MODEL QUESTION PAPER
(With Full Solution and Marking Scheme)

Time : 3 Hours] **[Total Marks : 70**

General Instructions :

The question paper is divided into four sections.

(1) ***Section A :*** *Q. No.* ***1*** *contains* ***ten*** *multiple choice type of questions carrying* ***one*** *mark each.*
Q. No. ***2*** *contains* ***eight*** *very short answer type of questions carrying* ***one*** *mark each.*

(2) ***Section B :*** *Q. No.* ***3*** *to Q. No.* ***14*** *are* ***twelve*** *short answer type of questions carrying* ***two marks*** *each. (Attempt* ***any eight****)*

(3) ***Section C :*** *Q. No.* ***15*** *to Q. No.* ***26*** *are* ***twelve*** *short answer type of questions carrying* ***three*** *marks each. (Attempt* ***any eight****)*

(4) ***Section D :*** *Q. No.* ***27*** *to Q. No.* ***31*** *are* ***five*** *long answer type of questions carrying* ***four*** *marks each. (Attempt* ***any three****)*

(5) Use log table is allowed. Use of calculator is not allowed.

(6) Figures to the right indicate full marks.

(7) For each multiple choice type of question, it is mandatory to write the correct answer along with its alphabet,
e.g., (a) ....../ (b) ....../ (c) ....../ (d) ...... , etc.
No mark(s) shall be given, if ONLY the correct answer or the alphabet of the correct answer is written.
Only the first attempt will be considered for evaluation.

SECTION – A

Q. 1. Select and write the correct answer for the following multiple choice type of questions : **[10]**

(i) The reaction,

$CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$ is of

(a) zero order

(b) first order

(c) second order

(d) pseudo first order reaction

(ii) In Frenkel defect
   (a) electrical neutrality of the substance is changed.
   (b) density of the substance is changed.
   (c) both cation and anion are missing.
   (d) overall electrical neutrality is preserved.

(iii) Tryptophan is called essential amino acid because
   (a) it contains aromatic nucleus.
   (b) it is present in all the human proteins.
   (c) it cannot be synthesised by human body.
   (d) it is an essential constituent of enzymes.

(iv) Bond enthalpies of $H-H$, $Cl-Cl$ and $H-Cl$ bonds are 434 kJ mol^{-1}, 242 kJ mol^{-1} and 431 kJ mol^{-1}, respectively. Enthalpy of formation of HCl is
   (a) 245 kJ mol^{-1} (b) $-$93 kJ mol^{-1}
   (c) $-$245 kJ mol^{-1} (d) 93 kJ mol^{-1}

(v) Identify the correct statement :
   (a) Vapour pressure of solution is higher than that of pure solvent.
   (b) Boiling point of solvent is lower than that of solution.
   (c) Osmotic pressure of solution is lower than that of solvent.
   (d) Osmosis is a colligative property.

(vi) In which of the following series all the elements are radioactive in nature
   (a) Lanthanides   (b) Actinides
   (c) *d*-block elements   (d) *s*-block elements

(vii) The number of carbon atoms present in the ring of ε-caprolactam is
   (a) Five   (b) Two   (c) Seven   (d) Six

(viii) Name the body part that gets affected by the hazardous nano pollution.
   (a) heart   (b) brain   (c) lungs   (d) eyes

(ix) The species which will behave both as a conjugate acid and base is
   (a) NH_4OH (b) CO_3^{--} (c) HSO_4^- (d) H_2SO_4

(x) Which of the following has the highest basic strength?
   (a) Trimethylamine   (b) Methylamine
   (c) Ammonia   (d) Dimethylamine

Ans. (i) (d) pseudo first order reaction (ii) (d) overall electrical neutrality is preserved (iii) (c) It cannot be synthesised by human body (iv) (b) -93 kJ mol^{-1} (v) (b) Boiling point of solvent is lower than that of solution (vi) (b) Actinides (vii) (d) Six (viii) (c) lungs (ix) (c) HSO_4^- (x) (d) Dimethylamine. ***(1 mark each)***

Q. 2. Answer the following questions : **[8]**

(i) Write the electrode reactions during electrolysis of molten KCl.

Ans. $KCl_{(molten)} \rightarrow K^+_{(l)} + Cl^+_{(l)}$

Reaction at cathode :

$2K^+_{(l)} + 2e^- \rightarrow 2K_{(s)}$ Reduction

Reaction at anode :

$2Cl^-_{(l)} \rightarrow 2Cl_{(g)} + 2e^-$

$2Cl_{(g)} \rightarrow Cl_{2(g)}$

Overall reaction : $2K^+_{(l)} + 2Cl^-_{(l)} \rightarrow 2K_{(s)} + Cl_{2(g)}$ ***(1 mark)***

(ii) What are interstitial compounds of transition metals?

Ans.

(1) The interstitial compounds of the transition metals are those which are formed when small atoms like H, C or N are trapped inside the interstitial vacant spaces in the crystal lattices of the metals.

(2) Sometimes, sulphides and oxides are also trapped in the crystal lattices of transition elements.

(3) Presence of these elements in the crystal lattices of metals provide new properties to the metals. ***(1 mark)***

(iii) Define Solvate or Hydrate isomerism.

Ans. Solvate or Hydrate isomerism : The phenomenon of isomerism in the coordination compounds arising due to the exchange of solvent or H_2O molecules inside the coordination sphere and outer sphere of the complex is known as solvate or hydrate isomerism. E.g. $[Co(H_2O)_4Cl_2] . 2H_2O$ and $[Co(H_2O)_3Cl_3] . 3H_2O$ ***(1 mark)***

(iv) Explain the following term :

Relative lowering of vapour pressure.

Ans. If P_0 and P are the respective vapour pressures of a pure liquid (solvent) and the solution containing a nonvolatile solute then $P < P_0$. Hence,

$P_0 - P$ represents the lowering of the vapour pressure due to addition of a nonvolatile solute.

$\therefore$ Relative lowering of vapour pressure

$$= \frac{P_0 - P}{P_0} = \frac{\Delta P}{P_0}\ .$$ ***(1 mark)***

(v) Why does fluorine show anomalous behaviour?

Ans. Fluorine exhibits anomalous behaviour as compared to other halogens in the group. The reasons for anomalous behaviour of fluorine are as follows :

(1) the smallest size of fluorine

(2) the highest electronegativity

(3) low bond dissociation enthalpy of F–F bond

(4) non-availability of *d*-orbitals in its valence shell. ***(1 mark)***

(vi) Name the reagents for the complete hydroboration-oxidation reaction in step 1 and step 2.

Ans. Step 1 : Diborane

Step 2 : Hydrogen peroxide and dil. NaOH. ***(1 mark)***

(vii) Acetic acid is prepared from methyl magnesium bromide and dry ice in presence of dry ether. Name the compound which serves not only reagent but also as cooling agent in the reaction.

Ans. The cooling agent used in the above reaction is dry ice ($O=C=O$).

(1 mark)

(viii) What is the standard enthalpy of combustion? Give an example.

Ans. Standard enthalpy of combustion or standard heat of combustion : It is defined as the enthalpy change when one mole of a substance in the standard state undergoes complete combustion in a sufficient amount of oxygen at constant temperature (298 K) and pressure (1 atmosphere or 1 bar). It is denoted by $\Delta_C H^0$.

E.g. $CH_3OH_{(l)} + \frac{3}{2} O_{2(g)} = CO_{2(g)} + 2H_2O \quad \Delta_C H^0 = -726 \text{ kJ mol}^{-1}$

($\Delta_C H^0$ is always negative.) ***(1 mark)***

SECTION – B

Attempt any *Eight* of the following questions : [16]

Q. 3. What are actinoids? Give their general electronic configuration.

Ans.

(1) **Actinoids :** The series of fourteen elements from $_{90}$Th to $_{103}$Lr which follow actinium ($_{89}$Ac) and in which differentiating electrons are progressively filled in 5 *f*-orbitals in prepenultimate shell are called actinoids. ***(1 mark)***

(2) Their general electronic configuration is, $[\text{Rn}]^{86}\, 5f^{1-14} 6d^{0-1}\, 7s^2$. ***(1 mark)***

Q. 4. When 2.2 moles of an ideal gas are expanded from 3.5 dm^3 to 12 dm^3 against a constant pressure, the work obtained is 3910 J. Estimate the external pressure.

Solution :

Given : $n = 2.2$ mol; $V_1 = 3.5$ dm^3; $V_2 = 12$ dm^3

$$W = -3910\ \text{J} = \frac{-3910}{100}\ \text{dm}^3\ \text{bar}$$

$$W = -P_{\text{ex}}(V_2 - V_1)$$ ***(1 mark)***

$$\therefore\ P_{\text{ex}} = \frac{-W}{(V_2 - V_1)}$$

$$= \frac{-\left(\frac{-3910}{100}\right)\text{dm}^3\ \text{bar}}{(12 - 3.5)\ \text{dm}^3}$$ ***(1 mark)***

$$= 4.6\ \text{bar}$$

Ans. P_{ex} = **4.6 bar**

Q. 5. What are high spin and low spin complexes?

Ans.

(1) High spin complex (HS) :

(i) The complex which has greater number of unpaired electrons and hence higher value of resultant spin and magnetic moment is called high spin (or spin free) or HS complex.

(ii) It is formed with weak field ligands and the complexes have lower values for crystal field splitting energy (CFSE), Δ_0.

(iii) The paramagnetism of HS complex is larger. ***(1 mark)***

(2) Low spin complex (LS) :

(i) The complex which has the least number of unpaired electrons or all electrons paired and hence the lowest (or no) resultant spin or magnetic moment is called low spin (or spin paired) or LS complex.

(ii) It is formed with strong field ligands and the complexes have higher values of crystal field splitting energy (Δ_0).

(iii) Low spin complex is diamagnetic or has low paramagnetism.

(1 mark)

Q. 6. What are the general compositions of interhalogen compounds?

Ans.

(i) The general compositions of interhalogen compounds are XX', XX'_3, XX'_5 and XX'_7 where halogen X is more electropositive and has larger size than another halogen X′. For example, ***(1 mark)***

XX'	XX'_3	XX'_5	XX'_7
ClF	ClF_3	ClF_5	IF_7
BrF	BrF_3	BrF_5	
$BrCl$	IF_3	IF_5	
ICl	ICl_3		
	(unstable)		

(ii) As the ratio of radii of X and X′ increases, the number of atoms of X′ per molecule of interhalogen compound increases. For example, iodine having the largest size with fluorine of the smallest size forms stable IF_7.

(1 mark)

Q. 7. How to apply the principle of green chemistry to achieve energy efficiency?

Ans.

(1) Energy requirements during chemical synthesis is huge. To minimize the energy use it is better to carry out reactions at room temperature and pressure. ***(1 mark)***

(2) This can be achieved by applying the principle of green chemistry, i.e. use of catalyst, use of micro-organisms or biocatalyst and use of renewable materials, etc. ***($\frac{1}{2}$ mark)***

(3) The use of less energy can be achieved by improving the technology of heating system, use of microwave, etc. ***($\frac{1}{2}$ mark)***

Q. 8. Express the rate of a reaction in terms of change in concentration of each constituent in the following reaction :

$$\boldsymbol{a\mathrm{A} + b\mathrm{B} \rightarrow c\mathrm{C} + d\mathrm{D}}$$

Ans. The rate of a reaction may be expressed in terms of decrease in concentration of the reactants or increase in concentration of the product per unit time,

$\therefore$ for the given reaction,

$$a\mathrm{A} + b\mathrm{B} \rightarrow c\mathrm{C} + d\mathrm{D}$$

$$\text{Rate of a reaction} = -\frac{1}{a}\frac{\Delta[\mathrm{A}]}{\Delta t}$$

$$= -\frac{1}{b}\frac{\Delta[\mathrm{B}]}{\Delta t}$$ ***(1 mark)***

$$= +\frac{1}{c}\frac{\Delta[\mathrm{C}]}{\Delta t}$$

$$= +\frac{1}{d}\frac{\Delta[\mathrm{D}]}{\Delta t}$$ ***(1 mark)***

$$\left[\text{OR Rate of a reaction} = -\frac{1}{a}\frac{d\,[\mathrm{A}]}{dt} = -\frac{1}{b}\frac{d\,[\mathrm{B}]}{dt} = +\frac{1}{c}\frac{d\,[\mathrm{C}]}{dt} = +\frac{1}{d}\frac{d\,[\mathrm{D}]}{dt}\right]$$

Q. 9. Give reasons :

Reactions involving Grignard reagent must be carried out under anhydrous condition.

Ans.

(1) Grignard reagent (R Mg X) is an organometallic compound. The carbon-magnesium bond is highly polar and magnesium halogen bond is in ionic in nature. Grignard reagent is highly reactive. ***(1 mark)***

(2) The reactions of Grignard reagent are carried out in dry conditions because traces of moisture may spoil the reaction and Grignard reagent reacts with water to produce alkane. Hence, reactions involving Grignard reagent must be carried out under anhydrous condition. ***(1 mark)***

Q. 10. Boiling point of a solvent is 80.2 °C. When 0.419 g of the solute of molar mass 252.4 g mol^{-1} is dissolved in 75 g of the above solvent, the boiling point of the solution is found to be 80.256 °C. Find the molal elevation constant.

Solution :

Given : $T_0 = (273 + 80.2)$ K

$T_b = 273 + 80.256$ (K)

$W_1 = 75$ g

$W_2 = 0.419$ g

$M_2 = 252.4$ g mol^{-1}

$K_b = ?$

$$\Delta T_b = T_b - T_0$$

$$= (273 + 80.256) - (273 + 80.2) = 0.056 \text{ K}$$

$$\Delta T_b = K_b \times \frac{W_2 \times 1000}{W_1 \times M_2}$$ ***(1 mark)***

$$\therefore K_b = \Delta T_b \times \frac{W_1 \times M_2}{W_2 \times 1000}$$

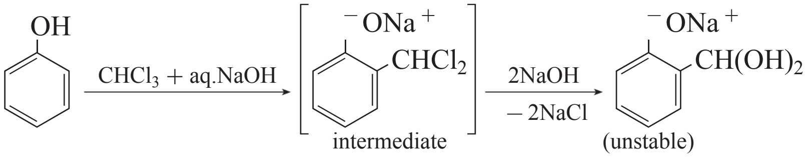
$$= 0.056 \times \frac{75 \times 252.4}{0.41 \text{ g} \times 1000}$$ ***(1 mark)***

$$= 2.53 \text{ K kg mol}^{-1}$$

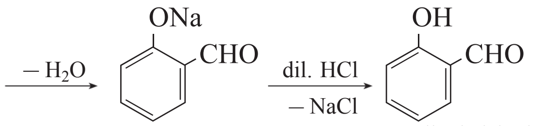
Ans. $K_b =$ **2.53 K kg** $\mathbf{mol^{-1}}$.

Q. 11. Explain Reimer–Tiemann reaction.

Ans. Reimer–Tiemann reaction : Phenol is heated with chloroform along with aqueous NaOH, this is followed by acidification with dil. HCl when salicyladehyde (2-hydroxy benzaldehyde) is formed as the major product, which can be separated from *p*-isomer by steam distillation. The stability of *o*-isomer is due to intramolecular hydrogen bonding.



(1 mark)



o-salicyladehyde or
2-hydroxybenzaldehyde

(1 mark)

Q. 12. Define (i) Oxidation potential (ii) Standard reduction potential

Ans.

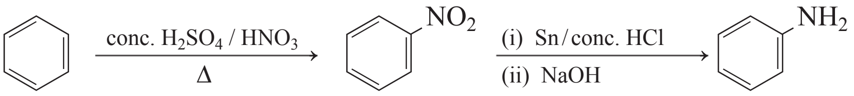
(i) Oxidation potential : It is defined as the difference of electrical potential between metal electrode surface and the solution around it at equilibrium developed due to oxidation reaction at anode and at constant temperature. ***(1 mark)***

(ii) Standard reduction potential : It is defined as the difference of electrical potential between metal electrode surface and the solution around it at equilibrium due to reduction reaction, when all the substances involved in the reduction reaction are in their standard states of unit activity or concentration at constant temperature. ***(1 mark)***

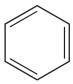
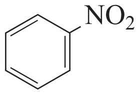
Q. 13. Identify the compounds A and B in the following reactions :

$$\mathbf{A} \xrightarrow{\textbf{Nitrating mixture}} \mathbf{B} \xrightarrow[\textbf{(ii) NaOH}]{\textbf{(i) Sn / conc. HCl}} \textbf{Aniline?}$$

Ans.



benzene nitrobenzene aniline

A is  benzene ***(1 mark)*** and B is  nitrobenzene ***(1 mark)***

Q. 14. Calculate pH and pOH of 0.02 M HCl solution.

Solution :

Given : $C = 0.02$ M HCl; pH = ? pOH = ?

$$\underset{}{HCl_{(aq)}} \longrightarrow \underset{0.02\text{ M}}{\overset{+}{H}_{(aq)}} + \overset{-}{Cl}_{(aq)}$$

$$[H^+] = [H_3O^+] = 0.02\text{ M}$$

$$\begin{aligned} pH &= -\log_{10}[H_3O^+] \\ &= -\log_{10} 0.02 \\ &= -(\bar{2}.3010) \\ &= 2 - 0.3010 \\ &= 1.699 \end{aligned}$$

(1 mark)

$$\begin{aligned} pH + pOH &= 14 \\ \therefore\ pOH &= 14 - pH \\ &= 14 - 1.699 \\ &= 12.3010 \end{aligned}$$

Ans. pH = **1.6990**; pOH = **12.3010**. ***(1 mark)***

SECTION – C

Attempt any *Eight* of the following questions : **[24]**

Q. 15. What is the action of Cl_2 on

(i) Cold and dil. NaOH

(ii) Hot and conc. NaOH

(iii) Iron (II)

Ans.

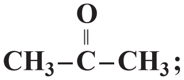
(i) $\underset{\text{(dil.)}}{Cl_2 + 2NaOH} \xrightarrow{\text{cold}} NaCl + \underset{\text{Sodium hypochlorite}}{NaOCl} + H_2O$ ***(1 mark)***

(ii) $\underset{\text{(conc.)}}{Cl_2 + 6NaOH} \xrightarrow{\text{hot}} 5NaCl + \underset{\text{Sodium chlorate}}{NaClO_3} + 3H_2O$ ***(1 mark)***

(iii) $2FeSO_4 + H_2SO_4 + Cl_2 \longrightarrow Fe_2(SO_4)_3 + 2HCl$ ***(1 mark)***

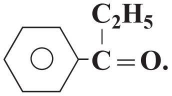
Q. 16. Explain Wolff–Kishner reduction in

(i) CH_3-CHO; (ii)

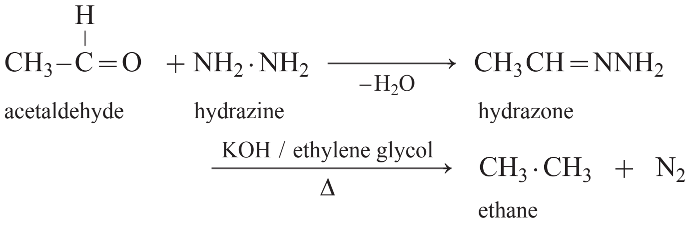


$CH_3-\overset{\overset{O}{\|}}{C}-CH_3$;

(iii)

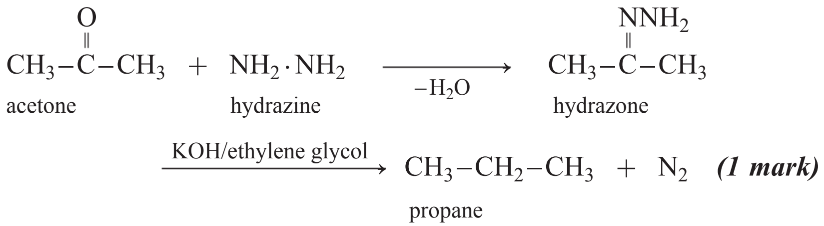


Ans. Hydrazine ($NH_2\cdot NH_2$) reduces carbonyl group ($>C=O$) of aldehydes or ketones to methylene group ($>CH_2$). When aldehyde or ketone is heated with hydrazine in the presence of base such as potassium hydroxide and ethylene glycol, an alkane is obtained due to reduction of carbonyl compound.



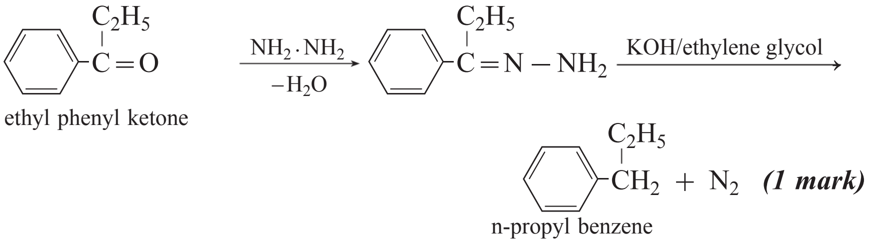
$$\underset{\text{acetaldehyde}}{CH_3-\overset{\overset{H}{|}}{C}=O} + \underset{\text{hydrazine}}{NH_2\cdot NH_2} \xrightarrow[-H_2O]{} \underset{\text{hydrazone}}{CH_3CH=NNH_2} \xrightarrow[\Delta]{\text{KOH / ethylene glycol}} \underset{\text{ethane}}{CH_3\cdot CH_3} + N_2$$

(1 mark)



$$\underset{\text{acetone}}{CH_3-\overset{\overset{O}{\|}}{C}-CH_3} + \underset{\text{hydrazine}}{NH_2\cdot NH_2} \xrightarrow[-H_2O]{} \underset{\text{hydrazone}}{CH_3-\overset{\overset{NNH_2}{\|}}{C}-CH_3} \xrightarrow{\text{KOH/ethylene glycol}} \underset{\text{propane}}{CH_3-CH_2-CH_3} + N_2$$

(1 mark)



(1 mark)

Q. 17. (i) What is a unit cell?

(ii) Explain tetrahedral void.

Ans.

(i)

(1) **Unit cell :** It is the smallest repeating structural unit of a crystalline solid (or crystal lattice) which when repeated in different directions produces the crystalline solid (lattice).

(2) The crystal is considered to consist of an infinite number of unit cells.

(3) The unit cell possesses all the characteristics of the crystalline solid.

(1 mark)

(ii)

(1) Tetrahedral void : The vacant space or void among four constituent particles having tetrahedral arrangement in the crystal lattice is called tetrahedral void.

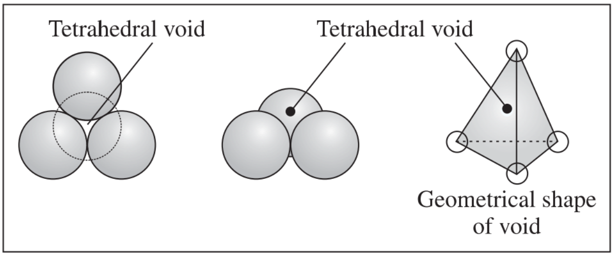


Fig. Tetrahedral void

The arrangement of four spheres around the void is tetrahedral. A tetrahedral void is formed when a triangular void made by three coplanar spheres is in contact with fourth sphere above or below it.

(1 mark)

(2) Characteristics of tetrahedral void :

(a) The volume of the void is much smaller than that of atom or sphere.

(b) Larger the size of sphere, more is the size of void.

(c) If R is the radius of the constituent atom, then the radius of the tetrahedral void is 0.225 R.

(d) Coordination number of tetrahedral void is four.

(e) There are two tetrahedral voids per sphere, in the crystal lattice. If the number of closed packed spheres is N, then the number of tetrahedral voids is 2N. ***(1 mark)***

Q. 18. (i) Write the order of the thermal stability of the hydrides of group 16 elements.

(ii) Arrange the halogen acids in the decreasing order of :

(a) Thermal stability (b) Acidic strength.

Ans.

(i) The thermal stability of the hydrides of group 16 elements decreases in the order of

$H_2O > H_2S > H_2Se > H_2Te$. ***(1 mark)***

(ii)

(a) Thermal stability : As the atomic size increases from F to I, the bond dissociation enthalpy of H–X decreases.

Thus, the thermal stability of hydrogen halides decreases down the group in the order

$HF > HCl > HBr > HI$ ***(1 mark)***

(b) Acidic strength : Since the bond dissociation enthalpy of H–X decreases down the group, the acidic strength varies in the order

$HI > HBr > HCl > HF$ ***(1 mark)***

Q. 19. How can alcohols be distinguished with the help of Lucas reagent?

Ans. Lucas reagent is a mixture of concentrated HCl and anhydrous $ZnCl_2$. It is used to distinguish between primary, secondary and tertiary alcohols.

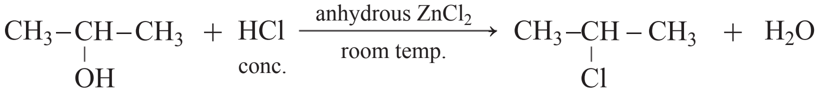
Alcohols are soluble in Lucas reagent. Alcohol with Lucas reagent forms an alkyl chloride, R–Cl which is insoluble and gives cloudiness and forms separate layer.

The time required for cloudiness to appear is based on the type of the alcohol and its reactivity :

(1) Primary alcohol : It reacts with the Lucas reagent very slowly and on heating forms alkyl chloride. The cloudiness and separation of a layer takes place after a long time on heating.

$$\underset{\text{ethyl alcohol}}{C_2H_5-OH} + \underset{\text{conc.}}{HCl} \xrightarrow[\Delta]{\text{anhydrous } ZnCl_2} \underset{\text{ethyl chloride}}{C_2H_5-Cl} + H_2O$$ ***(1 mark)***

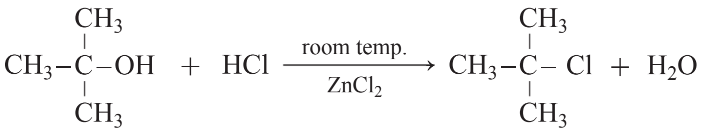
(2) Secondary alcohol : It reacts with the Lucas reagent much faster to form alkyl chloride. The cloudiness and separation of layer takes place slowly.



$$\underset{\text{isopropyl alcohol}}{CH_3-\underset{\displaystyle OH}{\underset{|}{C}H}-CH_3} + \underset{\text{conc.}}{HCl} \xrightarrow[\text{room temp.}]{\text{anhydrous } ZnCl_2} \underset{\text{isopropyl chloride}}{CH_3-\underset{\displaystyle Cl}{\underset{|}{C}H}-CH_3} + H_2O$$

isopropyl alcohol isopropyl chloride ***(1 mark)***

(3) Tertiary alcohol : It reacts immediately with the Lucas reagent at room temperature to form alkyl chloride. The cloudiness and separation of layer takes place instantaneously.



$$CH_3-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-OH + HCl \xrightarrow[ZnCl_2]{\text{room temp.}} CH_3-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-Cl + H_2O$$

tert-butyl alcohol tert-butyl chloride ***(1 mark)***

Q. 20. Explain the variation of molar conductivity with concentration for strong and weak electrolytes. *OR*

How is the molar conductivity of strong electrolytes at zero concentration determined by graphical method? Why is this method not useful for weak electrolytes?

Ans.

(1) As the dilution of an electrolytic solution increases (or concentration decreases), the dissociation of the electrolyte increases and hence the total number of ions increases, therefore, the molar conductivity increases.

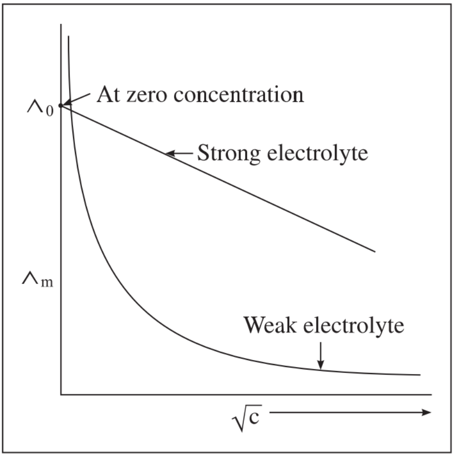


Fig. Variation of molar conductivity with $\sqrt{c}$ ***(1 mark)***

(2) The increase in molar conductivity with increase in dilution or decrease in concentration is different for strong and weak electrolytes. ***($\frac{1}{2}$ mark)***

(3) On dilution, the molar conductivity of strong electrolytes increases rapidly and approaches to a maximum limiting value at infinite dilution or zero concentration and represented as $\wedge\infty$ or $\wedge_0$ or $\wedge_m^0$.

In case of weak electrolytes which dissociate less as compared to strong electrolytes, the molar conductivity is low and increases slowly in high concentration region, but increases rapidly at low concentration or high dilution. This is because the extent of dissociation increases with dilution rapidly. ***($\frac{1}{2}$ mark)***

(4) $\wedge_0$ values for strong electrolytes can be obtained by extrapolating the linear graph to zero concentration (or infinite dilution). However $\wedge_0$ for the weak electrolytes cannot be obtained by this method, since the graph increases exponentially at very high dilution and does not intersect $\wedge_m$ axis at zero concentration. ***(1 mark)***

Q. 21. Explain the trend in the following atomic properties of group 16 elements :

(i) Atomic and ionic radii; (ii) Ionisation enthalpy;

(iii) Electronegativity.

Ans.

(i) Atomic and ionic radii :

(1) As compared to group 15 elements, the atomic and ionic radii of group 16 elements are smaller due to higher nuclear charge.

(2) The atomic and ionic radii increase down the group from oxygen to polonium. This is due to the addition of a new shell at each successive element on moving down the group.

The atomic radii increases in the order O $<$ S $<$ Se $<$ Te $<$ Po.

(1 mark)

(ii) Ionisation enthalpy :

(1) The ionisation enthalpy of group 16 elements has quite high values.

(2) Ionisation enthalpy decreases down the group from oxygen to polonium. This is due to the increase in atomic volume down the group.

(3) The first ionisation enthalpy of the lighter elements of group 16 (O, S, Se) have lower values than those of group 15 elements in the corresponding periods. This is due to difference in their electronic configurations.

Group 15 : (valence shell) $ns^2 \ np_x^1 \ np_y^1 \ np_z^1$

Group 16 : (valence shell) $ns^2 \ np_x^2 \ np_y^1 \ np_z^1$

Group 15 elements have extra stability of half filled and more symmetrical orbitals, while group 16 elements acquire extra stability by losing one of paired electrons from np_x-orbital forming half filled p-orbitals.

Hence group 16 elements have lower first ionisation enthalpy than group 15 elements. ***(1 mark)***

(iii) Electronegativity :

(1) The electronegativity values of group 16 elements have higher values than corresponding group 15 elements in the same periods.

(2) Oxygen is the second most electronegative element after fluorine. (O = 3.5, F = 4)

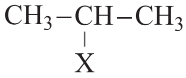
(3) On moving down the group electronegativity decreases from oxygen to polonium.

(4) On moving down the group atomic size increases, hence nuclear attraction decreases, therefore electronegativity decreases.

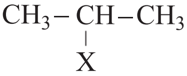
Elements	O	S	Se	Te	Po
Electronegativity	3.5	2.44	2.48	2.01	1.76

(1 mark)

Q. 22. Match the pairs :

Column I	**Column II**
(i)  $CH_3-\underset{\large X}{\underset{\vert}{C}}H-CH_3$ (ii) $CH_2=CH-CH_2X$ (iii) $CH_2=CH-X$	(a) vinyl halide (b) alkyl halide (c) allyl halide (d) benzyl halide (e) aryl halide

Ans.

(i)  $CH_3-\underset{\large X}{\underset{\vert}{C}}H-CH_3$ – (b) alkyl halide ***(1 mark)***

(ii) $CH_2=CH-CH_2X$ – (c) allyl halide ***(1 mark)***

(iii) $CH_2=CH-X$ – (a) vinyl halide ***(1 mark)***

Q. 23. Calculate the number of particles and unit cells in '*x*' g of metallic crystal.

Ans. Consider 'x' gram of a metallic crystal of molar mass M and density ρ. If the unit cell of the crystal has edge length 'a', then volume of unit cell $= a^3$.

Mass of one metal atom $= \frac{M}{N_A}$. If 'n' number of atoms are present in one unit cell, then

$$\text{Mass of unit cell} = \frac{n \times M}{N_A}.$$

If 'a' is the edge length of the unit cell, then

Volume of unit cell $= a^3$

$$\text{Density of unit cell} = \rho = \frac{n \times M}{N_A} \times \frac{1}{a^3}$$

$$\therefore M = \frac{\rho \times N_A \times a^3}{n}$$

$\because$ Molar mass M gram contains N_A particles

$\therefore$ x gram contains $\dfrac{x \times N_A}{M}$ particles. ***(1 mark)***

Substituting the value M,

(1) Number of particles in x g crystal

$$= \frac{x \times N_A}{\rho \times N_A \times a^3/n}$$

$$= \frac{x \times n}{\rho \times a^3} \text{ particles}$$ ***(1 mark)***

(2) Number of unit cells in x g crystal :

$\because$ n particles are present in 1 unit cell

$\therefore$ $\dfrac{x \times n}{\rho \times a^3}$ are present in, $\dfrac{x \times n}{\rho \times a^3} \times \dfrac{1}{n}$ unit cells $= \dfrac{x}{\rho \times a^3}$ unit cells

(1 mark)

(3) Number of unit cells in V volume of crystal $= \dfrac{V}{a^3}$

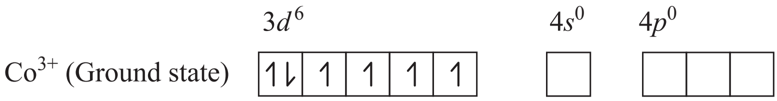
Q. 24. Explain the structure of octahedral complex, $[CO(NH_3)_6]^{3+}$ on the basis of valence bond theory.

Ans.

(1) Hexaamminecobalt(III) ion, $[CO(NH_3)_6]^{3+}$ is a cationic complex, the oxidation state of cobalt is + 3 and the coordination number is 6.

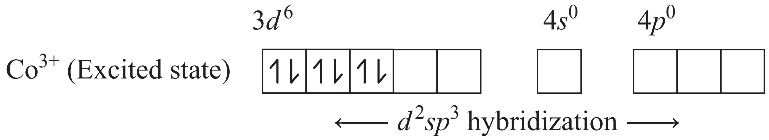
(2) Electronic configuration : $_{27}Co\ [Ar]^{18}\ 3d^7 4s^2$

Electronic configuration : $Co^{3+}\ [Ar]^{18}\ 3d^6 4s^0 4p^0$



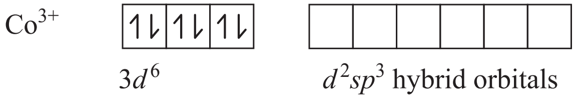
(1 mark)

(3) Since NH_3 is a strong ligand, due to spin pairing effect, all the four unpaired electrons in 3d-orbital are paired giving two vacant 3d-orbitals.



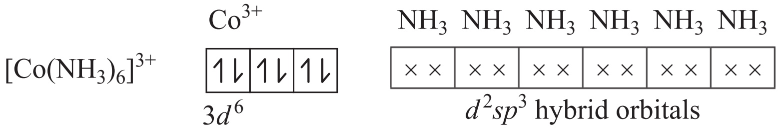
(4) Since the coordination number is 6, Co^{3+} ion gets six vacant orbitals by hybridization of two 3d vacant orbitals, one 4s and three 4p-orbitals

forming six d^2sp^3 hybrid orbitals giving *octahedral geometry.* It is an inner complex.

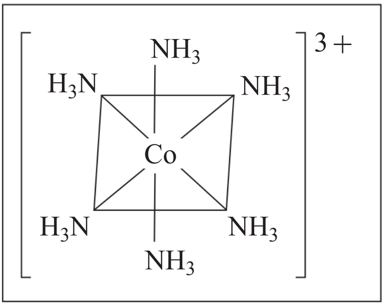


(1 mark)

(5) 6 lone pairs of electrons from $6NH_3$ ligands are accommodated in the six vacant d^2sp^3 hybrid orbitals. Thus six hybrid orbitals of Co^{3+} overlap with filled orbitals of NH_3 forming 6 coordinate bonds giving octahedral geometry to the complex.



Since the complex has all electrons paired, it is diamagnetic.



$[Co(NH_3)_6]^{3+}$ ***(1 mark)***

Fig. Structure of $[Co(NH_3)_6]^{3+}$

Complex	**Hybridization**	**Geometry**	**Magnetic property**
$[Co(NH_3)_6]^{3+}$	d^2sp^3 (inner)	Octahedral	Diamagnetic ($\mu = 0$)

Q. 25. (i) What is the order of the following reaction :

$$2N_2O_{5(g)} \longrightarrow 4NO_{2(g)} + O_{2(g)} \qquad \text{Rate} = k\,[N_2O_5]$$

(ii) Define and explain the term order of a chemical reaction.

Ans.

(i) Since the rate of the reaction is,

Rate $= k\,[N_2O_5]$

the reaction is of first order.

(ii) **Order of a chemical reaction :** The order of a chemical reaction is defined as the number of molecules (or atoms) whose concentrations influence the rate of the chemical reaction. *OR*

The order of a chemical reaction is defined as the sum of the powers (or exponents) to which the concentration terms of the reactants are raised in the rate law expression for the given reaction. ***(1 mark)***

Explanation : Consider a reaction,

$$n_1\text{A} + n_2\text{B} \longrightarrow \text{Products}$$

where n_1 moles of A react with n_2 moles of B.

The rate of this reaction can be expressed by the rate law equation as,

$R = k\,[\text{A}]^{n_1}\,[\text{B}]^{n_2}$ ***(1 mark)***

where k is the rate constant of the reaction, hence, the order of the reaction is

$n = n_1 + n_2$, (observed, experimentally).

If $n = 1$, the reaction is called the first order reaction, if $n = 2$, it is called the second order reaction, etc. ***(1 mark)***

If $n = 0$, it is called the zero order reaction, e.g., photochemical reaction of $H_{2(g)}$ and $Cl_{2(g)}$.

Q. 26. (i) What are different types of RNA which are found in the cell?

(ii) How many primary amines are possible for the compound C_3H_9N?

(iii) Consider the complexes $[Cu(NH_3)_4]\,[PtCl_4]$ and $[Pt(NH_3)_4]\,[CuCl_4]$. What type of isomerism these two complexes exhibit?

Ans.

(i) There are three different types of RNA found in the cell. (1) The messenger RNA which carries the message to the ribosome. (2) Ribosomal RNA where synthesis of protein takes place. (3) The transport RNA. ***(1 mark)***

(ii) For the compound C_3H_9N, two primary amines are possible.

(1 mark)

(iii) Since in these two given complexes, there is an exchange of ligands between cationic and anionic constituents, they exhibit coordination isomerism. ***(1 mark)***

SECTION – D

Attempt any *Three* of the following questions : [12]

Q. 27. (i) Derive the relation between molar mass of the solute and boiling point elevation.

(ii) State (or write) Nernst equation for the electrode potential and explain the terms involved.

Ans.

(i) The boiling point elevation, ΔT_b of a solution is directly proportional to molality (m) of the solution.

$\therefore \Delta T_b \propto m$

$\therefore \Delta T_b = K_b m$

where K_b is a proportionality constant

If $m = 1$ molal, then

$\Delta T_b = K_b$

where K_b is called molal elevation constant.

The molality of the solution is given by,

$$m = \frac{\text{Number of moles of the solute}}{\text{Weight of the solvent in kg}}$$

Let W_1 = Weight (in gram) of a solvent,

W_2 = Weight (in gram) of a solute *(1 mark)*

M_2 = Molecular weight of the solute

Then the molality (m) of the solution is given by

$$m = \frac{W_2 \times 1000}{W_1 M_2} = \frac{\overset{\text{kg}}{W_2}}{\underset{\text{kg}}{W_1} \times \underset{\text{kg mol}^{-1}}{M_2}} \text{ mol kg}^{-1}$$

$$\therefore \Delta T_b = K_b \times \frac{W_2 \times 1000}{W_1 M_2}$$

$$\therefore M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$OR \quad M_2 = \frac{\overset{\text{K kg mol}^{-1}}{K_b} \times \overset{\text{kg}}{W_2}}{\underset{\text{K}}{\Delta T_b} \times \underset{\text{kg}}{W_1}} \text{ kg mol}^{-1}$$

If the weights and molecular weight are expressed in kg, then,

$$\Delta T_b = K_b \times \frac{W_2}{W_1 M_2}.$$ ***(1 mark)***

(ii) The Nernst equation for the single electrode reduction potential for a given ionic concentration in the solution in the case,

$M^{n+}_{(aq)} + ne^- \rightarrow M_{(s)}$ is given by

$$E_{M^{n+}/M} = E^0_{M^{n+}/M} - \frac{2.303\,RT}{nF} \log_{10} \frac{[M]}{[M^{n+}]}$$ ***(1 mark)***

OR

$$E_{M^{n+}/M} = E^0_{M^{n+}/M} - \frac{2.303\,RT}{nF} \log_{10} \frac{[1]}{[M^{n+}]}$$

where $E_{M^{n+}/M}$ is the single electrode reduction potential,

$E^0_{M^{n+}/M}$ is the standard reduction electrode potential,

R is the gas constant = 8.314 $JK^{-1}\ mol^{-1}$, ***(1 mark)***

T is the absolute temperature,

n is the number of electrons involved in the reaction,

F is Faraday (96500 C)

$[M^{n+}]$ is the molar concentration of ions.

Q. 28. How are the following preparations carried out?

(i) Benzaldehyde from toluene. (Etard oxidation)

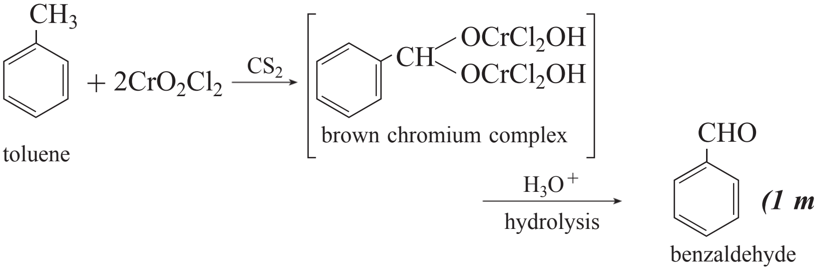
(ii) Benzaldehyde from methyl arene.

(iii) Benzaldehyde from toluene (commercial method).

(iv) Benzaldehyde from benzene (Gattermann-Koch synthesis).

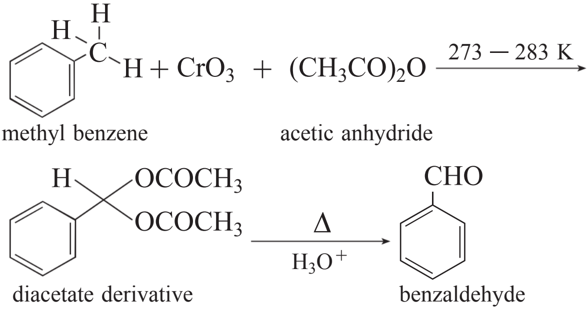
Ans.

(i) When toluene is treated with solution of chromyl chloride (CrO_2Cl_2) in Cs_2, brown chromium complex is obtained, which on acid hydrolysis gives benzaldehyde. This reaction is called **Etard reaction.**



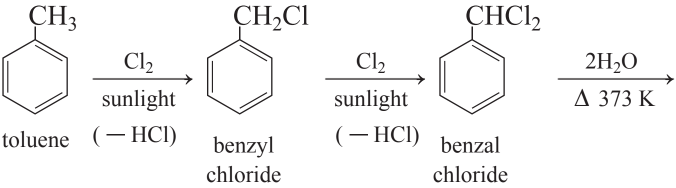
(1 mark)

(ii) Methylarene is converted into a benzyllidene diacetate on treatment with chromium oxide in acetic anhydride at 273 – 278 K. The diacetate derivative on acid hydrolysis gives benzaldehyde.

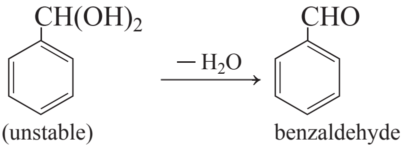


(1 mark)

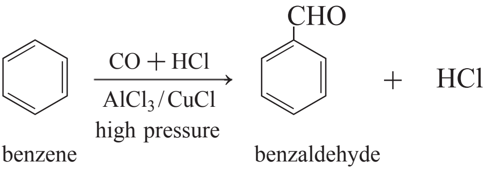
(iii) Side chain chlorination of toluene gives benzal chloride which on hydrolysis gives benzaldehyde.



(1 mark)



(iv) When benzene is treated with vapours of carbon monoxide and hydrogen chloride in the presence of a catalyst mixture of $AlCl_3$ and CuCl under high pressure, benzaldehyde is obtained. This reaction is called Gattermann-Koch synthesis.



(1 mark)

Q. 29. Discuss S_N2 mechanism of methyl bromide using aqueous KOH.

Ans.

(1) Consider alkaline hydrolysis of methyl bromide (Bromomethane), CH_3Br with aqueous NaOH or KOH.

$$\underset{\substack{\text{bromomethane}\\ \text{substrate}}}{CH_3-Br} \quad + \quad \underset{\text{nucleophile}}{OH^-} \longrightarrow \underset{\text{methanol}}{CH_3-OH} + Br^-$$

(2) Stereochemistry and Kinetics of the reaction (R.D.S.) : This hydrolysis reaction takes place only in one step which is a rate determining step i.e. R.D.S. The rate of hydrolysis reaction depends on the concentration of CH_3Br and OH^- which are present in the R.D.S. of the reaction.

Rate = R = k $[CH_3Br]$ $[OH^-]$, where k is rate constant of the reaction. ***(1 mark)***

S_N2 reaction : The reaction between methyl bromide and hydroxide ion to form methanol follows a second order kinetics, since the rate of the reaction depends on the concentrations of two reacting species, namely methyl bromide and hydroxide ion. It is bimolecular second order (2nd) Nucleophilic Substitution reaction denoted by **S_N2**. ***($\frac{1}{2}$ mark)***

(3) Mechanism of the reaction :

(a) It is a single step mechanism. The reaction takes place in the following steps :

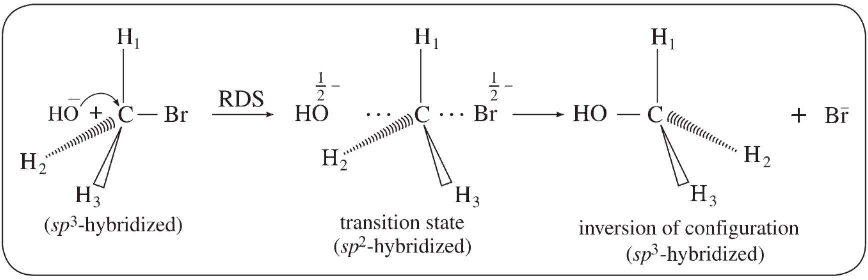


Fig. Backside attack of nucleophile in S_N2 mechanism ***($\frac{1}{2}$ mark for figure)***

(b) **Backside attack of the nucleophile :** Nucleophile, OH^- attacks carbon atom of CH_3Br from *back side* i.e. from opposite side to that of the leaving group, i.e. Br^- to experience minimum steric repulsion and electrostatic repulsion between the incoming nucleophile (OH^-) and leaving Br^-. ***($\frac{1}{2}$ mark)***

(c) **Transition state :** When a nucleophile, OH^- approaches carbon atom of CH_3Br, the potential energy of the system increases until a transition state (T.S.) of maximum potential energy is formed in which C–Br bond is *partially* broken and C–OH bond is *partially* formed. The negative charge is equally shared by both incoming nucleophile $-OH^-$ and outgoing, leaving group $-Br^-$. (Thus, the total negative charge is diffused.) ***($\frac{1}{2}$ mark)***

(d) In CH_3Br, carbon atom is sp^3-hybridized and CH_3Br molecule is tetrahedral. The hybridization of carbon atom changes to sp^2-hybridization. The transition state contains carbon having three σ (sigma) bonds in one plane making bond angles of 120° with each other i.e., H_1, H_2 and H_3 atoms lie in one plane while two partial covalent bonds containing Br and OH lie collinear and on opposite sides perpendicular to the plane. ***($\frac{1}{2}$ mark)***

(e) **Inversion of configuration :** The transition state decomposes fast by the complete breaking of the C–Br bond and the new C–OH bond is formed on the other side. The breaking of C–Br bond and the formation of C–OH bond take place simultaneously. The energy required to break the C–Br bond is partly obtained from the energy released when C–OH bond is formed. The formation of product CH_3OH is accompanied by *complete* or 100% *inversion* of configuration forming again sp^3-hybridized carbon atom giving tetrahedral CH_3OH molecule. But in this structure the positions of H_2 and H_3 atoms in the reactant (CH_3Br) and in the product are on the opposite side. This inversion of configuration is called *Walden inversion.* ***($\frac{1}{2}$ mark)***

Q. 30. (i) What are oxides? How are they classified? Give examples.

(ii) What are the common methods of concentration of an ore?

Ans.

(i) The oxides are binary compounds in which one element is oxygen and another may be a metal or a non-metal. ***(1 mark)***

They are classified as follows :

(1) Acidic oxides, CO_2, SO_2, etc.

(2) Basic oxides, CaO, BaO, etc.

(3) Amphoteric oxides, Al_2O_3, ZnO, etc.

(4) Neutral oxides, NO, N_2O, CO, etc. ***(1 mark)***

(ii) The concentration of an ore involves different methods depending upon the differences in physical properties of compounds or the metal present and the nature of the gangue. ***(1 mark)***

The common methods of concentration of ore are as follows :

(1) Gravity separation or hydraulic washing : This can be carried out by two processes as follows :
   (a) Hydraulic washing by using Wilfley's table method
   (b) Hydraulic classifier methods.
(2) Magnetic separation
(3) Froth floatation process.
(4) Leaching.

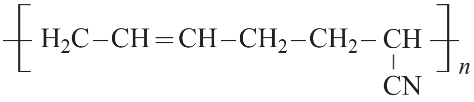
The method depends upon the nature of ore. ***(1 mark)***

Q. 31. (i) Write structural formula of the following synthetic rubbers :
(a) Buna-N rubber (b) Neoprene rubber.
(ii) How nanotechnology plays an important role in water purification techniques?

Ans.

(i)

(a) Buna-N rubber :

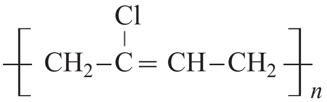


$$\left[H_2C-CH=CH-CH_2-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}} \right]_n$$

(1 mark)

buna-N

(b) Neoprene rubber :



$$\left[CH_2-\overset{\displaystyle Cl}{\overset{|}{C}}=CH-CH_2 \right]_n$$

(1 mark)

neoprene

(ii)

(1) Water purification is an important issue as 1.1 billion people do not have access to improved water supply. Water contains water-borne pathogens like viruses, bacteria. ***(1 mark)***

(2) Silver nanoparticles are highly effective bacterial disinfectant to remove E. coli from water. Hence, filter materials coated with silver nanoparticles is used to clean water. Silver nanoparticles (Agnps) is a cost effective alternative technology (e.g. water purifier). ***(1 mark)***