Maharashtra Board Class 12 Chemistry 2024 Question Paper with Solutions

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

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Section A: Question 1 contains 10 multiple-choice questions, each worth one mark. Only the first attempt will be considered for evaluation.
   Question 2 includes 8 very short answer questions, also worth one mark each.
2. Section B: Questions 3 to 14 are short answer questions, with twelve questions each carrying two marks. Candidates must attempt any eight.
3. Section C: Questions 15 to 26 are twelve short answer questions, each carrying three marks. Candidates must attempt any eight.
4. Section D: Questions 27 to 31 are five long answer questions, each carrying four marks. Candidates must attempt any three.
5. Use of log tables is allowed, but calculators are not permitted.
6. Figures to the right indicate full marks.
7. Given: $\mathrm{R} = 8.314 \quad \mathrm{J} \cdot \mathrm{K}^{-1} \cdot \mathrm{mol}^{-1}, N_A = 6.022 \times 10^{23}, F = 96500\,\mathrm{C}$

SECTION - A

1. Select and write the correct answer for the following multiple choice type questions:

(i) The spin-only magnetic moment of Cr^{3+} cation is ....
(a) 3.742 BM
(b) 3.755 BM
(c) 3.873 BM
(D) 3.633 BM

Correct Answer: (C) 3.873 BM
Solution:
The spin-only magnetic moment μ is given by:

$$\mu = \sqrt{n(n+2)}\ \mathrm{BM}$$

For Cr^{3+}, the electronic configuration is $3d^3$ (as it loses 3 electrons from its neutral state). The number of unpaired electrons (n) is 3.

$$\mu = \sqrt{3(3+2)} = \sqrt{15} = 3.873 \text{ BM}$$

Thus, the correct answer is (C) 3.873 BM.

> Quick Tip
>
> The spin-only magnetic moment depends on the number of unpaired electrons and is calculated using $\mu = \sqrt{n(n+2)}$ BM.

(ii) The linkage present in Lactose is ....

(a) $\alpha, \beta - 1, 2$ glycosidic linkage
(b) $\alpha - 1, 4$ glycosidic linkage
(c) $\beta - 1, 4$ glycosidic linkage
(d) $\alpha - 1, 4$ glycosidic linkage

Correct Answer: (C) $\beta - 1, 4$ glycosidic linkage
Solution:
Lactose is a disaccharide composed of one molecule of β-D-galactose and one molecule of D-glucose linked via a $\beta - 1, 4$ glycosidic bond.
Thus, the correct answer is (C) $\beta - 1, 4$ glycosidic linkage.

> Quick Tip
>
> Lactose consists of galactose and glucose linked by a $\beta - 1, 4$ glycosidic bond, making it a reducing sugar.

(iii) The product of the following reaction is:

$$\mathrm{C_2H_5} - \overset{\overset{\displaystyle \mathrm{O}}{\|}}{C} - \mathrm{CH_3} \xrightarrow{\mathrm{H_2/Ni},\ \Delta} \ ?$$

(a) $\mathrm{CH_3 - CH_2 - CH_2 - CH_2 - OH}$
(b) $\mathrm{CH_3 - CH(OH) - CH_2 - CH_3}$
(c) $\mathrm{CH_3 - CH_2 - CH_2 - CH_3}$
(d) $\mathrm{CH_3 - CH_2 - CH_2 - COOH}$

Correct Answer: (B) $\mathrm{CH_3 - CH(OH) - CH_2 - CH_3}$
Solution:
The given compound is butanone ($\mathrm{C_2H_5} - \overset{\overset{\mathrm{O}}{\|}}{C} - \mathrm{CH_3}$). When treated with hydrogen ($\mathrm{H_2}$) in the presence of a nickel (Ni) catalyst and heat (Δ), the reaction involves the reduction of the carbonyl group ($C = O$) into a hydroxyl group, resulting in the formation of a secondary alcohol.
The reaction proceeds as follows:

$$CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - CH_2 - CH_3 \xrightarrow{H_2/Ni,\ \Delta} CH_3 - CH(OH) - CH_2 - CH_3$$

Thus, the correct product is a secondary alcohol, which is $CH_3 - CH(OH) - CH_2 - CH_3$.
The correct answer is (B).

> Quick Tip
>
> Reduction of ketones with H_2/Ni forms a secondary alcohol by converting the carbonyl group to a hydroxyl group.

(iv) The pH of a 0.001 M HCl solution is ....
(a) 10
(b) 3
(c) 2
(d) 11

Correct Answer: (C) 3
Solution:
The pH of an acidic solution is given by:

$$pH = -\log[H^+]$$

For a 0.001 M HCl solution:

$$pH = -\log(1 \times 10^{-3}) = 3$$

Thus, the correct answer is (C) 3.

> Quick Tip
>
> For strong acids like HCl, the pH can be calculated directly as $-\log[H^+]$.

(v) The correct structure of the complex having IUPAC name sodium hexanitro-cobaltate(III) is:
(a) $Na_3[Co(NO_2)_5]$
(b) $Na_4[Co(NO_2)_6]$
(c) $Na_3[Co(NO_2)_6]$
(d) $Na_4[Co(NO_2)_5]$

Correct Answer: (c) $Na_3[Co(NO_2)_6]$
Solution:
The given IUPAC name is sodium hexanitrocobaltate(III).
- "Hexanitro-" refers to six NO_2 ligands.
- "Cobaltate" indicates the presence of a complex anion. - The oxidation state of cobalt is (III),

meaning Co^{3+}.
- The charge of $[Co(NO_2)_6]^{3-}$ requires three Na^+ ions for charge neutrality.

Thus, the correct formula is $Na_3[Co(NO_2)_6]$, making the correct answer (c).

> Quick Tip
>
> For complex salts, the number of counterions must balance the charge of the coordination complex.

(vi) The number of particles present in a Face-Centered Cubic (FCC) unit cell is/are ....
(a) 1
(b) 2
(c) 3
(d) 4

Correct Answer: (d) 4
Solution:
A face-centered cubic (FCC) unit cell consists of: - 8 corner atoms, each contributing $\frac{1}{8}$ of an atom. - 6 face-centered atoms, each contributing $\frac{1}{2}$ of an atom.
Thus, the total number of atoms per unit cell is:

$$8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$$

Therefore, the correct answer is (d) 4.

> Quick Tip
>
> FCC unit cells have a total of 4 atoms per unit cell due to contributions from both corner and face-centered atoms.

(vii) The monomer used in the preparation of Teflon is ....
(a) E-caprolactam
(b) vinyl chloride
(c) styrene
(d) tetrafluoroethene

Correct Answer: (d) tetrafluoroethene
Solution:
Teflon is a polymer formed by the polymerization of tetrafluoroethene (C_2F_4). The reaction follows:

$$n\,F_2C = CF_2 \xrightarrow{\text{polymerization}} [\text{-}CF_2\text{-}CF_2]_n$$

Thus, the correct answer is (d) tetrafluoroethene.

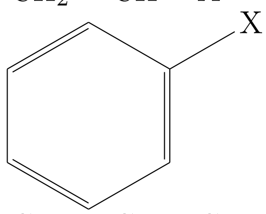
💡 Quick Tip

Teflon (PTFE) is synthesized from tetrafluoroethene and is known for its high chemical resistance and non-stick properties.

(viii) Among the following, the vinylic halide is ....

(a) $R - \mathrm{CH(X)} - R$

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

(c) 

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

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

Solution:

Vinylic halides are compounds in which the halogen (X) is directly bonded to a doubly bonded carbon (alkene carbon).

- (a) Contains a halogen on a saturated carbon, making it an alkyl halide.
- (c) Represents an aryl halide (halogen attached to a benzene ring).
- (d) Contains a halogen on an allylic position, making it an allylic halide.
- (b) Contains a halogen directly bonded to a doubly bonded carbon, making it a vinylic halide.

Thus, the correct answer is (b) $\mathrm{CH_2 = CH} - X$.

💡 Quick Tip

Vinylic halides have halogens attached directly to a double-bonded carbon, distinguishing them from allylic or aryl halides.

(ix) The product of hydrolysis of propyne in the presence of 1% $\mathrm{HgSO_4}$ and 40% $\mathrm{H_2SO_4}$ is ....

(a) methanal

(b) ethanal

(c) propanal

(d) propanone

Correct Answer: (d) propanone

Solution:

The hydration of propyne ($\mathrm{CH_3 - C \equiv CH}$) in the presence of 1% $\mathrm{HgSO_4}$ and 40% $\mathrm{H_2SO_4}$ follows Markovnikov's rule. The reaction undergoes keto-enol tautomerism, leading to the formation of propanone ($\mathrm{CH_3 - CO - CH_3}$) as the final stable product.

Thus, the correct answer is (d) propanone.

💡 Quick Tip

Hydration of alkynes follows Markovnikov's rule, leading to enol formation, which tautomerizes to a more stable ketone.

(x) If the unit of rate constant is mol dm^{-3}s^{-1}, the order of the reaction would be ....

(a) zero
(b) 1
(c) 2
(d) 3

Correct Answer: (a) zero
Solution:
The unit of the rate constant for a reaction of order n is given by:

$$k = \left(\text{mol}^{1-n}\text{dm}^{3(n-1)}\text{s}^{-1}\right)$$

For a zero-order reaction:

$$k = \text{mol dm}^{-3}\text{s}^{-1}$$

which matches the given unit. Thus, the correct answer is (a) zero.

💡 Quick Tip

The unit of the rate constant changes with reaction order and follows the formula mol^{1-n}dm$^{3(n-1)}$s^{-1}.

---

2. Answer the following questions:

(i) Write the name of the metal nanoparticle used to remove *E. coli* bacteria from water.
Solution:
Nanoparticles have been extensively used in water purification. Among them, certain metal nanoparticles exhibit strong antibacterial properties and are effective in eliminating *E. coli* bacteria.

💡 Quick Tip

Metal nanoparticles such as silver (Ag) and copper (Cu) exhibit strong antimicrobial properties.

(ii) Write the name of the reduction product formed when ethyl cyanide is treated with sodium and alcohol.

Solution:

Reduction of ethyl cyanide (CH_3CH_2CN) using sodium in the presence of alcohol leads to the formation of the corresponding amine.

> Quick Tip
>
> The reduction of nitriles with sodium and alcohol produces primary amines via catalytic hydrogenation.

(iii) Complete the reaction:

$$CH_3CH_2Cl \xrightarrow{\text{AgCN, alc., }\Delta} ?$$

Solution:

The reaction of ethyl chloride (CH_3CH_2Cl) with silver cyanide (AgCN) in alcoholic medium produces ethyl isocyanide (CH_3CH_2NC) instead of ethyl cyanide due to the ambident nature of the cyanide ion.

> Quick Tip
>
> Silver cyanide (AgCN) favors isocyanide (NC) formation, whereas alkali cyanides (NaCN or KCN) favor cyanide (CN) formation.

(iv) Calculate the effective atomic number (EAN) of $[Co(NH_3)_6]^{3+}$ ion.

Solution:

The effective atomic number (EAN) is calculated using the formula:

$$\text{EAN} = \text{Atomic number of metal} - \text{Oxidation state} + 2 \times \text{Coordination number}$$

For $[Co(NH_3)_6]^{3+}$:

- Atomic number of cobalt = 27 - Oxidation state of cobalt = +3 - Coordination number = 6

$$\text{EAN} = 27 - 3 + 2(6) = 36$$

> Quick Tip
>
> The EAN rule helps predict the stability of metal complexes; a value of 36 suggests a noble gas configuration.

(v) The compounds of Ti^{4+} ions are colourless due to _________.

Solution:

Titanium (Ti^{4+}) has an electronic configuration of [Ar], meaning it has no d-electrons. Since the colour of transition metal compounds arises due to d-d transitions, the absence of d-electrons in Ti^{4+} prevents such transitions, making its compounds colourless.

Quick Tip

Transition metal ions without d-electrons do not exhibit d-d transitions and appear colourless.

(vi) Write the SI unit of molar conductivity.
Solution:
The SI unit of molar conductivity (Λ_m) is:

$$\text{S m}^2\ \text{mol}^{-1}$$

where: - S (Siemens) is the unit of conductivity, - m^2 accounts for molar volume considerations, - mol^{-1} represents per mole of electrolyte.

Quick Tip

Molar conductivity is measured in S m^2 mol^{-1} and depends on electrolyte concentration.

(vii) Write the sign convention of work done during the expansion of gas.
Solution:
In thermodynamics, the sign convention for work done (W) is:

$$W \text{ is negative when the gas expands}$$
$$W \text{ is positive when the gas is compressed}$$

Since the system (gas) does work on the surroundings during expansion, energy leaves the system, making work negative.

Quick Tip

Expansion: $W < 0$, Compression: $W > 0$, as per the first law of thermodynamics.

(viii) Write the condition of reverse osmosis.
Solution:
Reverse osmosis (RO) occurs when pressure greater than the osmotic pressure is applied to the concentrated solution, forcing water molecules to move from the concentrated side to the dilute side through a semi-permeable membrane.

💡 Quick Tip

Reverse osmosis requires pressure exceeding osmotic pressure to force water through a semi-permeable membrane.

SECTION - B

Attempt any EIGHT of the following questions :

3. Derive an expression for maximum work obtainable during isothermal reversible expansion of an ideal gas from initial volume V_1 to final volume V_2.
Solution:
For an isothermal reversible expansion of an ideal gas, the work done (W) is given by:

$$W = nRT \ln\left(\frac{V_2}{V_1}\right)$$

where: - n is the number of moles of gas, - R is the universal gas constant, - T is the absolute temperature, - V_1 and V_2 are initial and final volumes, respectively.

💡 Quick Tip

Isothermal expansion follows Boyle's Law, where $PV = \text{constant}$.

---

4. What are interhalogen compounds? Write the chemical reaction when chlorine reacts with dry slaked lime.
Solution:
Interhalogen compounds are molecules formed by the combination of two different halogens. These compounds have the general formula AB_x, where $x = 1, 3, 5, 7$.
The reaction of chlorine with dry slaked lime ($\mathrm{Ca(OH)_2}$) produces bleaching powder:

$$\mathrm{Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O}$$

💡 Quick Tip

Bleaching powder ($\mathrm{CaOCl_2}$) is widely used as a disinfectant and oxidizing agent.

---

5. What is a nanomaterial? Write the reaction involved in the sol-gel process during hydrolysis.
Solution:
Nanomaterials are materials with structural features on the nanometer scale (1-100 nm). They exhibit unique optical, electrical, and mechanical properties.
The sol-gel process involves hydrolysis and condensation of metal alkoxides ($\mathrm{M(OR)}_x$):

$$M(OR)_x + xH_2O \rightarrow M(OH)_x + xROH$$

Quick Tip

The sol-gel process is widely used for synthesizing nanoparticles, ceramics, and glass coatings.

---

6. Write the classification of proteins with an example.
Solution:
Proteins are classified based on their structure and function:
1. Fibrous Proteins (e.g., Keratin, Collagen) - Structural proteins providing support. 2. Globular Proteins (e.g., Hemoglobin, Enzymes) - Functional proteins involved in biological processes.

Quick Tip

Proteins are essential macromolecules, functioning as enzymes, structural components, and transport molecules.

---

7. Calculate the time required to deposit 2.4 g of Cu, when 2.03 A of current is passed through $CuSO_4$ solution. (At. mass of Cu = 63.5 g mol^{-1})
Solution:
Using Faraday's first law of electrolysis:

$$m = \frac{ZIt}{F}$$

where: - m = mass deposited (2.4 g), - I = current (2.03 A), - F = Faraday's constant (96500 C/mol), - Z = electrochemical equivalent = $\frac{M}{nF}$ (for Cu, $M = 63.5$, $n = 2$).
We need to first calculate the electrochemical equivalent Z for copper:

$$Z = \frac{M}{nF} = \frac{63.5}{2 \times 96500} = \frac{63.5}{193000} \approx 3.296 \times 10^{-4}\,\text{g/C}$$

Now, rearrange the formula to solve for t:

$$t = \frac{m}{ZI}$$

Substituting the given values:

$$t = \frac{2.4}{(3.296 \times 10^{-4}) \times 2.03}$$

$$t = \frac{2.4}{6.686 \times 10^{-4}} \approx 3593.34\,\text{seconds}$$

Thus, the time required to deposit 2.4 g of Cu is approximately 3593.34 seconds.

Quick Tip

Faraday's laws relate the amount of substance deposited to the quantity of electric charge passed.

---

8. Why are amines basic in nature? Among dimethylamine (pK$_b$ = 3.27) and diethylamine (pK$_b$ = 3.0), which one is more basic?

Solution:

Amines are basic in nature because the nitrogen atom contains a lone pair of electrons that can accept protons (H^+), making them Lewis bases.

Since a lower pK_b value corresponds to a stronger base, diethylamine ($pK_b = 3.0$) is more basic than dimethylamine ($pK_b = 3.27$).

Quick Tip

Amines with larger alkyl groups are more basic due to the electron-donating inductive effect, which increases electron density on nitrogen.

---

9. Explain the buffer action of the sodium acetate-acetic acid buffer.

Solution:

A sodium acetate-acetic acid buffer maintains pH by neutralizing added acids or bases.

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

- When H^+ is added, it reacts with acetate ions (CH_3COO^-), preventing a pH drop.
- When OH^- is added, it reacts with acetic acid (CH_3COOH), preventing a pH rise.

Quick Tip

Buffer solutions resist changes in pH upon the addition of small amounts of acids or bases.

---

10. Write the preparation of (a) diethyl ether and (b) ethyl cyanide from ethyl bromide.

Solution:

(a) Diethyl Ether Preparation (Williamson Ether Synthesis):

$$C_2H_5Br + C_2H_5ONa \rightarrow C_2H_5\text{-O-}C_2H_5 + NaBr$$

(b) Ethyl Cyanide Preparation:

$$C_2H_5Br + KCN \rightarrow C_2H_5CN + KBr$$

Quick Tip

Williamson ether synthesis uses alkyl halides and sodium alkoxides to produce ethers.

---

11. Henry's constant for $CH_3Br(g)$ is 0.159 mol dm^{-3} bar^{-1} at 25°C. Calculate its solubility in water at 25°C if its partial pressure is 0.164 bar.

Solution:

Henry's law states:

$$C = k_H P$$

where:

- C = solubility (mol dm^{-3}),
- k_H = Henry's constant (0.159 mol dm^{-3} bar^{-1}),
- P = partial pressure (0.164 bar).

$$C = (0.159 \times 0.164) = 0.0261 \text{ mol dm}^{-3}$$

Quick Tip

Henry's law states that the solubility of a gas in a liquid is directly proportional to its partial pressure.

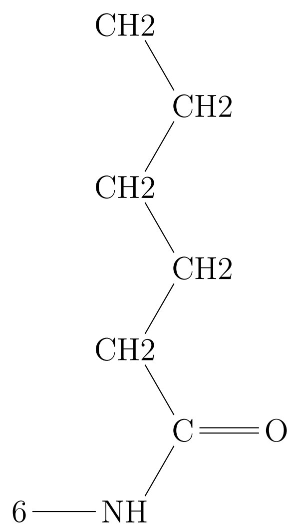
---

12. Write the structure and name of the monomer of:

(a) Nylon-6

Solution:

(a) Nylon-6 Monomer: The monomer for Nylon-6 is caprolactam.



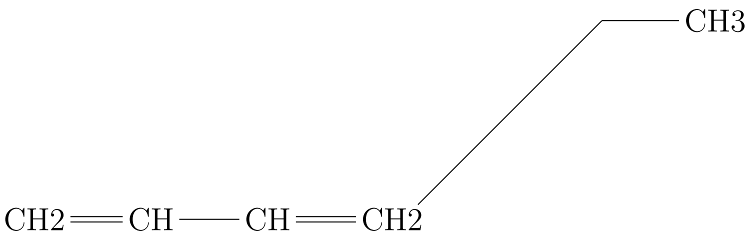
Quick Tip

Nylon-6 is synthesized by ring-opening polymerization of caprolactam.

(b) Natural rubber

Solution:

(b) Natural Rubber Monomer: The monomer of natural rubber is isoprene (2-methyl-1,3-butadiene).



Quick Tip

Natural rubber consists of polyisoprene chains.

---

13. Define Lanthanide contraction. Write the balanced chemical equation when acidified $K_2Cr_2O_7$ reacts with H_2S.

Solution:

Lanthanide Contraction: Lanthanide contraction refers to the gradual decrease in atomic and ionic radii of lanthanide elements across the series due to poor shielding of the nuclear charge by 4f electrons.

Reaction of Acidified $K_2Cr_2O_7$ with H_2S:

$$K_2Cr_2O_7 + 3H_2SO_4 + 3H_2S \rightarrow 2Cr_2(SO_4)_3 + 7H_2O + 3S$$

Quick Tip

Lanthanide contraction impacts transition metal chemistry, making elements of the 5d series similar in size to their 4d counterparts.

---

14. Derive the relationship between molar mass, density of the substance, and unit cell edge length.

Solution:

The density (ρ) of a crystalline solid is defined as the mass per unit volume. The volume of a unit cell is a^3, where a is the edge length of the unit cell.

1. Number of atoms per unit cell:

The number of formula units in a unit cell is denoted by Z. For example, in a simple cubic lattice, $Z = 1$, in a body-centered cubic (BCC) lattice, $Z = 2$, and in a face-centered cubic

(FCC) lattice, $Z = 4$.
2. Mass of the unit cell:
The mass of one formula unit of the substance is equal to its molar mass M divided by Avogadro's number N_A. Therefore, the mass of the unit cell is:

$$\text{Mass of unit cell} = \frac{ZM}{N_A}$$

3. Volume of the unit cell:
The volume of the unit cell is the cube of the edge length a, so:

$$V_{\text{unit cell}} = a^3$$

4. Density of the substance:
The density is defined as mass per unit volume. Therefore, the density of the substance is:

$$\rho = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{\frac{ZM}{N_A}}{a^3}$$

Simplifying the expression:

$$\rho = \frac{ZM}{N_A a^3}$$

Thus, the relationship between molar mass, density, and unit cell edge length is given by:

$$\rho = \frac{ZM}{N_A a^3}$$

where: - Z = Number of formula units per unit cell, - M = Molar mass, - N_A = Avogadro's number (6.022×10^{23} mol^{-1}), - a = Edge length of the unit cell.

Quick Tip

This equation helps determine the density of a solid using X-ray crystallography data.

SECTION - C

Attempt any EIGHT of the following questions :

15. What is osmotic pressure? How will you determine the molar mass of a solute from osmotic pressure?
Solution:
Osmotic Pressure (π) is the pressure required to prevent the net flow of solvent molecules through a semipermeable membrane from a dilute solution to a concentrated one.
The osmotic pressure is given by the van't Hoff equation:

$$\pi = CRT$$

where: - π = osmotic pressure,
- C = molar concentration of the solution,

- R = universal gas constant (0.0821 L atm mol^{-1} K^{-1}),
- T = absolute temperature in Kelvin.

Determination of Molar Mass from Osmotic Pressure:
Since concentration (C) is defined as:

$$C = \frac{n}{V} = \frac{m}{MV}$$

where n = moles of solute, m = mass of solute, and M = molar mass of the solute, we can rearrange the osmotic pressure equation:

$$\pi V = \frac{mRT}{M}$$

Solving for M:

$$M = \frac{mRT}{\pi V}$$

Thus, by measuring the osmotic pressure (π) of a solution of known mass (m) and volume (V), the molar mass (M) of the solute can be determined.

> Quick Tip
>
> Osmotic pressure is a colligative property used to determine the molar mass of large biomolecules like proteins and polymers.

---

16. Write chemical reactions involved in:

(a) Rosenmund Reduction
Solution:
Rosenmund reduction is used to convert acid chlorides to aldehydes using hydrogen gas in the presence of palladium (Pd) catalyst poisoned with barium sulfate ($BaSO_4$).

$$\mathrm{RCOCl + H_2 \xrightarrow[BaSO_4]{Pd} RCHO + HCl}$$

Example:

$$\mathrm{CH_3COCl + H_2 \xrightarrow[BaSO_4]{Pd} CH_3CHO + HCl}$$

> Quick Tip
>
> Rosenmund reduction selectively converts acid chlorides to aldehydes, preventing further reduction to alcohols.

(b) Gattermann-Koch Formylation
Solution :

The Gattermann-Koch reaction introduces a formyl ($-$CHO) group into benzene or activated aromatic rings using carbon monoxide (CO) and hydrogen chloride (HCl) in the presence of a Lewis acid catalyst such as $AlCl_3$ and CuCl.

$$C_6H_6 + CO + HCl \xrightarrow{AlCl_3, CuCl} C_6H_5CHO$$

> **Quick Tip**
>
> The Gattermann-Koch reaction is used to introduce formyl ($-$CHO) groups into benzene rings, producing benzaldehyde derivatives.

(c) Cannizzaro Reaction of Methanal
Solution:
The Cannizzaro reaction is a redox reaction in which non-enolizable aldehydes (without α-hydrogen) undergo disproportionation in the presence of a strong base (NaOH) to form an alcohol and a carboxylate ion.
For methanal (formaldehyde):

$$2HCHO + NaOH \rightarrow HCOO^-Na^+ + CH_3OH$$

> **Quick Tip**
>
> The Cannizzaro reaction occurs in aldehydes without α-hydrogen atoms, leading to simultaneous oxidation and reduction.

---

17. Calculate the standard enthalpy of combustion of methane, if the standard enthalpy of formation of methane, carbon dioxide, and water are -74.8, -393.5, and -285.8 kJ mol^{-1} respectively.
Solution:
The standard enthalpy of combustion (ΔH_c°) of methane is determined using the enthalpy of formation values and the balanced combustion equation:

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

Using Hess's Law:

$$\Delta H_c^\circ = \sum \Delta H_f^\circ(\text{products}) - \sum \Delta H_f^\circ(\text{reactants})$$

Substituting given values:

$$\Delta H_c^\circ = \left[\Delta H_f^\circ(CO_2) + 2 \times \Delta H_f^\circ(H_2O)\right] - \left[\Delta H_f^\circ(CH_4) + 2 \times \Delta H_f^\circ(O_2)\right]$$

Since $\Delta H_f^\circ(O_2) = 0$:

$$\Delta H_c^\circ = [(-393.5) + 2 \times (-285.8)] - (-74.8)$$

$$= (-393.5 - 571.6) + 74.8$$

$$= -890.3 \text{ kJ mol}^{-1}$$

Quick Tip

The standard enthalpy of combustion is always negative, as combustion reactions are exothermic.

---

18. What is the action of the following on ethyl bromide ?
(a) Silver Nitrite
Solution:
When ethyl bromide reacts with silver nitrite ($AgNO_2$), ethyl nitrite is formed due to the ambident nature of the nitrite ion.

$$C_2H_5Br + AgNO_2 \rightarrow C_2H_5ONO + AgBr$$

Quick Tip

Silver nitrite favors the formation of alkyl nitrites (R-ONO), whereas alkali metal nitrites ($NaNO_2$) form alkyl nitro compounds (R-NO_2).

(b) Magnesium in Dry Ether
Solution:
Ethyl bromide reacts with magnesium in dry ether to form an ethyl magnesium bromide (Grignard reagent).

$$C_2H_5Br + Mg \xrightarrow{\text{dry ether}} C_2H_5MgBr$$

Quick Tip

Grignard reagents (R-MgBr) are highly reactive and can be used for nucleophilic addition reactions with carbonyl compounds.

(c) Alcoholic Sodium Hydroxide
Solution:
Ethyl bromide undergoes dehydrohalogenation in the presence of alcoholic sodium hydroxide (NaOH), leading to the formation of ethene.

$$C_2H_5Br + \text{alc. NaOH} \rightarrow C_2H_4 + HBr$$

Quick Tip

Alcoholic NaOH promotes elimination (E2) reactions, forming alkenes, whereas aqueous NaOH promotes nucleophilic substitution (SN2).

---

19. For the reaction $A + B \rightarrow P$:
If $[B]$ is doubled at constant $[A]$, the rate of reaction doubles. If $[A]$ is tripled and $[B]$ is doubled, the rate of reaction increases by a factor of 6. Calculate the rate law equation.
Solution:
The rate law equation is given by:

$$\text{Rate} = k[A]^m[B]^n$$

where m and n are the reaction orders with respect to A and B, respectively.
Step 1: Determine n From the first condition:

$$[B] \text{ is doubled at constant } [A] \Rightarrow \text{Rate doubles}$$

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \left(\frac{[B]_2}{[B]_1}\right)^n$$

$$2 = (2)^n$$

Taking log:

$$\log 2 = n \log 2$$

$$n = 1$$

Step 2: Determine m From the second condition:

$$[A] \text{ is tripled and } [B] \text{ is doubled} \Rightarrow \text{Rate increases by factor of 6}$$

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \left(\frac{[A]_2}{[A]_1}\right)^m \times \left(\frac{[B]_2}{[B]_1}\right)^n$$

$$6 = (3)^m(2)^1$$

$$6 = 3^m \times 2$$

$$\frac{6}{2} = 3^m$$

$$3^m = 3^1$$

$$m = 1$$

Final Rate Law:

$$\text{Rate} = k[A]^1[B]^1$$

or

$$\text{Rate} = k[A][B]$$

> **Quick Tip**
>
> Reaction order is determined by analyzing how changes in reactant concentration affect the rate of reaction.

---

20. Arrange the following in increasing order of the property mentioned:

(i) $\mathbf{HOCl, HClO_2, HClO_3, HClO_4}$ (acidic strength)
Solution: Increasing Order of Acidic Strength: The acidic strength of oxyacids of chlorine increases with the oxidation state of chlorine. Higher oxidation states stabilize the conjugate base, making the acid stronger.

$$\text{HOCl} < \text{HClO}_2 < \text{HClO}_3 < \text{HClO}_4$$

> **Quick Tip**
>
> Acidic strength of oxyacids increases as the oxidation state of the central atom increases.

(ii) $\mathbf{MF, MCl, MBr, MI}$ (ionic character)
Solution:
Increasing Order of Ionic Character: Ionic character is influenced by the difference in electronegativity between the metal (M) and the halogen. As the halogen moves down the group, electronegativity decreases, leading to decreased ionic character. Therefore, the ionic character decreases as we go from F to I due to the decreasing electronegativity of the halogens.

$$\text{MI} < \text{MBr} < \text{MCl} < \text{MF}$$

> **Quick Tip**
>
> Ionic character decreases as the size of the halide ion increases, since larger halides form weaker ionic bonds.

(iii) $\mathbf{HF, HCl, HBr, HI}$ (thermal stability)

Solution: Increasing Order of Thermal Stability: Thermal stability of hydrogen halides (HX) decreases down the group due to decreasing bond strength (H-F being the strongest and H-I the weakest).

$$\mathrm{HI} < \mathrm{HBr} < \mathrm{HCl} < \mathrm{HF}$$

> Quick Tip
>
> Thermal stability of hydrogen halides decreases as bond strength weakens down the group.

---

21. Explain Wolff-Kishner reduction reaction. Write the preparation of propanone by using ethanoyl chloride and dimethyl cadmium.

Solution:

(i) Wolff-Kishner Reduction Reaction: Wolff-Kishner reduction is a method used to reduce carbonyl compounds ($C = O$) to alkanes using hydrazine (N_2H_4) and a strong base (KOH) in a high-boiling solvent like glycol.

$$\mathrm{R} - \mathrm{C} = O + \mathrm{N_2H_4} \xrightarrow{\text{KOH,heat}} \mathrm{R} - \mathrm{CH_2} + \mathrm{N_2}$$

Example:

$$\mathrm{CH_3COCH_3} + \mathrm{N_2H_4} \xrightarrow{\text{KOH,heat}} \mathrm{CH_3CH_2CH_3} + \mathrm{N_2}$$

> Quick Tip
>
> Wolff-Kishner reduction is useful for converting aldehydes and ketones into alkanes without affecting other functional groups.

(ii) Preparation of Propanone Using Ethanoyl Chloride and Dimethyl Cadmium:
Dimethyl cadmium ($(CH_3)_2Cd$) reacts with ethanoyl chloride (CH_3COCl) to form propanone.

$$\mathrm{CH_3COCl} + (\mathrm{CH_3})_2\mathrm{Cd} \rightarrow \mathrm{CH_3COCH_3} + \mathrm{CdCl_2}$$

> Quick Tip
>
> Dimethyl cadmium is a reagent used in organic synthesis for preparing ketones from acid chlorides.

---

22. Write postulates of Werner's theory of coordination complexes. Write the name of a hexadentate ligand.

Solution:

Postulates of Werner's Coordination Theory:
1. Primary Valency corresponds to oxidation state and is ionizable.
2. Secondary Valency determines coordination number and is non-ionizable.
3. The metal ion satisfies its secondary valency by forming coordinate bonds with ligands.

4. The spatial arrangement of ligands around the metal ion leads to different geometries.

Example of a Hexadentate Ligand: Ethylenediaminetetraacetate (EDTA) is a hexadentate ligand that binds metal ions through six donor atoms.

$$\text{EDTA}^{4-}$$

> Quick Tip
>
> Werner's theory explains the structure and bonding in coordination complexes, distinguishing primary and secondary valencies.

---

23. Define the electrochemical series and write its two applications.
Solution:
Definition of Electrochemical Series: The electrochemical series is a list of standard electrode potentials (E°) of elements arranged in order of increasing or decreasing ability to lose or gain electrons.
Applications of the Electrochemical Series:
1. Predicting Redox Reactions - A species with a lower reduction potential acts as a reducing agent. - A species with a higher reduction potential acts as an oxidizing agent.
2. Determining Electrochemical Cell Feasibility - A spontaneous reaction occurs when $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$ is positive.

> Quick Tip
>
> The electrochemical series helps predict the spontaneity of redox reactions and determines electrode potential differences in cells.

---

24. Identify 'A', 'B' and 'C' in the following chain reaction and rewrite the chemical reactions:

$$CH_3CH_2OH \xrightarrow{\text{red 'P', } Br_2} A \xrightarrow{\text{KCN, alc}} B \xrightarrow{\text{LiAlH}_4\text{,Ether}} C$$

Solution:
1. Conversion of Ethanol to Ethyl Bromide (A): Ethanol reacts with bromine in the presence of red phosphorus to form ethyl bromide.

$$CH_3CH_2OH + Br_2 \xrightarrow{\text{red P}} CH_3CH_2Br + HBr$$

So, A = Ethyl Bromide (CH_3CH_2Br).
2. Conversion of Ethyl Bromide to Propanenitrile (B): Ethyl bromide reacts with alcoholic potassium cyanide (KCN) to form propanenitrile.

$$CH_3CH_2Br + KCN \rightarrow CH_3CH_2CN + KBr$$

So, B = Propanenitrile (CH_3CH_2CN).

3. Conversion of Propanenitrile to Propylamine (C): Propanenitrile undergoes reduction with lithium aluminum hydride ($LiAlH_4$) in ether to form propylamine.

$$CH_3CH_2CN + 4[H] \xrightarrow{LiAlH_4,Ether} CH_3CH_2CH_2NH_2$$

So, C = Propylamine ($CH_3CH_2CH_2NH_2$).

Quick Tip

This reaction sequence involves nucleophilic substitution (S_N2) followed by reduction of nitriles to primary amines.

---

25. Define acids and bases according to Bronsted-Lowry theory. Derive the relationship between pH and pOH.

Solution:

(i) Bronsted-Lowry Definition:

- Acids: Proton (H^+) donors. - Bases: Proton (H^+) acceptors.

Example:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Here, NH_3 acts as a Bronsted base (accepting H^+), and H_2O acts as a Bronsted acid (donating H^+).

(ii) Relationship Between pH and pOH:

We know:

$$\text{pH} = -\log[H^+]$$

$$\text{pOH} = -\log[OH^-]$$

Since,

$$[H^+][OH^-] = 10^{-14}$$

Taking logarithm,

$$\text{pH} + \text{pOH} = 14$$

Quick Tip

pH and pOH are related by pH + pOH = 14, which applies to aqueous solutions at 25°C.

---

26. Write the preparation of potassium dichromate from chromite ore.

Solution:

Potassium dichromate ($K_2Cr_2O_7$) is prepared from chromite ore ($FeCr_2O_4$) through the following steps:

1. Roasting with Sodium Carbonate:

$$FeCr_2O_4 + 4Na_2CO_3 + 7O_2 \rightarrow 2Na_2CrO_4 + 2Fe_2O_3 + 4CO_2$$

2. Conversion to Dichromate:

$$2Na_2CrO_4 + H_2SO_4 \rightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$$

3. Formation of Potassium Dichromate:

$$Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$$

Quick Tip

Potassium dichromate is a powerful oxidizing agent used in redox reactions and analytical chemistry.

Section - D

Attempt any THREE of the following questions :

27. Convert the following:
(i) Acetaldehyde to Isopropyl Alcohol
Solution:
Acetaldehyde (CH_3CHO) can be converted to isopropyl alcohol ($CH_3CH(OH)CH_3$) through the following steps:
1. Aldol Condensation:

$$2CH_3CHO \xrightarrow{\text{Dil. NaOH}} CH_3CH(OH)CH_2CHO$$

2. Catalytic Hydrogenation:

$$CH_3CH(OH)CH_2CHO + H_2 \xrightarrow{\text{Ni, Heat}} CH_3CH(OH)CH_3$$

Thus, acetaldehyde undergoes aldol condensation followed by hydrogenation to yield isopropyl alcohol.

Quick Tip

Aldol condensation forms β-hydroxy aldehydes or ketones, which can be hydrogenated to alcohols.

(ii) Cumene to Phenol
Solution:
Cumene ($C_6H_5CH(CH_3)_2$) is converted to phenol by the cumene hydroperoxide process:
1. Oxidation of Cumene:

$$C_6H_5CH(CH_3)_2 + O_2 \rightarrow C_6H_5C(CH_3)_2OOH$$

2. Acidic Hydrolysis:

$$C_6H_5C(CH_3)_2OOH \xrightarrow{H^+} C_6H_5OH + CH_3COCH_3$$

Thus, cumene is oxidized to cumene hydroperoxide, which undergoes acid hydrolysis to give phenol and acetone as a byproduct.

Quick Tip

Cumene hydroperoxide rearranges under acidic conditions to produce phenol and acetone.

(iii) Anisole to Phenol
Solution:
Anisole ($C_6H_5OCH_3$) can be converted to phenol (C_6H_5OH) via hydrolysis using hydrobromic acid:

$$C_6H_5OCH_3 + HBr \xrightarrow{\text{Heat}} C_6H_5OH + CH_3Br$$

Quick Tip

Anisole undergoes cleavage in the presence of HBr, forming phenol and methyl bromide.

27(iii)(b). Write two uses of neon.
Solution:
Neon (Ne) is a noble gas with various applications. Two important uses include:

1. Illumination: Used in neon lights and advertising signs.
2. Cryogenics: Used in high-performance cooling systems, especially in refrigeration.

Quick Tip

Neon is chemically inert and primarily used in lighting and cooling applications.

---

28. Define:
(i) Extensive and Intensive Properties
Solution:
Extensive Properties: Extensive properties depend on the amount of matter present in the system. These properties change when the quantity of substance changes.
Examples: - Mass - Volume - Energy - Enthalpy
Intensive Properties: Intensive properties do not depend on the amount of substance. These properties remain unchanged regardless of the quantity of the system.
Examples: - Temperature - Density - Pressure - Refractive index

Quick Tip

Extensive properties depend on the system's size, whereas intensive properties remain independent of the system size.

(ii) Isobaric and Adiabatic Processes
Solution:
Isobaric Process: An isobaric process occurs at constant pressure, meaning:

$$\Delta P = 0$$

Example: - Heating water in an open container at constant atmospheric pressure.
Work done in an isobaric process:

$$W = P\Delta V$$

Adiabatic Process: An adiabatic process occurs without heat exchange between the system and surroundings.

$$q = 0$$

Example: - Sudden expansion or compression of gas in an insulated container.
For an adiabatic process:

$$PV^{\gamma} = \text{constant}$$

Quick Tip

Isobaric processes occur at constant pressure, while adiabatic processes involve no heat exchange.

28(b) What are Enzymes?
Solution:
Enzymes are biological catalysts that speed up chemical reactions in living organisms. They are typically proteins and function by lowering the activation energy of biochemical reactions.

Characteristics of Enzymes:
1. Highly specific in action.
2. Work under mild conditions (temperature and pH).
3. Can be regulated by inhibitors or activators.

Examples of Enzymes:
- Amylase: Converts starch into maltose.
- Lipase: Breaks down lipids into fatty acids and glycerol.
- Catalase: Decomposes hydrogen peroxide into water and oxygen.

Quick Tip

Enzymes act as biological catalysts, facilitating metabolic reactions without being consumed.

28(c) Write the Atomic Numbers of Transuranium Elements.
Solution:
Transuranium elements are elements with atomic numbers greater than uranium ($Z > 92$). They are artificially synthesized in laboratories.
Atomic Numbers of Some Transuranium Elements:
1. Neptunium (Np) - 93
2. Plutonium (Pu) - 94
3. Americium (Am) - 95
4. Curium (Cm) - 96
5. Berkelium (Bk) - 97
6. Californium (Cf) - 98

Quick Tip

Transuranium elements ($Z > 92$) are synthetic and often radioactive.

---

29. Predict the type of cubic lattice of a solid element having edge length of 400 pm and density of 6.25 g/ml. (Atomic mass of element = 60)
Solution:
The type of cubic lattice can be determined using the formula:

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

where: - Z = Number of atoms per unit cell, - ρ = Density (6.25 g/cm^3), - N_A = Avogadro's number (6.022×10^{23} mol^{-1}), - a = Edge length (400 pm = 4.0×10^{-8} cm), - M = Atomic mass (60 g/mol).

$$Z = \frac{(6.25) \times (6.022 \times 10^{23}) \times (4.0 \times 10^{-8})^3}{60}$$

Solving, we get $Z = 4$, indicating a Face-Centered Cubic (FCC) Lattice.

Quick Tip

A simple cubic lattice has $Z = 1$, a body-centered cubic (BCC) lattice has $Z = 2$, and a face-centered cubic (FCC) lattice has $Z = 4$.

29(b). Define: Nanoscience
Solution:

Nanoscience is the study of materials and structures at the nanoscale (1-100 nm). At this scale, materials exhibit unique physical and chemical properties due to the high surface area-to-volume ratio.

Applications of Nanoscience: - Medical: Drug delivery using nanoparticles. - Electronics: Quantum dots for display technology. - Energy: Solar cells with nanostructured coatings.

> **Quick Tip**
>
> Nanoscience enables innovations in medicine, electronics, and environmental sustainability.

29(c). Write the chemical reaction for the preparation of Polyacrylonitrile.

Solution:

Polyacrylonitrile (PAN) is synthesized by the polymerization of acrylonitrile in the presence of a radical initiator.

$$n\text{CH}_2\text{=CH-CN} \xrightarrow{\text{Peroxide}} [-\text{CH}_2 - \text{CH(CN)}-]_n$$

Polyacrylonitrile is used in textiles and as a precursor for carbon fibers.

> **Quick Tip**
>
> Radical polymerization of acrylonitrile produces PAN, a precursor for synthetic fibers and carbon materials.

---

30. Derive the relation between half-life period and rate constant for a first-order reaction.

Solution:

For a first-order reaction:

$$\text{Rate} = k[A]$$

The integrated rate law is:

$$[A] = [A]_0 e^{-kt}$$

At half-life ($t_{1/2}$), $[A] = \frac{[A]_0}{2}$,

$$\frac{[A]_0}{2} = [A]_0 e^{-kt_{1/2}}$$

Taking ln on both sides:

$$\ln \frac{1}{2} = -kt_{1/2}$$

$$t_{1/2} = \frac{0.693}{k}$$

Thus, $t_{1/2}$ is independent of concentration for first-order reactions.

Quick Tip

First-order reactions have a constant half-life, useful in radioactive decay and pharmacokinetics.

30(b). Write the net cell reaction during discharging of a lead accumulator.
Solution:
During discharging, lead (Pb) acts as the anode, and lead dioxide (PbO_2) acts as the cathode in a sulfuric acid medium.

$$\mathrm{Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O}$$

Quick Tip

Lead-acid batteries work on reversible redox reactions and are used in vehicles and backup power systems.

30(c). Draw the structure of Peroxymonosulfuric Acid.
Solution:
The chemical formula of Peroxymonosulfuric Acid (Caro's Acid) is H_2SO_5. Its structure contains one peroxy $(-O-O-)$ bond:

$$\mathrm{HO} \text{——} \mathrm{S} \text{═══} \mathrm{O} \text{——} \mathrm{OH}$$

It is a strong oxidizing agent used in organic synthesis.

Quick Tip

Peroxymonosulfuric acid (H_2SO_5) is a strong oxidizer, often used in wastewater treatment.

---

31. Mention the number of unpaired electrons and geometry of the following complexes:
(i) $[\mathbf{Ni(Cl)_4}]^{2-}$
Solution:
- Oxidation State of Ni:

$$x + 4(-1) = -2 \Rightarrow x = +2$$

Thus, Ni is in the +2 oxidation state.
- Electronic Configuration of Ni^{2+}:

$$[\mathrm{Ar}]3d^8 4s^0$$

- Nature of Ligand:
- Chloride (Cl^-) is a weak field ligand, so it does not cause strong pairing.

- The tetrahedral geometry is favored.
- Unpaired Electrons & Hybridization:
- Hybridization: sp^3
- Unpaired electrons: 2
- Geometry: Tetrahedral

Quick Tip

Weak field ligands (like Cl^-) favor high spin configurations and tetrahedral geometry.

(ii) $[\mathbf{Ni(CN)_4}]^{2-}$
Solution:
- Oxidation State of Ni:

$$x + 4(-1) = -2 \Rightarrow x = +2$$

So, Ni is in the +2 oxidation state.
- Electronic Configuration of Ni^{2+}:

$$[\mathrm{Ar}]3d^8 4s^0$$

- Nature of Ligand:
- Cyanide (CN^-) is a strong field ligand, which causes pairing of electrons.
- The square planar geometry is preferred.
- Unpaired Electrons & Hybridization:
- Hybridization: dsp^2
- Unpaired electrons: 0
- Geometry: Square Planar

Quick Tip

Strong field ligands (like CN^-) induce low-spin configurations, leading to square planar geometry.

Convert the following:
(a) Ethanentrile into Ethanal
Solution:
Ethanenitrile (CH_3CN) can be converted to ethanal (CH_3CHO) using partial reduction with DIBAL-H (Diisobutylaluminium Hydride).

$$\mathrm{CH_3CN} + \text{DIBAL-H} \xrightarrow{-78^\circ C} \mathrm{CH_3CHO}$$

Quick Tip

DIBAL-H selectively reduces nitriles to aldehydes under controlled conditions.

(b) Cyclohexane into Adipic Acid
Solution:
Cyclohexane (C_6H_{12}) is oxidized using nitric acid (HNO_3) or potassium permanganate ($KMnO_4$) to yield adipic acid ($C_6H_{10}O_4$).

$$C_6H_{12} + [O] \xrightarrow{HNO_3} \text{HOOC-(CH}_2)_4\text{-COOH}$$

Quick Tip

Adipic acid is an important precursor for Nylon-6,6 and is produced via controlled oxidation of cyclohexane.
