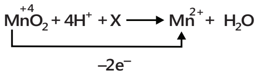
$SO_3^{2-} \longrightarrow \overset{+6}{S}O_4^{2-}$

–2e⁻

Sol 26: (A) $S_2O_7^{2-}$ +2x – 14 = –2

2x = +12; x = +6

Sol 27: (A)



$\overset{+4}{Mn}O_2 + 4H^+ + X \longrightarrow Mn^{2+} + H_2O$

–2e⁻

S_8

8x = 0; x= 0

Covalency = 2

Sol 28: (D) N_3H

3x + 1 = 0; x = $x = -\frac{1}{3}$

Sol 29: (C) $K_3\,[Fe(CN)_6]$

$+3-(x-6)=0;\ \ x=+3$

Sol 30: (D) MH_2

$+x+2=0;\ \ x=-2$

Sol 31: (C) $\overset{-3}{P}H_3$ to $H_3\overset{+5}{P}O_4$

Sol 32: (C) In chlorine atom had +5 oxidation state.

$HClO_3$ $+1+x-6=0;\ \ x=5$

Previous Years' Questions

Mole Concept

Sol 1: (A) If we consider that $\frac{1}{6}$, in place of $\frac{1}{12}$, mass of carbon atom is taken to be the relative atomic mass unit, the mass of one mole of a substance will decrease twice.

Sol 2: (C) According to definition of molar solution is one that contains one mole of a solute in one litre of the solution.

Sol 3: (D) $2Al_{(s)}+6HCl_{(s)}\longrightarrow$

$$2Al^{3+}_{(aq)}+6Cl^{-}_{(aq)}+3H_{2(g)}$$

For each mole of HCl reacted, 0.5 mole of is formed at STP.

1 mole of an ideal gas occupies 22.4 lit at STP.

Volume of H_2 gas formed at STP per mole of HCl reacted is 22.4 × 0.5 litre.

Sol 4: (B) From molecular formula of magnesium phosphate, it is evident that each mole of $Mg(PO_4)_2$ contains 8 mole of oxygen atoms.

Therefore, 0.25 mole of oxygen atom will remain present in $\frac{0.25}{8}$ mole i.e. 3.125×10^{-2} mole of $Mg(PO_4)_2$.

Sol 5: (A) 200 mg of $CO_2=200\times10^{-3}=0.2$ g

44g of $CO_2=6\times10^{23}$ molecules (approx.)

$$0.2\,g \text{ of } CO_2=\frac{6\times10^{23}}{44}\times0.2$$

$$=0.0272\times10^{23}\ =2.72\times10^{21} \text{ molecule}$$

Now, 10^{21} molecule are removed.

So remaining molecules $=2.72\times10^{21}-10^{21}$

$$=10^{21}(2.72-1)=1.72\times10^{21} \text{ molecule}$$

Now, 6.023×10^{23} molecules = 1 mol

$$1.72\times10^{21} \text{ molecules}=\frac{1\times1.72\times10^{21}}{6.023\times10^{23}}$$

$$=0.285\times10^{-2}=2.85\times10^{-3}$$

Sol 6: (C) $\underbrace{\underset{+12/\text{two atom}}{K_2Cr_2O_7}+4H_2SO_4\rightarrow K_2SO_4+\underset{+6/\text{two atom}}{Cr_2(SO_4)_3}}_{\text{Change by 6}}$

$$\text{Eq. wt.}=\frac{\text{Mol. wt.}}{6}$$

Sol 7: (A) $M_f=\frac{M_1V_1+M_2V_2}{V_1+V_2}$

$$=\frac{0.5\times\frac{3}{4}+2\times\frac{1}{4}}{1}=0.875\text{ M}$$

Sol 8: (D) 18 g H_2O contains 2 g H

$\therefore$0.72 g H_2O contains 0.08 g H.

44 g CO_2 contains 12 g C

$\therefore$ 3.08 g CO_2 contains 0.84 g C

$\therefore\ \ C:H=\frac{0.84}{12}:\frac{0.08}{1}=0.07:0.08\ =7:8$

$\therefore$ Empirical formula = C_7H_8

Sol 9: (B) $M_{0.98}O$

Consider one mole of the oxide.

Moles of M = 0.98, Moles of $O^{2-}=1$

Let moles of $M^{3+}=x$

$\Rightarrow$ Mole of $M^{2+}=0.98-X$

$\Rightarrow$ Doing charge balance

$(0.98-x)\times2+3x-2=0$

$\Rightarrow 1.96-2x+3x-2=0$

$\Rightarrow x=0.04$

$$\Rightarrow \%\text{ of }M^{3+}=\frac{0.04}{0.98}\times100=4.08\%$$

Sol 10: (B) Let the mass of O_2 = x

Mass of N_2 = 4x

Number of moles of $O_2 = \frac{x}{32}$

Number of moles of $N_2 = \frac{4x}{28} = \frac{x}{7}$

$\therefore$ Ratio $= \frac{x}{32} : \frac{x}{7} = 7 : 32$

Sol 11: (D) 1 g of $C_8H_7SO_3Na = \frac{1}{206}$ mole

$$\underset{\frac{1}{206}\text{ mole}}{2C_8H_7SO_3Na} + \underset{\frac{1}{412}\text{ mole}}{Ca^{2+}} \rightarrow (C_8H_7SO_3)_2Ca + 2Na^+$$

Sol 12: (A) $C_xH_y(g) + \left(x + \frac{y}{4}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(\ell)$

15 mL

Volume of O_2 used $= \frac{20}{100} \times 375 = 75$ ml.

Volume of air remaining = 300 mL

Total volume of gas left after combustion = 330 mL

Volume of CO_2 gases after combustion = 330 – 300 = 30 mL.

$$\underset{15\text{ ml}}{C_xH_y(g)} + \underset{75\text{ ml}}{\left(x + \frac{y}{4}\right)}O_2(g) \rightarrow \underset{30\text{ ml}}{xCO_2(g)} + \frac{y}{2}H_2O(\ell)$$

$$\frac{x}{1} = \frac{30}{15} \Rightarrow x = 2$$

$$\frac{x + \frac{y}{4}}{1} = \frac{75}{15} \Rightarrow x + \frac{y}{4} = 5$$

$\Rightarrow y = 12$

$\Rightarrow C_2H_{12}$

Redox Reactions

Sol 13: (C) Prevent action of water and salt.

Sol 14: (A) $2H\overset{-1}{I} + H_2\overset{+6}{S}O_4 \longrightarrow \overset{0}{I_2} + \overset{+4}{S}O_2 + 2H_2O$

Sol 15: (C) CH_2O

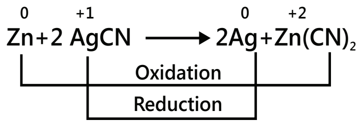
x + 2 – 2 = 0; x = 0

Sol 16: (D) $K_2Cr_2O_7 + 6KI + 7H_2SO_4 \longrightarrow$

$$4K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3I_2$$

$$\overset{+3}{C}r_2(SO_4)_3 \longrightarrow 2\overset{+3}{C}r + 3SO_4^{-2}$$

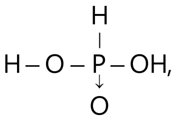
Sol 17: (C) Number of e^- transferred in each case is 1, 3, 4, 5.

Sol 18: (D) 

$$\overset{0}{Zn} + 2\overset{+1}{Ag}CN \longrightarrow 2\overset{0}{Ag} + \overset{+2}{Zn}(CN)_2$$

Sol 19: (A) $6MnO_4^- + I^- + 6OH^- \longrightarrow$

$6MnO_4^{2-} + IO_3^- + 2H_2O$

Sol 20: (A)  $H-O-\underset{\downarrow \atop O}{\overset{H \atop |}{P}}-OH$, hence it is dibasic. It acts as a reducing agent also.

Sol 21: (C)

$$\underset{\substack{vf = 1(7-2) \\ = 5}}{MnO_4^-} + \underset{\substack{vf = 2(3-2) \\ = 2}}{C_2O_4^{2-}} + H^+ \rightarrow Mn^2 + CO_2 + H_2O$$

$\therefore$ Balanced Equation:

$2MnO_4^- + 5C_2O_4^{2-} + 16\,H^+ \rightarrow 2Mn^2 + 10\,CO_2 + 8H_2O$

So, x = 2, y = 5 & z = 16.

Sol 22: (D) The reducing agent oxidises itself:

(A) $H_2O_2^{-1} + 2H^+ + 2e^- \rightarrow 2H_2O^{-2}$

(B) $H_2O_2^{-1} - 2e^- \rightarrow O_2^0 + 2H^+$

(C) $H_2O_2^{-1} + 2e^- \rightarrow 2\overset{-2}{O}H^-$

(D) $H_2O_2^{-1} + 2OH^- - 2e^- \rightarrow O_2^0 + H_2O$

Note: Powers of 'O' are oxidation number of 'O' in the compound.

Sol 23: (B)

The complex $\left[CoCl\left(NH_3\right)_5\right]^+$ decomposes under acidic medium, so $\left[CoCl\left(NH_3\right)_5\right]^+ + 5H^+ \rightarrow Co^{2+} + 5NH_4^+ + Cl^-$

Sol 24: (A) H_2O_2 can undergo reduction as well as oxidation because oxidation number of oxygen in H_2O_2 is -1. So, it can act both as reducing agent and oxidising agent.

JEE Advanced/Boards

Exercise 1

Mole Concept

Sol 1: $4HCl + MnO_2 \rightarrow MnCl_2 + 2H_2O + Cl_2$

69.6 gm

69.6 gm of $MnO_2 = \dfrac{69.6}{87}$mole

Mole of HCl = $\dfrac{69.6}{87}\times 4$ mole

Weight of HCl = $\dfrac{69.6}{87}\times 4\times 35.5 = 116$ gm

Sol 2: $3TiO_{2(s)} \quad + \quad 4C_{(s)} \quad + \quad 6Cl_{2(g)}$

4.32 gm 5.76 gm 6.82 gm

0.054 mole 0.48 mole 0.0960 mole

$\rightarrow 3TiCl_{4(g)} + 2CO_{2(g)} + 2CO_{(g)}$

L. R. = Cl_2

So $TiCl_4$ mole produced

$= \dfrac{1}{2}\times 0.0960$ = 0. 048 mole

Weight of $TiCl_4$ produced = 0.048 × 190 = 9.12 gm

Sol 3: $2SO_{2(g)} + O_{2(g)} + 2H_2O(\ell) \rightarrow 2H_2SO_4$

5.6 moles 4.8 moles

L. R. = SO_2

So H_2SO_4 mole obtained in maximum = 5.6 mole

Sol 4: Na_2CO_3 = x gram

Pure Na_2CO_3 = (0.95)x gm

$Na_2CO_3 + 2HCl(acid) \rightarrow H_2CO_3 + 2NaCl$

Mole of acid = (45.6 mL) × (0.235) = 10.716 m mole

Moles of Na_2CO_3 required = 5.358 m mole

Weight of Na_2CO_3 required = (0.95)x 5.358 (106) × 10^{-3}

x = 0.597 gm

Sol 5: $BaCl_2$ = 12%

Molecular weight of $BaCl_2.2H_2O$ = 208 + 36 = 244

$BaCl_2$ = 6 gm

$BaCl_2.\ 2H_2O = 6\times\dfrac{244}{208}$ = 7.038 gm

H_2O = 42.962 gm.

Sol 6: NaOH mole = 50(0.2) = 10 mole

HCl mole = 5 mole

$FeCl_3$ mole = 1.5 mole (acidic)

$NaOH + HCl \rightarrow NaCl + H_2O$

After this reaction NaOH left = 5 mole

$FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$

1. 5

After this reaction NaOH left = 5 – (1. 5)3 = 0. 5 mole

Volume after reaction = 15 + 5 + 50 = 70 litre

Normality = $\dfrac{0.5}{70} = 7.142\times 10^{-3}N$

$2Fe(OH)_3 \rightarrow Fe_2O_3 + 3H_2O$

Weight of Fe_2O_3 = $\dfrac{1.5}{2}\times 160$ = 120 gm

Sol 7: Oleum = $H_2S_2O_7 = H_2SO_4 + SO_3$

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

Mole of NaOH = (26.7)x (0.4) m mole = 10.68 m mole

Mole of H_2SO_4 = 5.34 m mole

Weight of H_2SO_4 = 0.523 gm

$H_2S_2O_7 = H_2SO_4 + SO_3$

x gram (0.5 – x) gm

$SO_3 + H_2O \rightarrow H_2SO_4$

$= \dfrac{(0.5-x)}{80}\times 98$ gm

Total H_2SO_4 = x + $\dfrac{(0.5-x)98}{80}\times 0.523$

x = $\dfrac{0.0895}{0.225}$ ~ 0.3977 gm

% $SO_3 = \dfrac{0.5-0.3977}{0.5}$ ~ 20.4%

Sol 8: HPh: $NaOH + HCl \rightarrow NaCl + H_2O$ ...(1)

$Na_2CO_3 + HCl \rightarrow NaHCO_3 + NaCl$ ...(2)

after MeOH:

$NaHCO_3 + HCl \rightarrow H_2CO_3 + NaCl$ ...(3)

Mole of HCl (when HPh) = 1.75 m mole

Mole of HCl (when MeOH) = 0.25 m mole (extra added)

Amount of $NaHCO_3$ = 0.25 m mole

Amount of HCl required in (2) and (3)

= $(0.25)_2$ = 0.5 m mole

Amount of Na_2CO_3 = 0.25 m mole

Amount of NaOH = 1.75 – (0.25) = 1.5 m mole

NaOH (in gram) = $1.5 \times 10^{-3} \times 40$ = 0.06 gm per 200 mL

Na_2CO_3 (in gram) = $0.25 \times 10^{-3} \times 106$

= 0.0265 gm/200 mL

Sol 9: $2KO_{2(s)} + H_2O_{(\ell)} \rightarrow 2KOH_{(S)} + \frac{3}{2}O_{2(g)}$

0. 158 mole 0. 1 mole

L. R = KO_2

Moles of O_2 formed = $\frac{3}{4} \times 0.158 = 0.1185$

Sol 10: $CaCl_2 + H_2CO_3 \rightarrow CaCO_3 + 2HCl$

$\underset{0.959\ gm}{CaCO_3} \rightarrow CaO + CO_2$

Moles of CaO = 0.017125 mole

Moles of $CaCl_2$ = 0.017125 mole

Mass of $CaCl_2$ = (0.017125) × 111

= 1.9 gm

% of $CaCl_2$ = $\dfrac{1.9}{4.22} = 45\%$

Sol 11: $\underset{100\ gm}{C_6H_{12}O} \xrightarrow{\text{Conc. } H_2SO_4} C_6H_{10}$

Moles of cyclohexanol = $\dfrac{100}{100}$ = 1 mole

Mole of cyclohexene = 0. 75 mole

Mass of cyclohexene = (0. 75) × 89 = 66. 75 gm

Sol 12: $2NaCl \rightarrow Na_2SO_4$ (By Na = atom balance)

Pure NaCl mole = $\dfrac{(0.95)250}{23+35.5}$ = 4.059 mole

Pure Na_2SO_4 = $\dfrac{4.059}{2} \times (46+96)$ = 288. 24 gm

Na_2SO_4 (90% pure) = $\dfrac{288.24 \times 100}{90}$ = 320.27 gm

Sol 13: $\underset{(0.466-x)gm}{AgCl} \longrightarrow$ unreacted

$\underset{x\ gm}{AgBr} \rightarrow AgCl$

AgCl formed = $\dfrac{x}{188}$ × (1435) gm = 0.763 x

Total weight after reaction = 0.4066 – x + 0.763 x

Weight lost = (1 – 0.763)x = 0.0725

x = 0.306 gm = 30.6%

Weight of Cl in initial mixture

= (0.4066 – 0.306) × $\dfrac{35.5}{143.5}$ = 0.0248 gm

% of Cl = $\dfrac{0.0248}{0.4066} = 6.1\%$

Sol 14: $\underset{0.\ 5\ gm}{CaCO_3} + H_2SO_4 \rightarrow CaSO_4 + H_2CO_3$

Moles of $CaCO_3$ = moles of H_2SO_4

required = $\dfrac{0.5}{63.5+60}$ = 4.048×10^{-3} mole

m litre of 0.5M H_2SO_4 required $\dfrac{4.048}{0.5}$ = mL = 8. 096 mL

Sol 15: $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

Moles of NaOH = $15 \times \frac{1}{10} = 1.5$ m mole

Moles of H_2SO_4 required = $\dfrac{1.5}{2}$ = 0.75 m mole

In 12 mL, mole of H_2SO_4 = 0.75 m mole

In 1 L, mole of H_2SO_4 = $\dfrac{0.75}{12}$mole

In 1 L, weight of H_2SO_4 required

= $\dfrac{0.75}{12} \times 98$ gram = 6.125 gm/L

Sol 16: Ethane (C_2H_6) $\xrightarrow{\text{monobromination}}$

$\xrightarrow[\text{reaction}]{\text{wurtz}}$ n-butane (C_4H_{10})

$2\,C_2H_6 \rightarrow C_4H_{10}$ (by carbon balance)

XV

Let's say volume of ethane = x *l*

Weight of C_4H_{10} = $\frac{x}{2\times 22.4}\times\frac{90}{100}\times\frac{85}{100}\times 58 = 55.53\ l$

x = 55. 53 *l*

Sol 17: Mole of HCl = 30 × 0.25 m mole = 7.5 m mole

let's say x fraction is K_2CO_3 so

$$\frac{7.5}{2}\times 10^{-3} = \frac{x(0.5)}{138}+\frac{(1-x)(0.5)}{74}$$

x ~ 96%

Sol 18: Mass of solution of HCl

= 100 × 1.18 gm = 118 gm

Mass of HCl in solution = (0.36) (118) = 42. 48 gm

n_{HCl} = mole of HCl = $\frac{42.48}{365}$ = 1.163 mole

$$2KMnO_4 + \underset{1.163\text{ mole}}{16HCl} \rightarrow 2KCl + 2MnCl_2 + 8H_2O + \underset{0.363\text{ mole}}{5Cl_2}$$

$$\underset{0.363\text{ mole}}{6Cl_2} + 6Ca(OH)_2 \rightarrow \underset{0.0606\text{ mole}}{Ca(ClO_3)_2} + 5CaCl_2 + 6H_2O$$

$$\underset{0.0606\text{ mole}}{Ca(ClO_3)_2} + Na_2SO_4 \rightarrow CaSO_4 + \underset{0.1212\text{ mole}}{2NaClO_3}$$

Mass prepared of $NaClO_3$

= 0.1212 x molecular weight = 12.911 gm

Sol 19: $NaH_2PO_4 \xrightarrow[NH_4^+]{Mg^{2+}} Mg(NH_4)PO_4 \cdot 6H_2O$

$\xrightarrow{\Delta} \frac{1}{2} Mg_2P_2O_7$ (by P-balance)

Mole of $Mg_2P_2O_7$ = $\frac{1.054}{224}$ = 4.747×10^{-3}

Weight of NaH_2PO_4 = $2 \times 4.747 \times 10^{-3} \times 119.98$

(Molecular weight) = 1.139 gm

Sol 20: Moles of HNO_3 = 8 × 5 m mole = 40 m mole

Mole of HCl = 4. 8 × 5 m mole = 24 m mole

Let's say volume of H_2SO_4 is V mL

So mole of H_2SO_4 = 17 V m mole

Moles of HNO_3 in 30 mL (picked up from 2 *l* sol)

= $\frac{40}{2000}\times 30 = \frac{120}{200}$ m mole

Moles of HCl in 30 mL (picked up from 2 *l* sol)

= $\frac{24}{2000}\times 30 = \frac{72}{200}$ m mole

Moles of H_2SO_4 is 30 mL (picked up from 2 lt. sol)

= $\frac{17V}{2000}\times 30 = \frac{51V}{200}$ m mole

Total moles of H^+ from 30 mL solution = $\frac{120}{200}+\frac{72}{200}+\frac{102V}{200}$

= $\left(\frac{192+102V}{200}\right)$ m mole

Mole $Na_2CO_3 . 10H_2O$ = $\frac{1}{286}$ mole

Mole of OH = $\frac{2}{286}$ mole (in 100 mL)

Mole of OH in 42.9 mL = $\frac{2\times 0.429}{2.86}$

= $\frac{0.858}{286} = 0.003$ mole

$10^{-3}\times\left(\frac{192+102V}{200}\right) = 0.003$; V = 4 mL

Amount of sulphate ion in gm = $\frac{51\times 4}{200}\times(96)\times 10^{-3}$

= 0.097.92 gm/30 mL

= 6.528 gm/L

Sol 21: $Mg \xrightarrow[O_2]{N_2} MgO + Mg_3N_2$

$$MgO + \underset{x\text{ Meq.}}{2HCl} \rightarrow \underset{\frac{x}{2}\text{ mole}}{MgCl_2} + H_2O$$

$$\underset{(60-x)\text{Meq.}}{Mg_3N_2} + \underset{(60-x)\text{Meq.}}{HCl} \rightarrow \underset{\frac{60-x}{2}\text{mole}}{3MgCl_2} + \underset{\left(\frac{60-x}{3}\right)\text{mole}}{2NH_3}$$

$$\underset{\left(x+\frac{60-x}{2}\right)}{MgCl_2} + \underset{12\text{Meq.}}{2NaOH} \rightarrow Mg(OH)_2 + 2NaCl$$

NH_3 + HCl → NH_4^+ + Cl^-

initially 10 Meq. x mole

after (10 – x) m mole

$$HCl + \underset{6\text{ Meq.}}{NH_4^+} + \underset{6\text{ Meq.}}{\overset{-}{OH}} \rightarrow NH_4OH + Cl^-$$

$$\frac{x}{2}+\frac{60-x}{2}=\frac{12}{2}$$

x = 27.27%

Sol 22: PV = n_TRT

(1) (40) = n_T (0.0821) (400)

n_T = Total mole = 1.2180

$$\underset{\text{x mole}}{C_2H_6}+\frac{7}{2}\,O_2 \to 2CO_2 + 3H_2O$$

$$\underset{(1.218-x)\text{ mole}}{C_2H_4} + 3O_2 \to 2CO_2 + 2H_2O$$

Mole of O_2 required

$$= \frac{7}{2}\,x + 3(1.218-x) = \frac{130}{32}$$

x = 0.817 mole

Mole fraction of C_2H_4 = $\frac{1.218-0.817}{1.218}=0.33$

Mole fraction of C_2H_6 = 0.67

Sol 23: $\underset{\text{x gm}}{Pb(NO_3)_2} \xrightarrow{\Delta} PbO + 2NO_2 + \frac{1}{2}O_2$

$$\underset{(5-x)\text{gm}}{2NaNO_3} \xrightarrow{\Delta} Na_2O + 2NO_2 + \frac{1}{2}O_2$$

$$\left[\frac{(5-x)}{85}\right]+\frac{1}{4}\left(\frac{5-x}{85}\right)+2(x)$$

Sol 24: $\underset{11.25\text{ m mole}}{3Pb(NO_3)_2}+\underset{2.5\text{ m mole}}{Cr_2(SO_4)_3} \to 3PbSO_4 + 2Cr(NO_3)_3$

L. R. = $CrSO_4$

So moles of $PbSO_4$ formed

= 2. 5 m mole × 3

= 7. 5 m mole

Molar conc. of $[Pb^{2+}]=\frac{11.25-7.5}{70}$ = 0. 0536 M

Molar conc. of $[NO_3^-]=\frac{(2\times 11.25)}{70}$ = 0. 32 M

$$[Cr^{3+}]=\frac{2\times 2.5}{70}=0.0714\text{M}$$

Sol 25: NaCl

$CaCl_2 + Na_2CO_3 \to CaCO_3 + 2NaCl$

$$CaCO_3 \xrightarrow{\Delta} \underset{1.12\text{gm}}{CaO} + CO_2$$

Mole of CaO = $\frac{1.12}{56}=0.02$ mole

Moles of $CaCl_2$ = 0.02 mole

Weight of $CaCl_2$ = 2.22 gm

NaCl = 10 − 2.22 = 7.78 gm

% NaCl = 77.8%

Sol 26: (i) $Fe_2O_3 + 2Al \to Al_2O_3 + 2Fe$

(ii) Mole ratio (to complete reaction) = 1 : 2

mass ratio = 1 × (112 + 48) (2 × 27) = 80 : 27

(iii) 2.7 kg of Al = $\frac{2700}{27}$ mole = 100 mole

16 kg of Fe_2O_3 = $\frac{16000}{160}$ mole = 1000 mole

L . R. = Al

So energy released = 200 × $\frac{100}{2}=10000$ unit

Sol 27: $N_2 : H_2$ (mole) = 1 : 3

$N_2 + 3H_2 \to 2NH_3$

Initially 1 3a

after 1–x 3–3x 2x

P(Molecular weight) = SRT

1(M.W.) = (0.497) × (0.0821) (298)

Molecular weight = 12. 15 gm

$$\frac{(2x)(17)+(3-3x)2+(1-x)28}{4-2x} = 12.15$$

34x + 6 − 6x + 28 − 28x = 48.63 − 24.31 x

24.31x = 14.63

x = 0.602

% composition by volume

$$N_2=\frac{1-0.602}{4-2(0.602)}=\frac{0.398}{2.795} = 14.21\%$$

H_2 = 3(N_2%) = 42.86%

$$NH_3=\frac{2(0.602)}{2.795}=42.86\%$$

We know average molecular weight = 12.15

So (1) (12.15)

$= \dfrac{\text{Mass}}{22.4} \times (0.0821) \times (273)$

Mass = 12.14 gm.

Sol 28: $x(CH_3)_2SiCl_2 + Zn\overset{-}{O}H \rightarrow ZnCl^- +$

$nH_2O + [(CH_3)_2SiO]_n$

Volume of film = $6 \times 10^{-10} \times 300 \times 1 \times 3\ m^3$

$= 54 \times 10^{-8}$ m3 $= 0.54\ cm^3$

Mass of the film = 0. 54 gm

Mole of $[(CH_3)_2SiO]_n = \dfrac{0.54}{n[30+28+16]}$

Mass of $[(CH_3)_2SiCl_2] = \dfrac{0.54}{71} \times (58+71) = 0.941$ gm.

Sol 29 $P_4 + 3O_2 \rightarrow P_4O_6$ ....(i)

$P_4 + 5O_2 \rightarrow P_4O_{10}$ ....(ii)

(i) $P_4 + 3O_2 \rightarrow P_4O_6$

1–x 4–y

$P_4 + 5O_2 \rightarrow P_4O_{10}$

x y

5x = y

3(1 – x) = 4 – y

3 – 3x = 4 – 5x

$x = \dfrac{1}{2}$

$y = \dfrac{5}{2}$

$P_4O_6 = P_4O_{10} = 50\%$

(ii) $P_4 + 3O_2 \rightarrow P_4O_6$

3–x 11–y

$P_4 + 5O_2 \rightarrow P_4O_{10}$

x y

5x = y

3(3 – x) = 11 – y

9 – 3x = 11 – 5x

x = 1

$P_4O_{10} = \dfrac{1}{3}$; $P_4O_6 = \dfrac{2}{3}$

(iii) $P_4 + 3O_2 \rightarrow P_4O_6$

3–x 13–y

$P_4 + 5O_2 \rightarrow P_4O_{10}$

x y

5x = y

3(3 – x) = 13 – y

9 – 3x = 13 – 5x

x = 2

$P_4O_6 = 2$

$P_4O_{10} = 1$

Sol 30: $Cl^- + AgNO_3 \rightarrow AgCl + NO_3^-$

Let's say V mL must be added

Weight of solution = (1. 04 V) gm

Weight of $AgNO_3$ = 0.05 × (1.04 V)gm

Moles of $AgNO_3 = \dfrac{(0.05)(1.04V)}{173}$

Minimum moles of Cl^- (it will be case of more molecular weight i. e. KCl)

$= \dfrac{0.3}{39+35.5} = \dfrac{0.3}{74.5}$

$\dfrac{(0.05)(1.04V)}{173} = \dfrac{0.3}{74.5}$

V = 13. 4 mL.

Sol 31: In 500 mL of NaOH

Weight of solution = 1.8 × 500 = 900 gm

So, weight of NaOH = (0.08) (900) = 72 gm

Mole of NaOH = $\dfrac{72}{40}$ = 1.8 mole

Moles of H^+ = 18 mole

On heating $NaHCO_3 \rightarrow CO_2 + H_2O$

On C-balance $n_{CO_2} = n_{NaHCO_3}$

Mass of $NaHCO_3 = \dfrac{18.6}{44} \times (84)$ = 33.50 gm

$H^+ = 1.8 = \dfrac{18.6}{44} + 3\left[\dfrac{x}{27+3(35.5)}\right] + 0$

$1.8 = \dfrac{x}{44.5} + 0.418 \Rightarrow x = 61.5$ gm = mass of $AlCl_3$

Mass of KNO_3 = 124 – 97 = 27 gm

Total mole = 0.267 + 0.460 + 0.422 = 1.149 mole

Sol 32: $\dfrac{1}{2}\underset{\text{(acetone)}}{CH_3COCH_3} + \dfrac{3}{2}CaOCl_2 \rightarrow \underset{30gm}{CHCl_3} + x$

Mole of $CHCl_3$ = $\dfrac{30}{119.5}$

By carbon balance

Mole of acetone (ideally)

$$= \frac{1}{2}\times\frac{30}{119.5}$$

As the yield is 75%

So, weight required

$$= \frac{30}{2\times119.5}\times\frac{100}{75}\times(58) = 9.\ 7 \text{ gm}$$

Sol 33: $Cu_2O + x$

Let's assume total 100 gm is given

Cu = 66.67 gm

$$0 = \frac{66.67}{63.5}\times\frac{1}{2}\times16$$

Oxygen (O) = 8.4

% Cu_2O = 66.67 + 8.4 = 75%

Sol 34: $Hg \quad + \quad I_2 \rightarrow \quad HgI_2$

$$\left(\frac{M}{200}-x\right)\ \left(\frac{M}{254}-\frac{x}{2}\right)$$

$2Hg \quad + \quad I_2 \quad \rightarrow \quad Hg_2I_2$

x mole $\dfrac{x}{2}$

Let's say M gm is initially taken

$$\frac{M}{200}-x=\frac{M}{254}-\frac{x}{2}$$

$$M\left(\frac{54}{200}\right)\frac{1}{254}=\frac{x}{2}$$

$$M=\left(\frac{254}{0.54}\right)x$$

(gm) Hg_2I_2 = $\dfrac{x}{2}$ × (200 + 127) × 2 = 327 x HgI_2(gm)

$$= \left(\frac{M}{200}-x\right) = \left[\frac{254}{(0.54)(200)}-1\right]$$

x Molecular weight = (1.351 × 454) × HgI_2

$HgI_2 : Hg_2I_2$ = 0.532 : 1.

Redox Reactions

Sol 1: (a) $NaNO_2$

$Na^+\ N^{x+}\ 2O_2^-$ + 1 + x – 4 = 0; x = +3

(b) H_2

2x = 0; x = 0

(c) Cl_2O_7

2x – 14 = 0; x = +7

(d) $KCrO_3Cl$

$K^+\ Cr^{x+}\ 3O^{2-}\ Cl^-$; + 1 + x – 6 – 1 = 0; x = +6

(e) Ba Cl_2

+ x – 2 = 0; x = +2

(f) ICl_3

+ x – 3 = 0; x = +3

(g) $K_2Cr_2O_7$

+ 2 + 2x – 14 = 0; x = +6

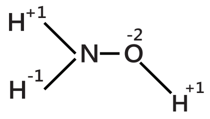
(h) CH_2O

+ x + 2 – 2 = 0; x = 0

(i) Ni $(CO)_4$

+ x + 0 = 0; x = 0

(j) NH_2OH



+ 3 + x – 2 = 0; x = –1

Sol 2: (a) $CuSO_4 + 4\overset{+1}{K}I \longrightarrow 2\overset{+1}{Cu}I + \underset{\text{Reduced}}{\overset{0}{I_2}} + 2\underset{\text{Oxidised}}{\overset{+2}{K_2SO_4}}$

(b) $2Na_2S + 4HCl + SO_2 \longrightarrow 4NaCl + \underset{\text{Oxidised}}{3S} + 2\underset{\text{Reduced}}{H_2O}$

(c) $NH_4NO_2 \xrightarrow{\Delta} \underset{\text{Reduced}}{N_2} + \underset{\text{Oxidised}}{2H_2O}$

Sol 3: (a) $3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2 = 8$ electrons

(b) $AlCl_3 + 3K \longrightarrow Al + 3KCl = 3$ electrons

Sol 4: (a) Sulphur shows various oxidation states such as –2, 0, +2, +4, +6

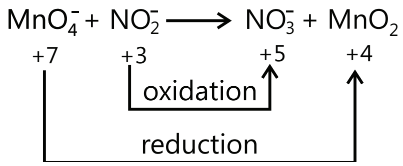
In H_2S, oxidation no. of S is '–2'

So now it can only act as a reducing agent because it can't get more electrons since S^{2-} is in its lowest oxidation state.

But in SO_2, oxidation state of S is +4 which is an intermediate oxidation state. So, it can gain or lose electrons and can go to –2, 0, +2 or higher +6 oxidation state.

(b) Oxidation state of oxygen in H_2O_2 is '–1' so it can get oxidised or reduced because O have multiple oxidation state like –2, –1, 0. By losing electrons it can form O_2 and act as a reducing agent and by gaining e^-s , it can form H_2O and behave as an oxidising agent.

Sol 5: NO_2^- is oxidized to NO_3^- by MnO_4^- (in basic medium) which is reduced to MnO_2



Thus, $MnO_4^- \longrightarrow MnO_3$ oxidation number decreases by 3-units

$NO_2^- \longrightarrow NO_3^-$ oxidation number increases by 2 units

$$\text{Thus, } 2MnO_4^- \equiv 3NO_2^-$$

$$MnO_4^- \equiv \frac{3}{2}NO_2^- = 1.5 \text{ mol } NO_2^-$$

Sol 6: (a) HSO_3^- (b) NO_2^- (c) Cl^-

Sol 7: (a) $4Zn + 10HNO_3 \longrightarrow 4Zn(NO_3)_2 + N_2O + 5H_2O$

(b) $6HI + 2HNO_3 \longrightarrow 3I_2 + 2NO + 4H_2O$

Sol 8: 5 moles of H_2SO_4 can produce

1 mole of H_2S

$0.2 \times V \times 10^{-3} = nH_2SO_4$

(equating equivalents)

∴ Volume = 25 lit.

Sol 9: ∴ 20 × 0. 2 × 2 = 0.167 M

Normality = $n_f \times M$ = 0.5 N

Sol 10: mole of $As_2O_3 = 5.54 \times 10^{-4}$

equating equivalents,

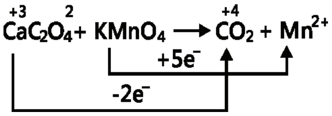
$(5.54 \times 10^{-4}) \times (2) = (26.1 \times 10^{-3}) \times M \times 5$

∴ Molarity = 8.49×10^{-3},

Normality = molarity × n-factor

$= (8.49 \times 10^{-3}) \times (5) = 4.24 \times 10^{-2}$

Sol 11: $CaO \longrightarrow CaC_2O_4$



Equating equivalents

$(\text{equivalent})_{CaC_2O_4} = (\text{equivalent})_{KMnO_4}$

$n_{CaC_2O_4} \times 2 = 40 \times 0.25 \times 10^{-3}$

Moles of $CaC_2O_4 = 5 \times 10^{-3}$

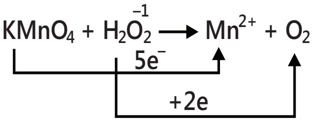
∴ Mole of CaO = CaC_2O_4 = 5×10^{-3}

∴ Mass of CaO = 0.28

∴ % composition

$$= \frac{0.28}{0.518} \times 100 = 54\%$$

Sol 12: Reaction



Assume mass of H_2O_2 = x gm

∴ Molarity of

$$H_2O_2 = \frac{\frac{x}{34} \times 1000}{20} = 147 \text{ x M}$$

$$\text{Moles of } KMnO_4 = \frac{0.316}{158} = 2 \times 10^{-3}$$

Now equating equivalents,

Equivalents of H_2O_2 = Equivalents of $KMnO_4$

$1.47x \times 20 \times 10^{-3} \times 2 = 2 \times 10^{-3} \times 5$

∴ x = 0. 17 gm

∴ Purity of H_2O_2 = 85% (i)

moles O_2 evolved = moles of H_2O_2 consumed.

∴ Moles of $O_2 = 5 \times 10^{-3}$

∴ Volume = $\frac{nRT}{P} = 124.8$ ml (ii)

Sol 13: (CaOCl)+ Cl^- 5.7 gm is taken

∴ Lets take moles of $CaOCl_2$ = x

molarity of

$$CaOCl_2 = \frac{x}{500} \times 1000 = 2x$$

Now on treatment with KI + HCl

$$\begin{tikzcd}(CaOCl)^+Cl^- + KI + HCl \arrow[r] & I_2 \arrow[d, "\text{treated with } Na_2S_2O_3"] \\ & {} \end{tikzcd}$$

$\therefore$ Equivalents of I_2 = equivalents of $Na_2S_2O_3$

$= 24.35 \times \frac{1}{10} \times 10^{-3} = 2.435$ milliequ.

Now, equiv. of I_2 = equiv. of Bleaching powder

$2.435 \times 10^{-3} = 2x \times 25 \times 10^{-3}$

$\therefore x = 4.87 \times 10^{-2}$

$\therefore$ Mass of bleaching powder = 1.73 gm

$\therefore$ % availability = $\frac{1.73}{5.7} \times 100 = 30.33\%$

Sol 14: (i) $3C_2H_5OH + 2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow$

$3\ C_2H_4O_2 + 1Cr_2(SO_4)_3 + 2\ K_2SO_4 + 11H_2O$

(ii) $1As_2S_5 + 40HNO_3 \longrightarrow$

$40NO_2 + 12H_2O + 2H_3AsO_4 + 5H_2SO_4$

(iii) $2CrI_3 + 27Cl_3 + 64KOH \longrightarrow$

$6KIO_4 + 2K_2CrO_4 + 54KCl + 32H_2O$

(iv) $3As_2S_3 + 14HClO_3 + 18H_2O \longrightarrow$

$14HCl + 6H_3AsO_4 + 9H_2SO_4$

Sol 15:

(i)

$As_2S_3 + 12OH^- + 14H_2O \longrightarrow 2As^{3-}O_4 + 3S^{2-}O_4 + 20H_2O$

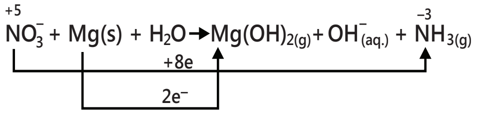
(ii)

$2CrI_3 + 10OH^- + 27H_2O_2 \longrightarrow 2Cr^{2-}O_4 + 6IO_4^- + 32H_2O$

(iii) $P_4 + 3OH^- + 3H_2O \longrightarrow 3H_2PO_2^- + PH_3$

(iv) $3As_2S_3 + 4H_2O + 10NO_3^- + 10^+ \longrightarrow$
$6H_3AsO_4 + 9S + 10NO$

Sol 16:



$NH_3 + HCl \longrightarrow NH_4Cl$

Say molarity of NO_3^- ions = x M

$\therefore$ Moles of $NO_3^- = x \times 25 \times 10^{-3}$

Equivalents of NO_3^-

= Equivalents of $NH_3 = 8 \times x + 25 \times 10^{-3} = 0.2\ x$

$\therefore$ Moles of $NH_3 = 0.2\ x$

Moles of NaOH = $32.10 \times 10^{-3} \times 0.1 = 3.21 \times 10^{-3}$

Now, moles of HCl = (moles of NH_3) + (moles of NaOH)

$50 \times 0.15 \times 10^{-3} = 0.2x + 3.21 \times 10^{-3}$

$x = 2.145 \times 10^{-2}$

$\therefore$ Molarity = 8x = 0.1716 M

Sol 17: $$\begin{tikzcd}K\overset{+7}{Re}O_4 + Zn \arrow[r] & Zn^{2+} + Re^{+x} \arrow[d, "K\overset{+7}{Mn}O_4"] \\ & \overset{+7}{Re}O_4^- + Mn^{2+}\end{tikzcd}$$

$\therefore$ Moles of $KReO_4 = 9.28 \times 10^{-5}$

$\therefore$ Moles of $KMnO_4 = 0.05 \times 11.45 \times 10^{-3} \times 5$

Now equating equivalents of

$Re^{x+} = KMnO_4$

$(x_{Re^{x+}})\ (7-x) = 5.725 \times 10^{-4}$ .... (1)

Now equating equivalents of

$KReO_4 = Re^{x+}$

$9.28 \times 10^{-5} = Re^{x+} = x_{Re^{x+}}$

$\therefore 7 - x = \frac{5.725 \times 10^{-4}}{9.28 \times 10^{-5}}$; x = +1

Sol 18: Let moles of FeC_2O_4 = x

$FeSO_4$ = y

$$\begin{tikzcd}FeC_2O_4 + FeSO_4 + KMnO_4 \arrow[r] & Fe^{2+} + CO_2\uparrow \arrow[d, "\text{Zn-dil HCl}"] \\ & Fe^{+3} \arrow[d, "KMnO_4"] \\ & Fe^{+2}\end{tikzcd}$$

Now, (2x + x + y) 0.1 = 60 × 0.02 × 5

$3x + y = 60$

$x + y = 40 \times 0.02 \times 5 = 4$

$\therefore 4 - x = 6 - 3x$

$2x = 2$

$x = 1$

$y = 3$

$\therefore$ Normality $= 1 \times 3 \times 10^{-2} = 0.03N$ of FeC_2O_4

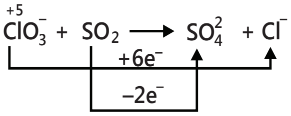
$= 3 \times 10^{-2} = 0.03$ M of $FeSO_4$

Sol 19: Mass of KCl = x gm

$H_2O = 1 - x - y$ gm

$KClO_3 = y$ gm

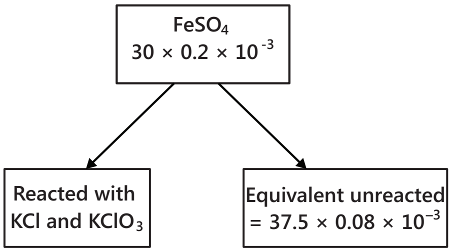
Treating with SO_2



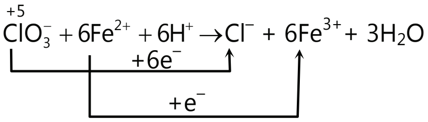
Then silver chloride formed

$\therefore$ Total moles of chloride $= 10^{-3} = \frac{x}{74.5} + \frac{y}{122.5}$

Now for another experiment



$\therefore$ Equivalents reacted $= 3 \times 10^{-3}$



Equivalents of Fe^{2+} = Equivalent of ClO_3^-

3×10^{-3}

$$= \frac{\frac{y}{122.5}}{25010} \times 10^{+3} \times 25 \times 10^{-3} \times 6$$

$y = 0.6125$ gm

Moles of $ClO_3^- = 0.005$

Molar ratio = 1 : 1

Sol 20: (iii) One mL of $Na_2S_2O_3$ is equivalent to

0.0499 gm of $CuSO_4$

0.2 millimole of $CuSO_4$

Since reaction is balanced

$Hg_5(IO_6)_2 \longrightarrow 8I_2$

1 8

5×10^{-4} 4 millimole

$2\ CuSO_4 \longrightarrow I_2$

2 1

0.2 millimole 0.1 millimole

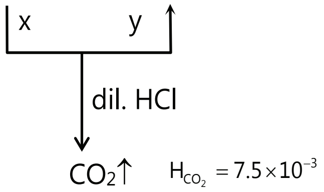
$\therefore$ 0.1 millimole of I_2 equivalent to 0.2 millimole of $CuSO_4$

But we have 4 millimole

So, 1 mL $\longrightarrow$ 0.1 millimole

40 mL $\longleftarrow$ 4 millimole

Sol 21: $BaCO_3 + CaCO_3 + CaO$



$x + y = 7.5 \times 10^{-3}$

$BaCrO_4 + I^- \longrightarrow I_2 + Cr^{3+}$

0.1 x

Equating equivalents of $BaCrO_4 = I^-$

$0.1\ x - 3 = 20 \times 0.05 \times 10^{-3}$

$x = \frac{10^{-2}}{3} = 3.33 \times 10^{-3}$

$\therefore y = 4.167 \times 10^{-3}$

Mass of $BaCO_3 = 0.659$ gm

$CaCO_3 = 0.4167$ gm

$\therefore$ Mass of CaO = 0.1733

% CaO = 13.87%

Sol 22: $Cu_2S + CuS + MnO_4^- \longrightarrow$

x y

$Mn^{2+} + Cu^{2+} + SO_2$

$200 \times 0.75 \times 10^{-3} = \frac{175 \times 10^{-3}}{5}$ + moles of required

$\therefore$ Moles required of $MnO_4^- = 0.115$

Let moles of $Cu_2S^{-2} = x$

$CuS = y$

$\therefore 0.115 \times 5 = 8x + 6y$

Let m = mass of Cu_2S

$8x + 6y = 0.575$

$$\frac{8m}{159} + \frac{6(10-m)}{95.5} = 0.575$$

$[(5.03 \times 10^{-2}) - (6.28 \times 10^{-2})]\,m = -5.327 \times 10^{-2}$

m = 4.26 gm

$$\%\ CuS = \frac{5.74}{10} \times 100 = 57.4\%$$

Sol 23: $2H^+ + \overset{0}{O_3} + I^- \rightarrow O_2 + I_2 + H_2O^{-2}$

moles of air

$= 0.406 = \dfrac{PV}{RT}$

$\Big\downarrow Na_2S_2O_3$

Equivalents of $I_2 = 1.5 \times 10^{-3} \times 0.01 = 1.5 \times 10^{-5}$

Moles of O_3 = x

$\therefore x \times 6 = 1.5 \times 10^{-5}$

$x = 2.5 \times 10^{-6}$

$\therefore$ Volume of $O_3 = 1.847 \times 10^{-4}$ lit.

$$\%\ O_3 = 1.847 \times 10^{-3} = \frac{V_{O_3}}{10} \times 100$$

Sol 24: $MnO_4^- + H_2C_2O_4 + Fe^{2+} \longrightarrow$

$30\times1.5 \quad 1.5\times0.5 \quad 15\times0.4$

$Fe^{3+} + CO_2 + Mn^{2+}$

$(30 \times 1.5) - (15 \times 0.5 + 15 \times 0.4) = 31.5$ milliequivalents

$$\therefore \text{Final of } MnO_4^- = \frac{31.5 \times 10^{-3}}{60 \times 10^{-3}} = 0.525\ M$$

Final molarity of

$$Fe^{3+} = \frac{15 \times 0.4 \times 10^{-3}}{60 \times 10^{-3}} = 0.1\ M$$

$\therefore$ Final normalities $MnO_4^- = 0.105M$

$Fe^{3+} = 0.1M$

Sol 25: (i) Equivalents of $I^- = 20 \times 0.1 \times 10^{-3}$

$H_2\overset{-1}{O_2} + I^- \longrightarrow H_2\overset{-2}{O} + I_2$

$\therefore$ Equivalents of $H_2O_2 = 2 \times 10^{-3}$

$$\therefore \text{Moles of } H_2O_2 = \frac{2 \times 10^{-3}}{2} = 10^{-3}$$

$$\text{Now, molarity} = \frac{10^{-3}}{25} \times 10^3 = 0.04\ M$$

$\therefore$ Normality = 0.04 × 2 = 0.08 N

(ii) $20 \times 0.3 \times 10^{-3}$ = equivalent of I^-

$$\therefore \text{Normality of } H_2O_2 = \frac{20 \times 0.3 \times 10^{-3}}{25 \times 10^{-3}} = 0.24$$

$\therefore$ Strength = 1.344

Sol 26: Let molarity of $Na_2S_2O_3$ solution = xM

$\therefore$ Equivalent of thiosulphate

$=$ Eq. of I^- = Eq. of $I_2 = x \times 45 \times 10^{-3}$

$$\frac{0.1}{214} \times 5 = x \times 45 \times 10^{-3}$$

x = 0.062 M

Sol 27: $\overset{+2}{Mn}SO_4 \cdot 5H_2O \xrightarrow{\Delta} \overset{+8/3}{Mn_3}O_4$

Now $\overset{+8/3}{Mn_3}O_4 + FeSO_4 \rightarrow Fe^{3+} + Mn^{+2} + KMnO_4$

Let assume no. of moles of

$MnSO_4 \cdot 5H_2O = x$

$\therefore$ Moles of $Mn_3O_4 = 3x$

$3x(6) + 100 \times 0.1 \times 10^{-3} = 0.12 \times 100 \times 10^{-3}$

$25 \times N = 30 \times 0.1$

N = 0.12

$\therefore x = 1.11 \times 10^{-4}$

$\therefore$ Mass of $MnSO_4 \cdot 4H_2O$ = 1.338 gm.

Sol 28:

(i) $\overset{+5}{Cl}O_3^- + Fe^{+2} \longrightarrow Cl^- + Fe^{+3} + H_2O$

$6H^+ + \overset{+5}{Cl}O_3 + 5e^- \longrightarrow Cl^- + 3H_2O$

$Fe^{+2} \longrightarrow Fe^{+3} + e^- \times (5)$

$6H^+ + ClO_3^- + 5Fe^{2+} \rightarrow 5Fe^{3+} + Cl^- + 3H_2O$

(ii) $8CuS^{-2} \rightarrow S_8 + 16e^- + 8Cu^{2+} \quad \times(3)$

$4H^+ + \overset{+5}{N}O_3^- + 3e^- \rightarrow \overset{+2}{N}O + 2H_2O \quad \times(16)$

$24\,CuS + 16NO_3^- + 64H^+ \longrightarrow 24\,Cu^{2+} + 3S_8 +$

$16NO + 32H_2O$

(iii) $S_2O_3^{2-} + Sb_2O_5 \longrightarrow SbO + H_2SO_3$

$6H^+ + Sb_2O_5 + 6e^- \rightarrow 2SbO + 3H_2O$

$H_2O + \overset{+2}{S_2}O_3^{2-} \rightarrow 2H_2\overset{+4}{S}O_3 + 4e^- + 2H^+$

$Sb_2O_5 + S_2O_3^{2-} + 4H^+ \rightarrow 2SbO + 2H_2SO_3$

(iv) $2HCl^{-1} \rightarrow Cl_2^{o} + 2H^+ + 2e^- \quad \times (5)$

$5e^- + KM\overset{+7}{N}O_4 \rightarrow KCl + \overset{+2}{Mn}Cl_2 + 4H_2O \times (2) + 8H^+$

$10HCl + 2KMnO_4 \rightarrow 5Cl_2 + 2KCl + 2MnCl_2 + 8H_2O$

(v) $H_2SO_4 + K\overset{+5}{Cl}O_3 \rightarrow H\overset{+7}{Cl}O_4 + 2e^- + KHSO_4$

$3SO_4 + K\overset{+5}{Cl}O_3 \rightarrow \overset{+4}{Cl}O_2 + H_2O + KHSO_4$

$3KClO_3 + 3H_2SO_4 \rightarrow 3KHSO_4 + HClO_4 + 2ClO_2 + H_2O$

(vi) $4H^+ + H\overset{+5}{N}O_3 + 3e^- \longrightarrow \overset{+2}{N}O + 2H_2O \times (2)$

$2\overset{+1}{H}Br \longrightarrow Br_2 + 2e^- + 2H^+ \quad \times (3)$

$2HNO_3 + 6HBr \rightarrow 2NO + 3Br_2 + 4H_2O$

(vii) $H^+ + 2\overset{+7}{I}O_4^- + 14e^- \rightarrow \overset{0}{I}_2 + 4H_2O$

$2I^- \rightarrow I_2 + 2e^- \times (7)$

$IO_4^- + 7I^- + 8H^+ \rightarrow 4I_2 + 4H_2O$

Sol 29: $P_4 + 3O_2 \rightarrow P_4O_6 \quad .... \text{(i)}$

$P_4 + 5O_2 \rightarrow P_4O_{10} \quad .... \text{(ii)}$

(i) $P_4 + 3O_2 \rightarrow P_4O_6$

$1-x \quad 4-y$

$P_4 + 5O_2 \rightarrow P_4O_{10}$

$x \quad y$

$5x = y$

$3(1-x) = 4-y$

$3-3x = 4-5x$

$x = \frac{1}{2}$

$y = \frac{5}{2}$

$P_4O_6 = P_4O_{10} = 50\%$

(ii) $P_4 + 3O_2 \rightarrow P_4O_6$

$3-x \quad 11-y$

$P_4 + 5O_2 \rightarrow P_4O_{10}$

$x \quad y$

$5x = y$

$3(3-x) = 11-y$

$9-3x = 11-5x$

$x = 1$

$P_4O_{10} = \frac{1}{3}$; $P_4O_6 = \frac{2}{3}$

(iii) $P_4 + 3O_2 \rightarrow P_4O_6$

$3-x \quad 13-y$

$P_4 + 5O_2 \rightarrow P_4O_{10}$

$x \quad y$

$5x = y$

$3(3-x) = 13-y$

$9-3x = 13-5x$

$x = 2$

$P_4O_6 = 2$

$P_4O_{10} = 1$

Sol 30:

(i) $H_2O + 2e^- + \overset{+1}{Ag_2}O \rightarrow 2Ag + 2OH^-$

$4OH^- + S_2O_4^{2-} \rightarrow 2SO_3^{2-} + 2e^- + H_2O$

$S_2O_4^{2-} + Ag_2O + 2OH^- \rightarrow 2Ag + 2SO_3^{2-} + H_2O$

(ii) $\overset{o}{Cl_2} + 2e^- \rightarrow 2Cl^-$

$\overset{o}{Cl_2} + 2OH^- \rightarrow 2\overset{+1}{Cl}O^- + 2e^- + 2H_2O$

$Cl_2 + 2OH \rightarrow Cl^- + ClO^- + H_2O$

(iii) $2OH^- + \overset{0}{H_2} \rightarrow \overset{+1}{H_2}O + 2e^- + H_2O \times (3)$

$3e^- + \overset{+7}{Re}O_4^- \rightarrow \overset{+4}{Re}O_2 + 4OH^- \quad \times(2)$

$3H_2 + 2ReO_4^- \rightarrow 2ReO_2 + 2H_2O + 2OH^-$

(iv) $\overset{+4}{Cl}O_2 + e^- \rightarrow \overset{+3}{Cl}O_2^- \quad \times(2)$

$2H_2O + \overset{+3}{Sb}O_2^- \rightarrow \overset{+5}{Sb}(OH)_6^- + 2e^- + 2OH^- + H_2O$

$2ClO_2 + SbO_2^- + 2OH^- + 2H_2O \rightarrow 2ClO_2^- + Sb(OH)_6^-$

(v) $4H_2O + \overset{+7}{Mn}O_4^- + 5e^- \rightarrow Mn^{+2} + 8OH^-$

$Fe^{+2} \rightarrow Fe^{+3} + e^- \quad \times(5)$

$$MnO_4^- + 5Fe^{+2} + 4H_2O \rightarrow Mn^{2+} + 5Fe^{3+} + 8OH^-$$

Exercise 2

Mole Concept

Single Correct Choice Type

Sol 1: (D) $A + Cl_2 \rightarrow ACl_2$

$$\frac{x}{M} \quad \frac{y}{71+M}$$

$$\frac{x}{M} = \frac{y}{71+M}$$

$71x + Mx = My$

$$M = \frac{71x}{x-y}$$

Sol 2: (B) Equivalents of H_2SO_4 = 1.200 × 0.2 = 0.24

Moles of H_2SO_4 = 0.12

Mass of H_2SO_4 = 0.12 × 98 = 11.76 gm

Sol 3: (C) NaI consumption per day

$$= \frac{0.5}{100} \times 3\text{ gm} = 0.015\text{ gm}$$

Number of I^- = $\frac{0.015}{127+23} \times 6.023 \times 10^{23} = 6.023 \times 10^{19}$

Assertion Reasoning Type

Sol 4: (B) Statement-I: moles of $N_2 = \frac{0.28}{28} = 0.01$ mole

$PV = nRT$

At same P and T, $V \propto n$

If M. W. = 44 gm of gas

n = 0. 01 mole

$V \propto n$

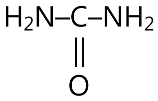
So, volume will be same as moles are also same.

Sol 5: (A) We know that for isotopes

$M_{avg.} = x(M_1) + (1-x)M_2$

So, statement-II is explaining statement-I and both are correct.

Sol 6: (C) Statement-I: Mass of urea = 60



$$H_2N-\underset{\underset{O}{\|}}{C}-NH_2$$

Mass of nitrogen = 28

$$\% = \frac{28}{60} = 46.66$$

Statement-II: Urea not ionic.

Sol 7: (B) Statement-I: $S_2O_3^{2-}$

$2x + 3(-2) = -2$

$x = +2$

Statement: Yes, Because these may be per-oxide bond.

Sol 8: (A) Statement-I: Molarity = $\frac{n}{v}$ density increases $\Rightarrow n \uparrow$ (at const. V)

$$= \text{molality} = \frac{\text{moles of solute}}{\text{mass of solvent}}$$

Density increases = moles of solute ↑

Molality and molarity both changes.

Statement-II: Density results in change in mass thus increases moles.

Sol 9: (C) Statement-I: Incorrect because it depends in extent of reaction

Statement-II: Correct.

Multiple Correct Choice Type

Sol 10: (A, C, D) (A) $NH_3 \rightarrow HNO_3 + HNO_2$ (till reaction III)

by nitrogen balance

$$n_{HNO_3} = \frac{1}{2} n_{NH_3}$$

(B) $3HNO_2 \rightarrow HNO_3 + 2NO + H_2O$

Let's say 1 mole of NH_3 is initially taken.

It makes $\frac{1}{2} - \frac{1}{2}$ mole of HNO_2 and HNO_3 till reaction-III $\frac{1}{2}$ mole HNO_2 make $\frac{1}{6}$ mole of HNO_3 in reaction-IV so HNO_3 made

$= \frac{1}{2}+\frac{1}{6}$ mole $= \frac{2}{3}$ mole

% increase = $\frac{\frac{1}{6}}{\frac{1}{2}} = \frac{100}{3}\%$

(C) By above data, it is correct

(D) Mole of NO produced = $\frac{1}{2}\times\frac{2}{3}$ = 50 % of HNO_3

Comprehension Type

Paragraph 1

Sol 11: (A) Initially mole of HCl = $\frac{1}{2}$ mole

$= \frac{1}{2}$ × 36.5 gm = 18.25 gm

So, after heating mole of HCl

$= \frac{18.25-2.75}{36.5} = \frac{15.5}{36.5}$ = 0. 424 mole

Normality = $\frac{0.424}{0.750}$ = 0. 5662 ~ 0. 58

Sol 12: (C) Please note that, there is a small hypo in questions,

Instead of Ca(OH), it should be $Ca(OH)_2$

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

Moles of HCl = 0.1 × 10 = 1m mole

Moles of $Ca(OH)_2$ required = 0.5 m mole

Volume = $\frac{0.5}{0.1}$ mL = 5 mL

Sol 13: (A) We know valency factor for Na_2CO_3 is 2

So, molarity will be = $\frac{0.5}{2} = 0.25M$

Sol 14: (A) 6.90 N means in 1 lit. solution

KOH = 6.90 moles

Weight of KOH = 6.90 × (56) = 386. 4 gm

given 30% by weight is KOH

So, weight of solution = 12.88 gm

Density = $\frac{12.88}{1} = 12.88$

Sol 15: (C) Ferrous ammonium sulphate

$= FeSO_4(NH_4)_2SO_4.6H_2O$

Molecular weight = 390

Moles in 0.1 N, 250 mL = $\frac{(0.1)(0.250)}{\text{Valency factor}}$

$Fe^{2+} \rightarrow Fe^{3+}$ Valency factor = 1

Mass of ferrous ammonium sulphate required

= (0.1) (0.250) (390) = 9.8 gm

Paragraph 2

Sol 16: $\underset{(4.925-x)gm}{CuCl_2} + \underset{(5.74-y)gm}{AgCl} \rightarrow$ unreacted

$\underset{x\ gm}{CuBr_2} + \underset{y\ gm}{2AgCl} \rightarrow 2AgBr + CuCl_2$

Let's say initially $CuBr_2$ = x gm

$CuCl_2$ = 4. 925 – x gm

AgCl = y gram (reacts with reacted)

AgCl = 5. 74 – y gram (in reacted)

Finally same AgCl → AgBr and $CuBr_2$ → $CuCl_2$ (completely)

Moles of AgCl in reaction = $\frac{y}{143.5}$

= Mole of AgBr produced

Finally AgCl = (5.74 – y) gm

AgBr = $\frac{y}{143.5}\times(80+108)$ = y(1.310)

AgCl + AgBr = 6.63 = 5.74 + y(0.310)

y = 2.87 gm

So moles of $CuBr_2$ = $\frac{2.87}{2\times143.5} = \frac{x}{223.5}$

x = 2.235 gm

(1) **(C)** $CuBr_2$ mass % = $\frac{2.235}{4.925} = 45.38\%$

(2) **(B)**% mass of Cu =

$$\left[\left(\frac{2.235}{223.5}\right)+\left(\frac{4.925-2.235}{63.5+71}\right)\right]\times\frac{63.5}{4.925}$$

$$= \frac{0.03\times63.5}{4.925} = 38.68\%$$

(3) **(B)** Mole % of AgBr =

$$\frac{\left(\frac{2.87}{143.5}\right)}{\left(\frac{2.87}{143.5}\right)+\left(\frac{9.74-2.87}{143.5}\right)} = 50\%$$

(4) **(A)** Moles of $CuBr_2$ = Moles of $CuCl_2$ produced

= 0.01 mole

Moles of $CuCl_2$ initially take

$$= \frac{4.925-2.235}{134.5} = 0.02 \text{ mole}$$

Mole of Cl^- in final solution = (0.01 + 0.02) × 2 = 0.06

Paragraph 3

Sol 17: $UF_6 + xH_2O \rightarrow UO_xF_y + \text{gas } (F_{6-y}.\ H_{2x})$

3.52gm 3.08 gm 0.8 gm

0.01 mole

Gas contains 95% fluorine by mass

$$= 0.8\times\frac{95}{100} = (6-y)\times 19$$

y = 5. 96

$$0.8\times\frac{5}{100} = (2x)$$

x = 0. 02

(1) **(C)** So empirical formula $F_{6-596}\ H_{2(0.\ 02)}$

$= F_{0.\ 04}\ H_{0.\ 04}$

= HF

(2) **(A)** Empirical formula of solid = UO_xF_y

final reaction

$UF_6 + BH_2O \rightarrow UO_xF_y + A(HF)$

0. 01 0. 01

A = 2B (H-balance)

6 = Y + A (F - balance)

$B = X = \frac{A}{2}$ (O - balance)

Y = 6 – A

$UO_{\frac{A}{2}}F_{6-A}$ molecular weight $= \frac{3.08}{0.01} = 308\,\text{gm}$

$238+\frac{A}{2}(16) + (6-A)\times 19 = 308$

8A + 114 – 19A = 70

11A = 44

A = 4

So UO_2F_2

(3) **(A)** % of F converted $= \frac{A}{6} = 66.\ 66\%$

Match the Columns

Sol 18: A → r; B → p; C → q

$\frac{1}{3}$ Al_5O1_2 molecular weight = 267 + 135 + 196 = 598

(A) $Y = \frac{267}{598} = 44.95\%$

(B) $Al = \frac{135}{598} = 22.57\%$

(C) $O = \frac{196}{598} = 32.32\%$

Sol 19: A → r; B → q; C → p

$C_6H_8O_6$ molecular weight = 72 + 8 + 96 = 176

Moles of $C_6H_8O_6 = \frac{17.6\text{ mg}}{176} = 0.1$ m mole

(A) O – atom $= 6 \times n_{C_6H_8O_6} \times N_A = 3.6 \times 10^{20}$

(B) Mole $= \frac{1}{176} = 5.68 \times 10^{-3}$

(C) Moles of $C_6H_8O_6$ = 0.1 m mole

Sol 20: (C) Volume strength

$2H_2O_2(\ell) \rightarrow O_2(g) + 2H_2O(\ell)$

1 lt. of H_2O_2 gives x lt. of O_2 gas then X is said to be volume strength of H_2O_2

It X – V is given at S. T. P. then

Mole of O_2 produced $= \frac{x}{22.4}$

Mole of H_2O_2 required $= \frac{x}{11.2}$ (in litre)

Molarity $= \frac{x}{11.2}$

Normality $= \frac{x}{11.2} \times \text{(valency factor)} = \frac{x}{5.6}$

Strength in g/L $= \frac{x}{11.2}\times 34 = \frac{17x}{5.6}$

Volume strength = Normality × 5.6

Sol 21: (B) (A) acid + acid → No reaction

$$M_{avg.} = \frac{M_1V_1 - M_2V_2}{V_1 + V_2} = \frac{\text{Total no. of moles}}{\text{Total volume}}$$

Similarly (B)

(C) acid + basic →

$$M_{avg.} = \frac{M_1V_1 - M_2V_2}{V_1 + V_2}$$

(D) Mili equivalent = x × M × VmL

(E) Molarity $= \frac{\text{moles}}{\text{volume}} = \frac{M_1V_1}{\text{Volume}} = \frac{M_1V_1}{V_2}$

or $= \frac{\text{moles}}{\text{volume}} = \frac{\text{mass (gm)}}{M_{solute} \times \text{Volume (lt.)}}$

Redox Reactions

Single Correct Choice Type

Sol 1: (C) $\overset{-2}{N_2}H_4 \rightarrow y = 10e^-$

Each nitrogen coses $5e^-$

∴ Oxidation no. of N in

y = –2 + 5 = +3

Sol 2: (D) The ore which get easily oxidised is best reducing agent

$I^- \rightarrow \frac{1}{2} I_2$ is most feasible because.

Sol 3: (C) Alumino thermite process :-

$Al + Mn_3O_4 \rightarrow Al_2O_3 + Mn$

↓

Reducing agent

Sol 4: (D) (a) Oxidation number of S in H_2S=+2

Oxidation number of S in SO_2 = +4

(b) H_2O_2 can undergo reduction as well as oxidation because oxidation number of oxygen in H_2O_2 is -1. So, it can act both as reducing agent and oxidising agent.

Sol 5: (C) $\overset{+5}{Cl}O_3^- + 6H^+ + x \rightarrow Cl^- + 3H_2O$

↓

$6e^- + 5 \rightarrow -1$

Sol 6: (A) $[Fe(H_2O)_5(NO)^+]^{-1}\ SO_4^{2-}$

$Fe^{x+}\ 5(H_2O)^0\ (NO)^+$

x + 1 = +2; x = +1

Sol 7: (A) KO_2^-

$K^+\ O_2^-\quad 2x = -1$

$\therefore x = -\frac{1}{2}$

Sol 8: (B) $3\overset{0}{Br_2} + 6CO_3^{2-} + 3H_2O \rightarrow 5Br^- + 6HCO_3^- + +5\overset{+5}{Br}O_3^-$

$BrO \rightarrow Br^{-1}$ Reduction

$BrO \rightarrow Br^{+5}$ Oxidation

Comprehension Type

Paragraph 1

Sol 9: (D)

$$\begin{tikzcd} H_2O_2 + \underset{(\times 5)}{KI} \arrow[r] & I_2 \arrow[d] \\ & \text{hypo} \end{tikzcd}$$

Sol 10: (D) Eq. of hypo solution eq. of I_2

$20 \times 0.1 \times 10^{-3} = 50 \times 10^{-3} \times N_{H_2O_2}$

$\therefore N_{H_2O_2} = 0.04$

∴ Concentration of H_2O_2

in gm/lit. $= \frac{0.04}{4} \times 34 = 0.34$

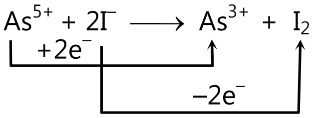
Sol 11: (D) ∴ Eq. of MnO_2 + Eq. of hypo solution

$\frac{m}{87} \times 2 = 30 \times 0.1 \times 10^{-3}$

m = 0.1305

$\therefore \% = \frac{0.1305}{0.5} \times 100 = 26.1\%$

Sol 12: (D)



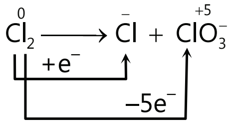
$As^{5+} + 2I^- \longrightarrow As^{3+} + I_2$

∴ Valence factor = 5 for As

2 for I

Paragraph 2

Sol 13: (C)

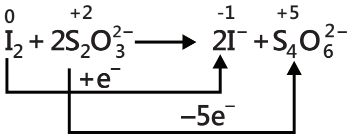


$\overset{0}{Cl_2} \longrightarrow \overset{-}{Cl} + \overset{+5}{ClO_3^-}$

Disproportionation

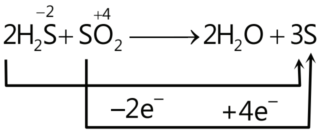
(oxidation as well as reduction)

Sol 14: (B, C)



$\overset{0}{I_2} + 2\overset{+2}{S_2}O_3^{2-} \longrightarrow 2\overset{-1}{I^-} + \overset{+5}{S_4}O_6^{2-}$

Sol 15: (B)



$2H_2\overset{-2}{S} + \overset{+4}{S}O_2 \longrightarrow 2H_2O + 3S$

$H_2S \to S \quad 0 - (-2) = +2$

$SO_2 \to S \quad 0 - (4) = -4$

Multiple Correct Choice Type

Sol 16: (A, B, D) Meq. of formed = Meq. of HCl used for NH_3

$= 50 \times 0.15 - 32.10 \times 0.10$

= 4.29

These Meq. of NH_3 are derived using valance factor of NH_3 = 1 (an acid base reaction)

In redox change valence factor of NH_3 is 8;

$8e + N^{5+} \to N^{3-}$

∴ Meq. of NH_3 for valence factor

Also, Meq. of NO_3^- = Meq. of NH_3

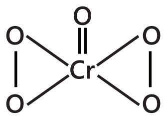
$= 8 \times 4.29 = 34.32$

$\therefore N_{NO_3^-} = \dfrac{34.32}{25} = 1.37$

$(N \times V \text{ in mL} = \text{Meq.})$

Assertion Reasoning Type

Sol 17: (A)



Valency of Cr is 6 all O have higher electronegativity than Cr

∴ Cr's oxidation no. = +6

$$K_2Cr_2O_7 \underset{H^+}{\overset{OH^-}{\rightleftharpoons}} K_2CrO_4$$

Orange dichromate — Yellow chromate

	$BaCl_2$	$+ Al_2(SO_4)_3$	$\longrightarrow BaSO_4$	$+ AlCl_3$
Meq. before reaction	$30 \times 0.1 = 3$	$40 \times 0.2 = 8$	0 = 0	0 = 0
Meq. after reaction	0	5	3	3

Sol 18: (D) Avg. oxidation no. of Pb_3O_4 is $+\frac{8}{3}$. But in reality, Pb_3O_4 is made up of PbO + PbO_2 .So, actively, Pb have oxidation state +2, +4.

Sol 19: (C) Oxidation no. of Cl = +7 it can not be greater than this

∴ It can get only reduced

∴ $HClO_4$ is an oxidising agent

∴ In $HClO_3$, oxidation no. of chlorine = + 5

E. N. order O > Cl > H

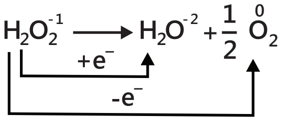
Sol 20: (D) Since S_2^{2-} has S – S⁻ linkage structure

∴ $FeS_2^{2-} \to Fe^{2+}$ (S – S) oxidation no. = +2

Sol 21: (B) Yes, the given reaction is an example of disproportionation

∴ H_2O_2 is a reducing as well as an oxidising agent

So it is not only bleaching (oxidising agent)



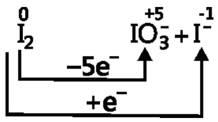
$H_2\overset{-1}{O_2} \longrightarrow H_2\overset{-2}{O} + \frac{1}{2}\overset{0}{O_2}$

Sol 22: (A)

$$K_2Cr_2O_7 \underset{H^+}{\overset{OH^-}{\rightleftharpoons}} K_2CrO_4$$

Orange dichromate — Yellow chromate

Sol 23: (B)



$\overset{0}{I_2} \quad \overset{+5}{IO_3^-} + \overset{-1}{I^-}$

These reactions show E° > 0

∴ It is not feasible because iodine can show multiple oxidation state.

Match the Columns

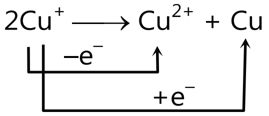
Sol 24: A → w; B → x; C → u; D → p; E → v; F → q; G → r; H → s; I → t

(1) Increase in oxidation no:- Loss of electrons (oxidation)

(2) Decrease in oxidation no:- Gain of only e⁻s (reduction)

(3) Oxidation agent:- Gain of e⁻s

(4) Reducing agent:- Loss of e⁻s

(5)

$2Cu^+ \longrightarrow Cu^{2+} + Cu$

Disproportionation reaction

(6) Redox reaction

(7) Mn_3O_4 oxidation no:-

$+\frac{8}{3}$ fractional

(8) CH_2Cl_2

x + 2 – 2 = 0 zero oxidation no.

x = 0

(9) NaOH + HCl → NaCl + H2O

Simple neutralisation reaction

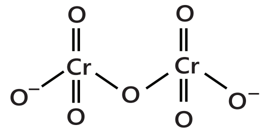
Sol 25: A → p, s; B → r; C → p, q; D → p

(a) $\overset{-\frac{1}{2}}{O_2^-} \longrightarrow \overset{0}{O_2} + \overset{-1}{O_2^{2-}}$

Disproportionation

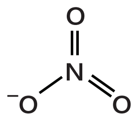
Redox reaction

(b) $\underset{\text{tetrahedral}}{CrO_4^{2-}} + H^+ \rightarrow \underset{\text{dimeric bridged tetrahedral ion}}{Cr_2O_7^{2-}}$



(c) $\underset{\text{tetrahedral}}{MnO_4^-} + NO_2^- + H^+ \rightarrow Mn^{2+} + \underset{\text{trigonal plonar}}{NO_3^-}$

Redox Reaction



(d) $NO_3^- + H_2SO_4 + Fe^{2+} \rightarrow Fe^{3+} + NO_2 + H_2O$

Redox reaction

Previous Years' Questions

Mole Concept

Sol 1: Average atomic weight

$$= \frac{\text{Percentage of an isotope} \times \text{atomic weight}}{100}$$

$$\Rightarrow 10.81 = \frac{10.01x + 11.01(100 - x)}{100}$$

⇒ x = 20%

Therefore, natural boron contain 20% (10.01) isotope and 80% other isotope.

Sol 2: From the vapour density information,

Molar mass = Vapour density × 2

(∵ Molar mass of H_2 = 2)

= 38.3 × 2 = 76.6

Now, let us consider 1.0 mole of mixture and it contains x mole of N_2.

⇒ 46x + 92 (1 – x) = 76.6

⇒ x = 0.3348

Also, in 100 g mixture, number of moles $= \frac{100}{76.6}$

⇒ Moles of in mixture

$$= \frac{100}{76.6} \times 0.3348 = 0.437$$

Sol 3: Heating below 600ºC converts $Pb(NO_3)_2$ into PbO but to $NaNO_3$ into $NaNO_2$ as:

$$Pb(NO_3)_2 \xrightarrow{\Delta} PbO(s) + 2NO_2 \uparrow + \frac{1}{2}O_2 \uparrow$$

MW. 330 222

$$NaNO_3 \xrightarrow{\Delta} NaNO_2(s) + \frac{1}{2}O_2 \uparrow$$

MW.85 69

Weight loss $= 5 \times \frac{28}{100} = 1.4$ g

⇒ Weight of residue left = 5 – 1.4 = 3.6 g

Now, let the original mixture contain x g of $Pb(NO_3)_2$

$\because$ 330 g gives 222 g PbO

$\therefore$ x g $Pb(NO_3)_2$ will give $\frac{222\,x}{330}$ g PbO

Similarly, 85 g $NaNO_3$ gives 69 g

$\Rightarrow$ (5 – x)g will give

$\frac{69(5-x)}{85}$ g $NaNO_2$

$\Rightarrow$ Residue: $\frac{222x}{330}+\frac{69(5-x)}{85}=3.6g$

x = 3.3 g $Pb(NO_3)_2$

$\Rightarrow$ $NaNO_3$ = 1.7 g

Sol 4: Compound B forms hydrated crystals with $Al_2(SO_4)_3$ Also, B is formed with univalent metal on heating with sulphur. Hence, compound B must have the molecular formula M_2SO_4 and compound A must be an oxide of M which reacts with sulphur to give metal sulphate as

$$A+S\longrightarrow \underset{B}{M_2SO_4}$$

$\because$ 0.321 g sulphur gives 1.743 g of M_2SO_4

$\therefore$ 32.1 g S (one mole) will give 174.3 g M_2SO_4

Therefore, molar mass of M_2SO_4 = 174.3 g

$\Rightarrow$ 174.3 = 2 × Atomic weight of M + 32.1 + 64

$\Rightarrow$ Atomic weight of M = 39, metal is potassium (K)

K_2SO_4 on treatment with aqueous $Al_2(SO_4)_3$ gives potash-alum.

$$\underset{B}{K_2SO_4}+Al_2(SO_4)_3+24H_2O\longrightarrow \underset{C}{K_2SO_4Al_2(SO_4)_3\cdot 24H_2O}$$

If the metal oxide A has molecular formula MO_x, two moles of it combine with one mole of sulphur to give one mole of metal sulphate as

$$2KO_x+S\longrightarrow K_2SO_4$$

$\Rightarrow$ x = 2, i.e., A is KO_2.

Sol 5: 93% H_2SO_4 solution weight by volume indicates that there is 93 g H_2SO_4 in 100 mL of solution.

If we consider 100 mL solution, weight of solution = 184 g

Weight of H_2O in 100 mL solution

= 184 – 93 = 91 g

$$\Rightarrow \text{Molality}=\frac{\text{Moles of solute}}{\text{Weight of solvent (g)}}\times 1000$$

$$=\frac{93}{98}\times\frac{1000}{91}=10.43$$

Sol 6: Partial pressure of N_2 = 0.001 atm,

T = 298 K, V= 2.46 dm^3.

From Ideal Gas law : pV = nRT

$$n(N_2)=\frac{pV}{RT}=\frac{0.001\times 2.46}{0.082\times 298}=10^{-7}$$

$\Rightarrow$ No. of molecules of

$=6.023\times 10^{23}\times 10^{-7}$

$=6.023\times 10^{17}$

Surface sites used in adsorption

$$=\frac{20}{100}\times 6.023\times 10^{17}=2\times 6.023\times 10^{16}$$

$\Rightarrow$ Sites occupied per molecules

$$=\frac{\text{Number of sites}}{\text{Number of molecules}}=\frac{2\times 6.023\times 10^{16}}{6.023\times 10^{16}}=2$$

Sol 7: (D) The balanced chemical reaction is

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

In this reaction, 3 moles of $BaCl_2$ combined with 2 moles of Na_3PO_4 Hence, 0.5 mole of $BaCl_2$ requires

$\frac{2}{3}\times 0.5=0.33$ mole of Na_3PO_4.

Since available Na_3PO_4 (0.2 mole) is less than required mole (0.33), it is the limiting reactant and would determine the amount of product $Ba_3(PO_4)_2$.

$\because$ 2 moles of Na_3PO_4 gives 1 mole $Ba_3(PO_4)_2$

$\therefore$ 0.2 mole of Na_3PO_4 would give

$\frac{1}{2}\times 0.2$ = 0.1 mole $Ba_3(PO_4)_2$

Sol 8: (B) The following reaction occur between

$S_2O_3^{-2}$ and $Cr_2O_7^{-2}$:

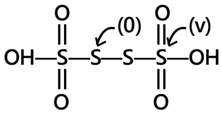
$$26H^{+}+3S_2O_3^{-2}+4Cr_2O_7^{-2}\longrightarrow 6SO_4^{-2}+8Cr^{3+}+13H_2O$$

Change in oxidation number of $Cr_2O_7^{-2}$ per formula unit is 6 (it is always fixed for $Cr_2O_7^{-2}$).

Hence, equivalent weight of $K_2Cr_2O_7$

$$=\frac{\text{Molecular weight}}{6}$$

Sol 9: $Na_2S_4O_6$ is a salt of $H_2S_4O_6$ which has the following structure



⇒ Difference in oxidation number of two types of sulphur = 5.

Sol 10: (B) 1. Both assertion and reason are factually true but the reason does not exactly explain the assertion. The correct explanation is, methyl orange and phenolphthalein changes their colours at different pH.

Sol 11: For the oxidation of A^{n+} as:

$A^{n+} \longrightarrow AO_3^-$ n-factor = 5 – n

Gram equivalent of A^{n+} = 2.68×10^{-3} (5 – n)

Now equating the above gram equivalent with gram equivalent of $KMnO_4$:

$2.68 \times 10^{-3}(5-n) = 1.61 \times 10^{-3} \times 5$

⇒ n = +2

Sol 12: The redox reaction involved is :

$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$

If M is molarity of H_2O_2 solution, then

$$5M = \frac{0.508 \times 1000}{254}$$

($\because$ 1 mole $H_2O_2 \equiv 1$ mole I_2)

⇒ M = 0.4

Also, n-factor of H_2O_2 is 2, therefore normality of H_2O_2 solution is 0.8 N.

⇒ Volume strength = Normality × 5.6

= 0.8 × 5.6 = 4.48 V

Sol 13: With $KMnO_4$ oxalate ion is oxidized only as:

$5C_2O_4^{-2} + 2MnO_4^- + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

Let, in the given mass of compound, x millimol of $C_2O_4^{-2}$ ion is present, then

Meq. of $C_2O_4^{-2}$ = Meq of MnO_4^-

⇒ 2x = 0.02 × 5 × 22.6; ⇒ x = 1.13

At the later stage, with I^-, Cu^{2+} is reduced as :

$2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$

and $I_2 + 2S_2O_3^{-2} \longrightarrow 2I^- + S_4O_6^{-2}$

Let there be x millimole of Cu^{2+}

⇒ Meq of Cu^{2+} = Meq of I_2 = meq of hypo

⇒ x = 11.3 + 0.05 = 0.565

⇒ Meq of Cu^{2+} : Meq of $C_2O_4^{-2}$ = 0.565 : 1.13 = 1 : 2

Sol 14: Let us consider 10 mL of the stock solution contain x millimol oxalic acid $H_2C_2O_4$ and y millimol of $NaHC_2O_4$. When titrated against NaOH, basicity of oxalic acid is 2 while that of $NaHC_2O_4$ is 1.

⇒ 2x + y = 3 × 0.1 = 0.3 ...(i)

When titrated against acidic $KMnO_4$, n-factor of both oxalic acid and $NaHC_2O_4$ would be 2.

2x + 2y = 4 × 0.1 = 0.4 ...(ii)

Solving equations (i) and (ii) gives y = 0.1, x = 0.1.

⇒ In 1.0 L solution, mole of $= \frac{0.1}{1000} \times 100 = 0.01$

Mole of $NaHC_2O_4$ $= \frac{0.1}{1000} \times 100 = 0.01$

⇒ Mass of $H_2C_2O_4$ = 90 × 0.01 = 0.9 g

Mass of $NaHC_2O_4$ = 112×0.01 = 1.12 g

Sol 15: (D) (p) $PbO_2 + H_2SO_4 \xrightarrow{\Delta} PbSO_4 + O_2 + \frac{1}{2}O_2$

(q) $2Na_2S_2O_3 + Cl_2 + 2H_2O$
$\longrightarrow 2NaCl + 2NaHSO_4 + 2S$

(r) $N_2H_4 + 2I_2 \longrightarrow N_2 + 4HI$

(s) $XeF_2 + 2NO \longrightarrow Xe + 2NOF$

Sol 16: (A, B, D) The balanced equation is

$ClO_3^- + 6I^- + 6H_2SO_4 \rightarrow 3I_2 + Cl^- + 6HSO_4^- + 3H_2O$

Sol 17: (A) $KIO_4 + H_2O_2 \rightarrow KIO_3 + H_2O + O_2$

$NH_2OH + 3H_2O_2 \rightarrow HNO_3 + 4H_2O$