Maharashtra Board Class 12 Chemistry Question Paper 2023 with Solutions

Time Allowed :3 Hours	**Maximum Marks :**70	**Total questions :**31

General Instructions

Instructions:

The question paper is divided into four sections:

(i) 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.

(ii) Section B: Q. No. 3 to Q. No. 14 contain Twelve short answer type of questions carrying Two marks each. (Attempt any Eight).

(iii) Section C: Q. No. 15 to Q. No. 26 contain Twelve short answer type of questions carrying Three marks each. (Attempt any Eight).

(iv) Section D: Q. No. 27 to Q. No. 31 contain Five long answer type of questions carrying Four marks each. (Attempt any Three).

(v) Use of the log table is allowed. Use of calculator is not allowed.

(vi) Figures to the right indicate full marks.

(vii) 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)……. No marks(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.

(viii) Given:

R = 8.314 J.K–1. mol–1
NA = 6.022 × 1023
F = 96500C

Section-A

1 Select and write the correct answers for the following multiple choice type of questions:

i. The relation between radius of sphere and edge length in body centered cubic lattice is given by formula:

(A) $3r = 4a$

(B) $r = \frac{3}{a} \times 4$

(C) $r = \frac{\sqrt{3}}{4}a$

(D) $r = \frac{\sqrt{2}}{4} \times a$

Correct Answer: (C) $r = \frac{\sqrt{3}}{4}a$

Solution: In a body-centered cubic (BCC) lattice, the body diagonal equals $\sqrt{3}a$, where a is the edge length. The body diagonal equals $4r$ (two atomic radii from corner to body center). Thus:

$$4r = \sqrt{3}a \quad \Rightarrow \quad r = \frac{\sqrt{3}}{4}a.$$

ii. The pH of weak monoacidic base is 11.2, its OH ion concentration is:

(A) $1.585 \times 10^{-3}\,\text{mol dm}^{-3}$

(B) $3.010 \times 10^{-11}\,\text{mol dm}^{-3}$

(C) $3.010 \times 10^{-3}\,\text{mol dm}^{-3}$

(D) $1.585 \times 10^{-11}\,\text{mol dm}^{-3}$

Correct Answer: (A) $1.585 \times 10^{-3}\,\text{mol dm}^{-3}$

Solution: pH = 11.2, so pOH = $14 - 11.2 = 2.8$.

$$[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-2.8} = 10^{-2} \times 10^{-0.8} \approx 10^{-2} \times 0.1585 = 1.585 \times 10^{-3}\,\text{mol dm}^{-3}.$$

iii. Which of the following correctly represents integrated rate law equation for a first order reaction in gas phase:

(A) $k = \frac{2.303}{t} \log \frac{P_i}{P_i - P}$

(B) $k = \frac{2.303}{t} \log \frac{P_i}{2P_i - P}$

(C) $k = \frac{2.303}{2t} \log \frac{P_i}{P_i - P}$

(D) $k = \frac{2.303 P_i}{t} \log \frac{P_i}{2P_i - P}$

Correct Answer: (B) $k = \frac{2.303}{t} \log \frac{P_i}{2P_i - P}$

Solution: For a first-order gas phase reaction $A \to 2B$, initial pressure P_i, pressure of A at time t = P_A, total pressure $P = P_A + P_B$. Since $P_B = 2(P_i - P_A)$, total pressure $P = P_A + 2P_i - 2P_A = 2P_i - P_A$. Thus, $P_A = 2P_i - P$. Integrated rate law:

$$k = \frac{2.303}{t} \log \frac{[A]_0}{[A]} = \frac{2.303}{t} \log \frac{P_i}{2P_i - P}.$$

iv. The spin only magnetic moment of Mn^{2+} ion is

(A) $4.901\,\text{BM}$

(B) $5.916\,\text{BM}$

(C) $3.873\,\text{BM}$

(D) $2.846\,\text{BM}$

Correct Answer: (B) $5.916\,\text{BM}$

Solution: Mn^{2+} has electron configuration [Ar] 3d^5. Number of unpaired electrons $n = 5$. Spin-only magnetic moment:

$$\mu = \sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{35} \approx 5.916\,\text{BM}.$$

v. The correct formula of a complex having IUPAC name Tetraamminedibromoplatinum (IV) bromide is

(A) $[PtBr(NH_3)_4]Br_2$

(B) $[PtBr_2(NH_3)_4]Br$

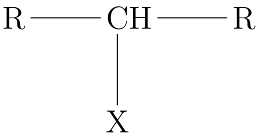
(C) $[PtBr_2(NH_3)_4]Br_2$

(D) $[PtBr(NH_3)_4]Br$

Correct Answer: (C) $[PtBr_2(NH_3)_4]Br_2$

Solution: Tetraamminedibromoplatinum(IV) indicates Pt^{4+} with 4 NH_3 (ammine) and 2 Br^- (bromo) ligands in the coordination sphere, and bromide counter ions balance the +2 charge of the complex ion. Thus, $[PtBr_2(NH_3)_4]^{2+}$ with 2 Br^- gives $[PtBr_2(NH_3)_4]Br_2$.

vi. The allylic halide, among the following is

(A) 
$\mathrm{R-\underset{\displaystyle X}{\underset{|}{CH}}-R}$

(B) $\mathrm{CH_2{=}CH-X}$

(C) X

(D) $\mathrm{CH_2{=}CH-CH_2-X}$

Correct Answer: (D) $\mathrm{CH_2{=}CH-CH_2-X}$

Solution: An allylic halide has a halogen atom on a carbon adjacent to a C=C double bond. Option (D) $\mathrm{CH_2{=}CH-CH_2-X}$ shows the halogen on the CH_2 next to the double bond, making it allylic.

vii. The product of following reaction is

$\mathrm{CH_3-CH{=}CH-CH_2-CHO} \xrightarrow{\textbf{i) LiAlH}_4\textbf{,ii) H}_3\textbf{O}^+} \textbf{?}$

(A) $\mathrm{CH_3-CH_2-CH_2-CH_2-CH_2-OH}$

(B) $\mathrm{CH_3-CH{=}CH-CH_2-CH_2-OH}$

(C) $\mathrm{CH_3-CH_2-CH_2-CH_2-COOH}$

(D) $\mathrm{CH_3-CH{=}CH-CH_2-COOH}$

Correct Answer: (B) $\mathrm{CH_3-CH{=}CH-CH_2-CH_2-OH}$

Solution: $LiAlH_4$ reduces aldehydes to primary alcohols without affecting the C=C double bond. The aldehyde $\mathrm{-CHO}$ becomes $\mathrm{-CH_2OH}$, resulting in $\mathrm{CH_3-CH{=}CH-CH_2-CH_2-OH}$.

viii. Ozonolysis of 2,3-dimethyl but-2-ene, followed by decomposition by Zn dust and water gives

(A) acetaldehyde

(B) propionaldehyde and acetone

(C) acetone

(D) acetaldehyde and butyraldehyde

Correct Answer: (C) acetone

Solution: 2,3-dimethyl but-2-ene is $(CH_3)_2C{=}C(CH_3)_2$. Ozonolysis cleaves the C=C bond, each carbon forming a carbonyl. Both carbons have two methyl groups, yielding two molecules of acetone ($(CH_3)_2C{=}O$).

ix. The glycosidic linkage present in maltose is

(A) α, β-1, 2-glycosidic linkage

(B) α-1, 4-glycosidic linkage

(C) β-1, 4-glycosidic linkage

(D) α-1, 6-glycosidic linkage

Correct Answer: (B) α-1, 4-glycosidic linkage

Solution: Maltose is a disaccharide of two glucose units linked by an α-1,4-glycosidic bond, where the anomeric carbon (C1) of one glucose is linked to C4 of the other in α configuration.

x. The monomer of natural rubber is

(A) Isoprene

(B) Acrylonitrile

(C) ε-Caprolactam

(D) Tetrafluoroethylene

Correct Answer: (A) Isoprene

Solution: Natural rubber is a polymer of isoprene (2-methyl-1,3-butadiene), with repeating units forming polyisoprene.

Quick Tip

For chemistry MCQs, focus on key concepts like lattice geometry, pH calculations, reaction mechanisms, and molecular structures to select the correct option efficiently.

2. Answer the following questions:

i. Write the name of the technique used to know geometry of nanoparticles.

Correct Answer: Transmission Electron Microscopy (TEM)

Solution: TEM is commonly used to determine the geometry, size, and shape of nanoparticles by passing electrons through a thin sample to produce high-resolution images of its structure.

ii. Write the name of the product formed by the action of LiAlH4/ether on acetamide.

Correct Answer: Ethylamine

Solution: Acetamide ($CH_3 - C \equiv ONH_2$) is reduced by $LiAlH_4$ in dry ether, converting the carbonyl group to a methylene group, yielding ethylamine ($CH_3 - CH_2 - NH_2$).

iii. Write the structure of the product formed when chlorobenzene is treated with sodium metal in the presence of dry ether.

Correct Answer: $C_6H_5 - C_6H_5$ (Biphenyl)

Solution: Chlorobenzene ($C_6H_5 - Cl$) reacts with sodium in dry ether via the Wurtz-Fittig reaction, coupling two phenyl groups to form biphenyl ($C_6H_5 - C_6H_5$).

iv. Write the chemical composition of cryolite.

Correct Answer: Na_3AlF_6

Solution: Cryolite is a naturally occurring mineral used in aluminum extraction, with the chemical formula Na_3AlF_6 (sodium hexafluoroaluminate).

v. Write the name of platinum complex used in the treatment of cancer.

Correct Answer: Cisplatin

Solution: Cisplatin (cis-$[PtCl_2(NH_3)_2]$) is a platinum-based coordination complex widely used as a chemotherapeutic agent for treating various cancers.

vi. Write the SI unit of cryoscopic constant.

Correct Answer: K kg mol^{-1}

Solution: The cryoscopic constant (K_f) relates freezing point depression to molality: $\Delta T_f = K_f \cdot m$. Its SI unit is derived as:

$$K_f = \frac{\Delta T_f}{m} = \frac{\text{K}}{\text{mol kg}^{-1}} = \text{K kg mol}^{-1}.$$

vii. Write the correct condition for spontaneity in terms of Gibbs energy.

Correct Answer: $\Delta G < 0$

Solution: For a process to be spontaneous at constant temperature and pressure, the Gibbs free energy change must be negative: $\Delta G = \Delta H - T\Delta S < 0$.

viii. Calculate molar conductivity for 0.5 M BaCl$_2$ if its conductivity at 298K is 0.01 Ω^{-1}cm^{-1}.

Correct Answer: $20\,\Omega^{-1}\text{cm}^2\text{mol}^{-1}$

Solution: Molar conductivity $\Lambda_m = \frac{\kappa \cdot 1000}{C}$, where $\kappa = 0.01\,\Omega^{-1}\text{cm}^{-1}$, $C = 0.5\,\text{mol dm}^{-3} = 0.5\,\text{mol L}^{-1} = 500\,\text{mol m}^{-3}$. Convert units:

$$\Lambda_m = \frac{0.01 \cdot 1000}{0.5} = \frac{10}{0.5} = 20\,\Omega^{-1}\text{cm}^2\text{mol}^{-1}.$$

Quick Tip

For short-answer chemistry questions, ensure precise chemical formulas, unit derivations, and awareness of standard techniques or compounds used in specific contexts.

Section-B

Attempt any EIGHT questions of the following:

3. Distinguish between lanthanides and actinides.

Solution:

Lanthanides and actinides are f-block elements, but they differ as follows:

1. **Electronic Configuration:**

- Lanthanides: Electrons fill the 4f orbitals ([Xe] $4f^{1-14}$ $5d^{0-1}$ $6s^2$).

- Actinides: Electrons fill the 5f orbitals ([Rn] $5f^{1-14}$ $6d^{0-1}$ $7s^2$).

2. **Radioactivity:**

- Lanthanides: Mostly non-radioactive (except promethium).

- Actinides: All are radioactive due to unstable nuclei.

3. **Oxidation States:**

- Lanthanides: Predominantly +3, rarely +2 or +4.

- Actinides: Show variable oxidation states (e.g., +3 to +6 for uranium).

4. **Chemical Reactivity:**

- Lanthanides: Less reactive, similar to group 2 metals.

- Actinides: More reactive, form complexes easily due to higher charge density.

Quick Tip

Focus on orbital filling and radioactivity to distinguish lanthanides from actinides effectively.

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4. Calculate the mole fraction of solute, if the vapour pressure of pure benzene at certain temperature is 640 mmHg and vapour pressure of solution of a solute in benzene is 600 mmHg.

Solution:

Using Raoult's law for a non-volatile solute: $P = P_0 x_A$, where $P_0 = 640\,\text{mmHg}$, $P = 600\,\text{mmHg}$, x_A is mole fraction of solvent (benzene).

$$x_A = \frac{P}{P_0} = \frac{600}{640} = 0.9375.$$

Mole fraction of solute $x_B = 1 - x_A = 1 - 0.9375 = 0.0625.$

Answer: Mole fraction of solute = 0.0625.

Quick Tip

Raoult's law applies to non-volatile solutes; mole fractions sum to 1.

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5. Define: Green chemistry. Write two advantages of nanoparticle and nanotechnology.

Solution:

Definition: Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances, promoting sustainability and environmental safety.

Advantages of Nanoparticles and Nanotechnology:

1. **Enhanced Reactivity:** Nanoparticles have a high surface area-to-volume ratio, increasing efficiency in catalysis and drug delivery.
2. **Targeted Applications:** Nanotechnology enables precise targeting (e.g., in medicine for cancer treatment), reducing side effects and improving efficacy.

Quick Tip

Green chemistry emphasizes eco-friendly processes; nanoparticles excel due to size-dependent properties.

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6. Explain the following terms:

i. Substitutional impurity defect

ii. Interstitial impurity defect

Solution:

i. Substitutional Impurity Defect: Occurs when an atom in a crystal lattice is replaced by a different type of atom. For example, in a silicon crystal, a phosphorus atom may substitute a silicon atom, altering electrical properties (used in doping semiconductors).

ii. Interstitial Impurity Defect: Occurs when a foreign atom occupies an interstitial (empty) site in the lattice, not replacing any host atom. For example, carbon atoms in iron form interstitial defects, increasing hardness in steel.

Quick Tip

Substitutional defects involve atom replacement, while interstitial defects involve atoms in lattice voids.

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7. Write the chemical reactions for the following:

i. Chlorobenzene is heated with fuming H_2SO_4

ii. Ethyl bromide is heated with silver acetate

Solution:

i. Chlorobenzene with fuming H_2SO_4:

$$\mathrm{C_6H_5 - Cl + H_2SO_4 \xrightarrow{heat} C_6H_5 - SO_3H + HCl}$$

Fuming H_2SO_4 (containing SO_3) causes sulfonation, forming benzenesulfonic acid.

ii. Ethyl bromide with silver acetate:

$$\mathrm{CH_3 - CH_2 - Br + CH_3COOAg \xrightarrow{heat} CH_3 - CH_2 - OCOCH_3 + AgBr}$$

This is a nucleophilic substitution reaction, forming ethyl acetate and silver bromide precipitate.

Quick Tip

Aromatic compounds undergo electrophilic substitution with strong reagents; alkyl halides react with silver salts to form esters.

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8. Define: Acidic buffer solution. Write the relationship between solubility and solubility product for PbI_2.

Solution:

Definition: An acidic buffer solution is a mixture of a weak acid and its conjugate base (or salt), maintaining a relatively constant pH (below 7) by resisting changes upon addition of small amounts of acid or base. Example: CH_3COOH and CH_3COONa.

Relationship for PbI_2: For $PbI_2 \rightleftharpoons Pb^{2+} + 2I^-$, let solubility = S mol L^{-1}. Then, $[Pb^{2+}] = S$, $[I^-] = 2S$. Solubility product:

$$K_{sp} = [Pb^{2+}][I^-]^2 = S \cdot (2S)^2 = 4S^3.$$

Quick Tip

Acidic buffers use weak acid-conjugate base pairs; for sparingly soluble salts, express K_{sp} in terms of solubility S.

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9. What is the action of the following reagents on ethyl amine:

i. Chloroform and caustic potash

ii. Nitrous acid

Solution:

i. Chloroform and Caustic Potash: Ethyl amine ($CH_3 — CH_2 — NH_2$) undergoes the carbylamine reaction:

$$CH_3 — CH_2 — NH_2 + CHCl_3 + 3KOH \xrightarrow{\text{heat}} CH_3 — CH_2 — NC + 3KCl + 3H_2O.$$

Product: Ethyl isocyanide (foul-smelling).

ii. Nitrous Acid: Ethyl amine reacts with HNO_2 (from $NaNO_2$ + HCl) to form an alcohol via diazonium ion decomposition:

$$CH_3 — CH_2 — NH_2 + HNO_2 \to CH_3 — CH_2 — OH + N_2 + H_2O.$$

Product: Ethanol.

Quick Tip

Primary amines give isocyanides with chloroform/KOH and alcohols with nitrous acid due to diazonium instability.

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10. Calculate standard Gibbs energy change at 25°C for the cell reaction

$Cd(s) + Sn^{2+}(aq) \to Cd^{2+}(aq) + Sn(s)$, $E^\circ_{Cd} = -0.403\,V$, $E^\circ_{Sn} = -0.136\,V$.

Solution:

Cell: $Cd|Cd^{2+}||Sn^{2+}|Sn$.

Anode: $Cd \to Cd^{2+} + 2e^-$, cathode: $Sn^{2+} + 2e^- \to Sn$.

$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = -0.136 - (-0.403) = 0.267\,\text{V}$.

Number of electrons $n = 2$.

Gibbs energy: $\Delta G^\circ = -nFE^\circ_{\text{cell}}$, $F = 96485\,\text{C mol}^{-1}$, T = 25°C = 298 K (not needed for standard conditions).

$$\Delta G^\circ = -2 \times 96485 \times 0.267 \approx -51529.59\,\text{J mol}^{-1} = -51.53\,\text{kJ mol}^{-1}.$$

Quick Tip

Use $\Delta G^\circ = -nFE^\circ$ for electrochemical cells; positive E° indicates spontaneity ($\Delta G^\circ < 0$).

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11. Write chemical reaction for the preparation of glucose from sucrose. Write structure of D-ribose.

Solution:

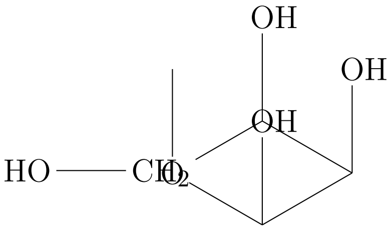
i. Preparation of Glucose from Sucrose: Sucrose ($C_{12}H_{22}O_{11}$) is hydrolyzed in the presence of dilute acid (e.g., HCl) or enzyme (invertase) to produce glucose and fructose:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+ \text{ or invertase}} C_6H_{12}O_6(\text{glucose}) + C_6H_{12}O_6(\text{fructose}).$$

ii. Structure of D-Ribose: D-Ribose is a pentose sugar with the following open-chain structure:

$$HO - CH_2 - OH - OH - OH - CH = O$$

In its cyclic form (furanose), it is:



Quick Tip

Sucrose hydrolysis yields equal amounts of glucose and fructose; D-ribose is commonly depicted in its furanose ring form in biochemical contexts.

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12. Define Extensive property. Calculate the work done during the expansion of 2 moles of an ideal gas from 10 dm^3 to 20 dm^3 at 298 K in vacuum.

Solution:

Definition: An extensive property is a physical property of a system that depends on the amount or extent of the substance, such as mass, volume, or total energy.

Calculation of Work Done: For an ideal gas expanding in a vacuum (free expansion), external pressure $P_{\text{ext}} = 0$. Work done $W = -P_{\text{ext}}\Delta V$.

$$\Delta V = 20\,\text{dm}^3 - 10\,\text{dm}^3 = 10\,\text{dm}^3 = 0.01\,\text{m}^3.$$

$$W = -0 \cdot 0.01 = 0\,\text{J}.$$

Answer: Work done = 0 J.

Quick Tip

In free expansion (in vacuum), no work is done since $P_{\text{ext}} = 0$; extensive properties scale with system size.

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13. Write the reactions for the formation of nylon 6,6 polymer.

Solution:

Nylon 6,6 is a polyamide formed by condensation polymerization of hexamethylenediamine ($H_2N - 6CH_2 - NH_2$) and adipic acid ($HOOC - 4CH_2 - COOH$).

$$nH_2N - 6CH_2 - NH_2 + nHOOC - 4CH_2 - COOH \rightarrow {}_{n} + 2nH_2O.$$

The reaction forms amide bonds, releasing water molecules.

Quick Tip

Nylon 6,6 involves condensation of a diamine and a dicarboxylic acid, forming repeating amide linkages.

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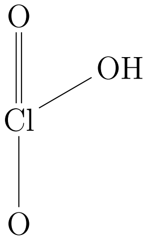
14. Draw structures of the following compounds:

i. Chloric acid

ii. Peroxydisulphuric acid

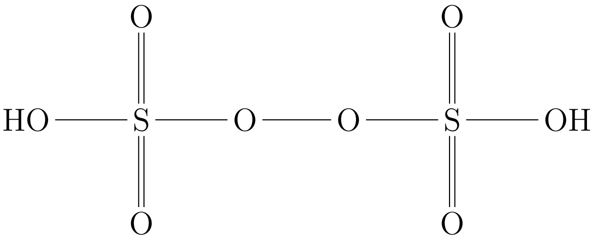
Solution:

i. Chloric Acid ($HClO_3$):



Chlorine is bonded to one hydroxyl group and two double-bonded oxygens.

ii. Peroxydisulphuric Acid ($H_2S_2O_8$):



Contains a peroxide ($-O-O-$) bond linking two sulfur atoms, each with two double-bonded oxygens and one hydroxyl group.

Quick Tip

Use Lewis structures to confirm oxidation states and bonding in oxoacids; peroxydisulphuric acid has a characteristic peroxide linkage.

Section-C

Attempt any EIGHT questions of the following:

15. Define Osmosis. How will you determine molar mass of non-volatile solute by elevation of boiling point?

Solution:

Definition: Osmosis is the spontaneous movement of solvent molecules through a semi-permeable membrane from a region of lower solute concentration to a region of higher solute concentration, tending to equalize concentrations.

Determination of Molar Mass:

The elevation of boiling point (ΔT_b) for a non-volatile solute is given by:

$$\Delta T_b = K_b \cdot m,$$

where K_b is the molal boiling point elevation constant, and m is molality (mol kg^{-1}).

Step 1: Measure the boiling point of the pure solvent (T_0) and the solution (T). Calculate $\Delta T_b = T - T_0$.

Step 2: Molality $m = \frac{n_B}{w_A}$, where $n_B = \frac{w_B}{M_B}$ (moles of solute, w_B = mass of solute, M_B = molar mass of solute), and w_A = mass of solvent in kg.

$$\Delta T_b = K_b \cdot \frac{w_B}{M_B \cdot w_A}.$$

$$M_B = \frac{K_b \cdot w_B}{\Delta T_b \cdot w_A}.$$

Step 3: Use known K_b, measured ΔT_b, w_B, and w_A to calculate M_B.

Quick Tip

Use precise temperature measurements and known K_b values for accurate molar mass determination.

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16. Convert the following:

i. Ethyl alcohol into ethyl acetate

ii. Phenol into benzene

iii. Diethyl ether into ethyl chloride

Solution:

i. Ethyl Alcohol to Ethyl Acetate:

$$\mathrm{CH_3}\text{——}\mathrm{CH_2}\text{——}\mathrm{OH{+}CH_3}\text{——}\mathrm{COOH} \xrightarrow{\mathrm{H_2SO_4,heat}} \mathrm{CH_3}\text{——}\mathrm{C}{=\!=}\mathrm{O}\text{——}\mathrm{CH_2}\text{——}\mathrm{CH_3{+}H_2O}.$$

Ethyl alcohol reacts with acetic acid via esterification to form ethyl acetate.

ii. Phenol to Benzene:

$$\mathrm{C_6H_5}\text{——}\mathrm{OH} \xrightarrow{\text{Zn dust, heat}} \mathrm{C_6H_6} + \mathrm{ZnO}.$$

Phenol is reduced by heating with zinc dust, removing the hydroxyl group to form benzene.

iii. Diethyl Ether to Ethyl Chloride:

$$\mathrm{CH_3}\text{——}\mathrm{CH_2}\text{——}\mathrm{O}\text{——}\mathrm{CH_2}\text{——}\mathrm{CH_3} + \mathrm{HCl} \xrightarrow{\mathrm{ZnCl_2,heat}} \mathrm{2CH_3}\text{——}\mathrm{CH_2}\text{——}\mathrm{Cl} + \mathrm{H_2O}.$$

Diethyl ether reacts with concentrated HCl in the presence of $ZnCl_2$ to form ethyl chloride.

Quick Tip

Choose reagents specific to functional group transformations for efficient organic conversions.

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17. A weak monobasic acid is 10 percent dissociated in 0.05 M solution. What is percent dissociation in 0.15 M solution?

Solution: For a weak monobasic acid $HA \rightleftharpoons H^+ + A^-$, the dissociation constant $K_a = \frac{\alpha^2 C}{1-\alpha}$, where α is the degree of dissociation, and C is concentration.

Step 1: For 0.05 M, $\alpha = 0.1$:

$$K_a = \frac{(0.1)^2 \cdot 0.05}{1 - 0.1} = \frac{0.01 \cdot 0.05}{0.9} = \frac{0.0005}{0.9} \approx 5.5556 \times 10^{-4}.$$

Step 2: For 0.15 M, use K_a:

$$5.5556 \times 10^{-4} = \frac{\alpha^2 \cdot 0.15}{1-\alpha}.$$

Since α is small, approximate $1 - \alpha \approx 1$:

$$\alpha^2 \cdot 0.15 \approx 5.5556 \times 10^{-4}, \quad \alpha^2 \approx \frac{5.5556 \times 10^{-4}}{0.15} \approx 3.7037 \times 10^{-3}.$$

$$\alpha \approx \sqrt{3.7037 \times 10^{-3}} \approx 0.06086.$$

Percent dissociation = $0.06086 \times 100 \approx 6.09\%$.

Quick Tip

For weak electrolytes, dilution increases dissociation but percent dissociation decreases with higher concentration due to K_a constancy.

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18. Explain dehydrohalogenation reaction of 2-chlorobutane. Write use and environmental effect of CFC.

Solution:

Dehydrohalogenation of 2-Chlorobutane: Dehydrohalogenation involves the removal of HX from an alkyl halide using a strong base (e.g., alcoholic KOH) to form an alkene. For 2-chlorobutane ($CH_3 - \overset{Cl}{C}H - CH_2 - CH_3$):

$$CH_3 - \overset{Cl}{C}H - CH_2 - CH_3 \xrightarrow{\text{KOH (alc.), heat}} CH_3 - CH = CH - CH_3 + HCl.$$

Major product (Saytzeff rule): 2-butene (more substituted alkene). Minor product: 1-butene ($CH_2 = CH - CH_2 - CH_3$).

Use of CFC: Chlorofluorocarbons (CFCs) are used as refrigerants, propellants in aerosols, and solvents due to their stability and low toxicity.

Environmental Effect of CFC: CFCs deplete the ozone layer by releasing chlorine radicals upon UV exposure, catalyzing ozone (O_3) breakdown, leading to increased UV radiation reaching Earth.

Quick Tip

Saytzeff rule favors the more substituted alkene; CFCs are phased out due to ozone depletion.

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19. 2000 mmol of an ideal gas expanded isothermally and reversibly from 20 L to 30 L at 300 K, calculate the work done in the process ($R = 8.314$ J K^{-1}mol^{-1}).

Solution: For isothermal reversible expansion, work done $W = -nRT \ln\left(\frac{V_f}{V_i}\right)$.
$n = 2000\,\text{mmol} = 2\,\text{mol}$, $T = 300\,\text{K}$, $V_i = 20\,\text{L}$, $V_f = 30\,\text{L}$, $R = 8.314\,\text{J K}^{-1}\text{mol}^{-1}$.

$$W = -2 \cdot 8.314 \cdot 300 \cdot \ln\left(\frac{30}{20}\right) = -2 \cdot 8.314 \cdot 300 \cdot \ln(1.5).$$

$$\ln(1.5) \approx 0.405465, \quad W \approx -2 \cdot 8.314 \cdot 300 \cdot 0.405465 \approx -2022.77\,\text{J}.$$

Answer: Work done $\approx -2022.77\,\text{J}$.

Quick Tip

For isothermal reversible expansion, work depends on the volume ratio; negative sign indicates work done by the system.

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20. What are interstitial compounds? Give the classification of alloys with examples.

Solution:

Interstitial Compounds: These are compounds formed when small atoms (e.g., H, C, N) occupy interstitial sites in the lattice of transition metals (e.g., Fe, Ti). Example: TiC (titanium carbide), where carbon atoms fit in the metal lattice, enhancing hardness.

Classification of Alloys:

1. **Substitutional Alloys:** Atoms of one metal replace atoms of another in the lattice. Example: Brass (Cu and Zn).

2. **Interstitial Alloys:** Small atoms occupy interstitial sites in a metal lattice. Example: Steel (Fe with C).

3. **Intermetallic Alloys:** Specific stoichiometric compounds of metals. Example: Ni_3Al (used in jet engines).

Quick Tip

Interstitial compounds enhance material properties; alloys are classified based on atomic arrangement.

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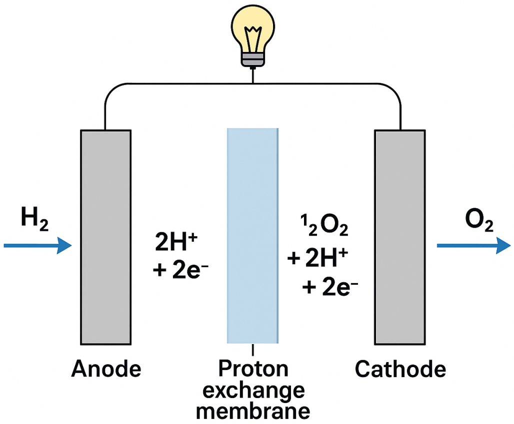
21. Draw labelled diagram of $H_2 – O_2$ fuel cell. Write two applications of fuel cell.

Solution:

Diagram:



Reactions: Anode: $2H_2 \to 4H^+ + 4e^-$, Cathode: $O_2 + 4H^+ + 4e^- \to 2H_2O$.

Applications:

1. Power generation in spacecraft (e.g., Apollo missions).
2. Electric vehicle power sources for clean energy.

Quick Tip

Fuel cells convert chemical energy directly to electrical energy; H_2-O_2 cells produce water as a byproduct.

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22. Explain formation of $[CoF_6]^{3-}$ complex with respect to:

i. Hybridisation

ii. Magnetic properties

iii. Inner/outer complex

iv. Geometry

Solution:

For $[CoF_6]^{3-}$, Co is in +3 oxidation state (Co^{3+}, d^6).

i. Hybridisation: F^- is a weak-field ligand, so high-spin complex. Co^{3+} uses 3d, 4s, and 4p orbitals for d^2sp^3 hybridisation (outer orbital complex).

ii. Magnetic Properties: d^6 high-spin: 4 unpaired electrons ($t_{2g}^4 e_g^2$). Magnetic moment:

$$\mu = \sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} \approx 4.9\,\text{BM}.$$

iii. Inner/Outer Complex: Uses 4s and 4p orbitals, so it's an outer orbital complex (d^2sp^3).

iv. Geometry: Octahedral, as six F^- ligands coordinate around Co^{3+}.

Quick Tip

Weak-field ligands like F^- cause high-spin complexes; check ligand field strength for hybridisation.

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23. What is Pseudo first order reaction? Derive integrated rate law equation for zero order reaction.

Solution:

Pseudo First Order Reaction: A reaction that is second order (or higher) but appears first order due to one reactant in large excess, keeping its concentration nearly constant. Example: Hydrolysis of ester in water (H_2O in excess).

Zero Order Integrated Rate Law: For a zero-order reaction $A \to$ products, rate = k.

$$-\frac{d[A]}{dt} = k.$$

Integrate: $\int_{[A]_0}^{[A]} d[A] = -k \int_0^t dt$.

$$[A] - [A]_0 = -kt \quad \Rightarrow \quad [A] = [A]_0 - kt.$$

Quick Tip

Pseudo first order simplifies kinetics; zero-order reactions have constant rates, common in catalyzed reactions.

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24. Explain Aldol condensation of ethanal.

Solution:

Aldol condensation involves the reaction of two aldehyde molecules (with α-H) in the presence of a base to form a β-hydroxy aldehyde, which may dehydrate to an unsaturated aldehyde. For ethanal ($\mathrm{CH_3{-}CHO}$):

$$\mathrm{2CH_3{-}CHO} \xrightarrow{\text{dil. NaOH}} \mathrm{CH_3{-}\rlap{CH}OH{-}CH_2{-}CHO} \xrightarrow{-\mathrm{H_2O}} \mathrm{CH_3{-}CH{=}CH{-}CHO}.$$

Step 1: Enolate ion forms from one ethanal, attacking the carbonyl of another, forming 3-hydroxybutanal (aldol).

Step 2: Dehydration yields crotonaldehyde ($\mathrm{CH_3{-}CH{=}CH{-}CHO}$).

Quick Tip

Aldol condensation requires α-hydrogen; dehydration yields conjugated products.

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25. Explain anomalous behaviour of oxygen in group 16 with respect to:

i. Atomicity

ii. Magnetic property

iii. Oxidation state

Solution:

i. Atomicity: Oxygen exists as a diatomic gas (O_2), whereas other group 16 elements (S, Se, Te) form polyatomic structures (e.g., S_8) due to stronger tendency for catenation.

ii. Magnetic Property: O_2 is paramagnetic due to two unpaired electrons in its molecular orbitals (π^*_{2p}), while others like S_8 are diamagnetic.

iii. Oxidation State: Oxygen commonly shows -2 (e.g., H_2O), rarely +2 (e.g., OF_2) due to high electronegativity. Others (S, Se, Te) show +4, +6 due to d-orbital availability.

Quick Tip

Oxygen's anomalies stem from its small size, high electronegativity, and lack of d-orbitals.

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26. Write chemical reactions for the following conversions:

i. Acetic acid into acetic anhydride

ii. Acetic acid into ethyl alcohol

Write IUPAC name and structure of methylphenylamine.

Solution:

i. Acetic Acid to Acetic Anhydride:

$$2\mathrm{CH_3} — \mathrm{COOH} \xrightarrow{\mathrm{P_2O_5,heat}} \mathrm{CH_3} — \mathrm{C} = \mathrm{O} — \mathrm{C} = \mathrm{OH_3} + \mathrm{H_2O}.$$

P_2O_5 dehydrates two acetic acid molecules.

ii. Acetic Acid to Ethyl Alcohol:

$$\mathrm{CH_3} — \mathrm{COOH} \xrightarrow{\text{i) LiAlH}_4\text{,ii) H}_3\text{O}^+} \mathrm{CH_3} — \mathrm{CH_2} — \mathrm{OH}.$$

$LiAlH_4$ reduces the carboxyl group to a primary alcohol.

Methylphenylamine:

IUPAC Name: N-Methylaniline.

Structure: $C_6H_5 — NH — CH_3$.

Quick Tip

Use strong reducing agents like $LiAlH_4$ for carboxylic acid reductions; IUPAC names prioritize functional group hierarchy.

Section-D

Attempt any THREE questions of the following:

27. Show that, time required for 99.9 percent completion of a first order reaction is three times the time required for 90 percent completion. Give electronic configuration of Gd (Z = 64). Write the name of nano structured material used in car tyres to increase the life of tyres.

Solution:

i. Time for First Order Reaction: For a first-order reaction, the rate law is $\ln \frac{[A]_0}{[A]} = kt$. For 90 percent completion, 10% of reactant remains: $\frac{[A]}{[A]_0} = 0.1$.

$$\ln \frac{1}{0.1} = kt_{90\%} \quad \Rightarrow \quad kt_{90\%} = \ln 10 \approx 2.3026.$$

For 99.9% completion, 0.1% remains: $\frac{[A]}{[A]_0} = 0.001$.

$$\ln \frac{1}{0.001} = kt_{99.9\%} \quad \Rightarrow \quad kt_{99.9\%} = \ln 1000 \approx 6.9078.$$

Ratio:

$$\frac{t_{99.9\%}}{t_{90\%}} = \frac{\ln 1000}{\ln 10} = \frac{3 \ln 10}{\ln 10} = 3.$$

Thus, $t_{99.9\%} = 3t_{90\%}$.

ii. Electronic Configuration of Gd (Z = 64): Gadolinium: [Xe] $4f^7$ $5d^1$ $6s^2$.

iii. Nanostructured Material in Car Tyres: Carbon black nanoparticles.

Solution: Carbon black nanoparticles are used in car tyres to enhance durability, improve traction, and increase resistance to wear.

Quick Tip

For first-order reactions, use $\ln \frac{[A]_0}{[A]} = kt$; nanomaterials like carbon black improve mechanical properties in applications.

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28. Derive relationship between ΔH and ΔU for gaseous reaction. Define: Vulcanization. What is peptide bond?

Solution:

i. Relationship between ΔH and ΔU: Enthalpy $H = U + PV$. For a gaseous reaction at constant T, $\Delta H = \Delta U + \Delta(PV)$. Using ideal gas law, $PV = nRT$, so:

$$\Delta H = \Delta U + \Delta(n_g RT) = \Delta U + \Delta n_g RT,$$

where Δn_g is the change in moles of gas, $R = 8.314\,\text{J K}^{-1}\text{mol}^{-1}$, T is temperature in K.

ii. Vulcanization: The process of heating natural rubber with sulfur to form cross-links between polymer chains, improving elasticity, strength, and durability.

iii. Peptide Bond: A covalent bond ($-\text{CO}-\text{NH}-$) formed between the carboxyl group of one amino acid and the amino group of another, with loss of water, linking amino acids in proteins.

Quick Tip

Use Δn_g to relate ΔH and ΔU; vulcanization enhances rubber properties; peptide bonds are amide linkages in proteins.

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29. Silver crystallizes in fcc structure. If edge length of unit cell is 400 pm, calculate density of silver (Atomic mass of Ag = 108). Write a note on Haloform reaction.

Solution:

i. Density of Silver: For FCC, number of atoms per unit cell $Z = 4$. Edge length $a = 400\,\text{pm} = 4 \times 10^{-8}\,\text{cm}$, atomic mass $M = 108\,\text{g mol}^{-1}$, Avogadro's number $N_A = 6.022 \times 10^{23}\,\text{mol}^{-1}$.

Density $\rho = \frac{Z \cdot M}{N_A \cdot a^3}$.

$$a^3 = (4 \times 10^{-8})^3 = 6.4 \times 10^{-23}\,\text{cm}^3.$$

$$\rho = \frac{4 \cdot 108}{6.022 \times 10^{23} \cdot 6.4 \times 10^{-23}} \approx \frac{432}{3.85408 \times 10^1} \approx 11.21\,\text{g cm}^{-3}.$$

ii. Haloform Reaction: Compounds with a methyl ketone group ($\text{CH}_3-\text{C}=\text{O}$) or acetaldehyde, when treated with halogens (e.g., I_2) and a base (e.g., NaOH), form haloforms (e.g., CHI_3) and a carboxylate. Example:

$$\text{CH}_3-\text{CO}-\text{CH}_3 + 3\text{I}_2 + 4\text{NaOH} \rightarrow \text{CHI}_3 + \text{CH}_3\text{COONa} + 3\text{NaI} + 3\text{H}_2\text{O}.$$

Used in iodoform test to detect methyl ketones or acetaldehyde.

Quick Tip

FCC density uses $Z = 4$; haloform reaction is diagnostic for compounds with CH_3CO-.

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30. Define: Diastereoisomers. Give cis and trans isomers of [Co(NH$_3$)$_4Cl_2]^+.Whatisreferenceelectrode?Givereason:$

$Bleachingactionofozoneisalsocalleddrybleach.$

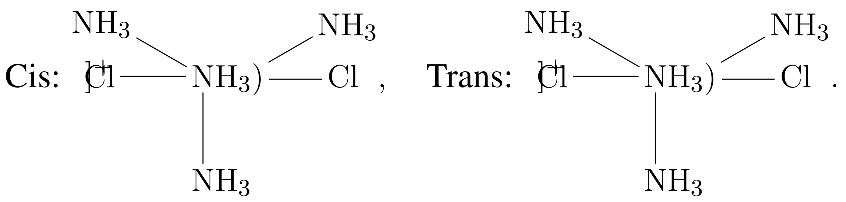
Solution:

i. Diastereoisomers: Stereoisomers that are not mirror images of each other, differing in physical properties like melting point or solubility. Example: cis- and trans-2-butene.

ii. Cis and Trans Isomers of [Co(NH$_3$)$_4Cl_2]^+$:

- Cis: $^+$ with Cl ligands adjacent (90° apart).

- Trans: Cl ligands opposite (180° apart).



iii. Reference Electrode: An electrode with a stable, known potential used to measure the potential of another electrode. Example: Standard Hydrogen Electrode (SHE, $E^\circ = 0\,\mathrm{V}$).

iv. Reason for Ozone as Dry Bleach: Ozone (O_3) oxidizes organic compounds without water, bleaching materials via gas-phase reactions, unlike wet bleaching agents (e.g., Cl_2).

Quick Tip

Diastereoisomers lack mirror symmetry; reference electrodes provide a potential baseline; ozone's gas-phase bleaching is water-free.

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31. Write Dow process for preparation of Phenol. What is the action of bromine water on phenol? Give reason: Group 16th elements have lower ionisation enthalpy

compared to group 15th elements. Write two uses of dioxygen.

Solution:

i. Dow Process for Phenol:

$$C_6H_5 — Cl \xrightarrow{\text{NaOH, 350°C, high pressure}} C_6H_5 — ONa \xrightarrow{\text{HCl}} C_6H_5 — OH + NaCl.$$

Chlorobenzene reacts with aqueous NaOH to form sodium phenoxide, which is acidified to yield phenol.

ii. Action of Bromine Water on Phenol: Phenol reacts with Br_2 in water to form 2,4,6-tribromophenol (white precipitate):

$$C_6H_5 — OH + 3Br_2 \rightarrow \underset{Br_3}{C_6H_2} — OH + 3HBr.$$

iii. Reason for Lower Ionisation Enthalpy in Group 16: Group 16 elements (e.g., O, S) have np^4 configuration, with paired electrons in one p-orbital, causing electron-electron repulsion, making it easier to remove an electron compared to group 15's stable half-filled np^3 configuration.

iv. Uses of Dioxygen:

1. Respiration in living organisms.
2. Combustion and industrial processes (e.g., steel production).

Quick Tip

Dow process uses high temperature/pressure; phenol's high reactivity with Br_2 is due to ring activation; group 16's paired electrons lower ionisation energy.
