SECOND YEAR HIGHER SECONDARY EXAMINATION, MARCH 2026

CHEMISTRY

Question Paper with Solutions

Time Allowed:	Maximum Marks:	Total Questions:	Cool-off Time:
2 Hours	60	31	15 Minutes

General Instructions to Candidates

Read the following instructions very carefully and strictly follow them:

(I) There is a ”Cool-off time” of 15 minutes in addition to the writing time.

(II) Use the ’Cool-off time’ to get familiar with questions and to plan your answers.

(III) Read questions carefully before answering.

(IV) Read the instructions carefully.

(V) Calculations , figures and graphs should be shown in the answer sheet itself.

(VI) Malayalam version of the questions is also provided.

(VII) Give equations wherever necessary.

(VIII) Electronic devices except non-programmable calculators are not allowed in the Examination hall.

Answer any 4 questions from 1 to 5 Each carries 1 score.

1. In the electrolysis of molten NaCl, the substance liberated at the cathode is:

(a) Cl_2

(b) Na

(c) H_2

(d) O_2

Correct Answer: (b) Na

Solution:

Concept: Electrolysis is the process of decomposing ionic compounds into their elements by passing a direct electric current through the compound in a fluid form.

- **Cathode:** The negative electrode where reduction (gain of electrons) occurs.
- **Anode:** The positive electrode where oxidation (loss of electrons) occurs.

Step 1: Identify the ions present in molten $NaCl$.
In the molten state, Sodium Chloride dissociates into Sodium ions ($Na+$) and Chloride ions ($Cl-$).
Step 2: Determine the reaction at the cathode.
The positively charged cations ($Na+$) migrate towards the negative electrode (cathode). At the cathode, they gain electrons (reduction) to form sodium metal:

$$Na + +e- \rightarrow Na(l)$$

Quick Tip

Remember: **An Ox** and **Red Cat**. - **An**ode = **Ox**idation (Loss of electrons) - **Red**uction = **Cat**hode (Gain of electrons) In molten salts, the metal cation always reduces to the metal at the cathode.

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2. The half-life of a first-order reaction depends on:

(a) Initial concentration

(b) Temperature only

(c) Rate constant

(d) Both (a) and (c)

Correct Answer: (c) Rate constant

Solution:

Concept: The half-life ($t_{1/2}$) is the time required for the concentration of a reactant to decrease to half of its initial value.

Step 1: Recall the formula for the half-life of a first-order reaction.

For a first-order reaction, the integrated rate law leads to the expression:

$$t_{1/2} = \frac{\ln(2)}{k} \approx \frac{0.693}{k}$$

where k is the rate constant.

Step 2: Analyze dependencies.

From the formula, it is clear that $t_{1/2}$ is inversely proportional to the rate constant k. Notably, the initial concentration $[A]_0$ does not appear in the equation, meaning the half-life is independent of the starting amount.

Quick Tip

For first-order reactions, the half-life is constant regardless of how much material you start with. If it takes 10 minutes for 100g to become 50g, it will also take 10 minutes for 2g to become 1g.

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3. Which of the following is a chelating ligand?

(a) NH_3

(b) H_2O

(c) $Cl-$

(d) C_2O_42-

Correct Answer: (d) C_2O_42-

Solution:

Concept: A chelating ligand is a polydentate ligand that can bond to a single central metal atom through two or more donor atoms simultaneously, forming a ring structure (chelate ring).

Step 1: Identify the denticity of the options.

- NH_3 (Ammonia): Unidentate (one donor N atom).
- H_2O (Water): Unidentate (one donor O atom).
- $Cl-$ (Chloride): Unidentate (one donor Cl atom).
- C_2O_42- (Oxalate): Didentate (two donor O atoms).

Step 2: Determine the chelating agent.
Because the oxalate ion (C_2O_42-) has two donor atoms that can coordinate to the same metal ion to form a five-membered ring, it is classified as a chelating ligand.

Quick Tip

Chelation generally increases the stability of a complex. Look for molecules with multiple lone pairs on different atoms that are positioned to "grab" a metal like a claw.

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4. Which of the following is least reactive towards nucleophilic substitution (S_N1)?
(a) Benzyl chloride
(b) Methyl chloride
(c) Chlorobenzene
(d) Allyl chloride

Correct Answer: (c) Chlorobenzene

Solution:
Concept: S_N1 reactivity depends on the stability of the carbocation intermediate formed after the leaving group departs.
Step 1: Evaluate carbocation stability for each option.

- **Benzyl chloride:** Forms a benzyl carbocation ($C_6H_5CH_2+$), which is highly resonance-stabilized.
- **Allyl chloride:** Forms an allyl carbocation ($CH_2 = CH - CH_2+$), which is resonance-stabilized.

- **Methyl chloride:** Forms a methyl carbocation (CH_3+), which is unstable but can still undergo substitution (usually via S_N2).
- **Chlorobenzene:** The $C - Cl$ bond has partial double bond character due to resonance, and the phenyl carbocation (C_6H_5+) is extremely unstable.

Step 2: Identify the least reactive species.
Chlorobenzene is inert to nucleophilic substitution under ordinary conditions because the $sp2$ hybridized carbon holds the chlorine more tightly, and the resulting phenyl cation is not stabilized by resonance.

Quick Tip

Aryl halides and vinyl halides are generally very unreactive toward nucleophilic substitution because the lone pair on the halogen delocalizes into the π system, strengthening the bond.

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5. Which of the following is a polysaccharide?

(a) maltose

(b) sucrose

(c) fructose

(d) cellulose

Correct Answer: (d) cellulose

Solution: Concept: Carbohydrates are classified into three main groups based on their complexity and the number of sugar units they contain:

- **Monosaccharides:** The simplest form of sugar (e.g., glucose, fructose).
- **Disaccharides:** Formed by the union of two monosaccharides (e.g., sucrose, maltose, lactose).
- **Polysaccharides:** Complex carbohydrates made of long chains of monosaccharide units joined by glycosidic bonds (e.g., starch, glycogen, cellulose).

Analyzing the given options.

- **Fructose:** It is a simple sugar with the formula $C_6H_{12}O_6$. It cannot be hydrolyzed further, making it a **monosaccharide**.
- **Maltose:** It consists of two glucose units linked together. Since it is composed of two units, it is a **disaccharide**.
- **Sucrose:** Common table sugar, composed of one glucose and one fructose unit. It is also a **disaccharide**.
- **Cellulose:** It is a linear polymer of hundreds to thousands of D-glucose units. Because it is a long-chain macromolecule, it is classified as a **polysaccharide**.

Quick Tip

Remember the "Big Three" polysaccharides often tested in biology and chemistry:

1. **Starch** (Energy storage in plants)
2. **Glycogen** (Energy storage in animals)
3. **Cellulose** (Structural component of plant cell walls)

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6. Why saline water is mixed with medicine before injected into the blood of a patient?

Correct Answer: Saline water is used because it is isotonic with human blood cells.

Solution: **Concept:** The process is based on the principle of Osmosis. Osmosis is the movement of solvent molecules through a semi-permeable membrane from a region of lower solute concentration to a region of higher solute concentration. For medical injections:

- **Isotonic Solutions:** Have the same osmotic pressure as blood (0.9% w/v $NaCl$).
- **Hypotonic Solutions:** Lower concentration than blood; causes cells to swell and burst (hemolysis).
- **Hypertonic Solutions:** Higher concentration than blood; causes cells to shrink (plasmolysis).

Step 1: Matching Osmotic Pressure. Human blood cells have an osmotic pressure equivalent to a 0.9% (mass/volume) sodium chloride solution, commonly known as normal saline. When medicine is mixed with this saline, the resulting solution remains **isotonic** with the fluid inside the red blood cells.

Step 2: Preventing Cell Damage. If pure water (hypotonic) were injected, water would enter the red blood cells by osmosis, causing them to swell and potentially burst. Conversely, if a highly concentrated solution (hypertonic) were injected, water would leave the cells, causing them to shrivel. Mixing with saline ensures the cells maintain their normal shape and function.

Quick Tip

Normal saline ($0.9\% NaCl$) is the "gold standard" for IV fluids because it creates an osmotic balance that prevents damage to blood cells.

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7. The standard electrode potential for Daniell cell is 1.1 V. Calculate the standard Gibbs Energy change for the reaction: Zn(s) + Cu2+(aq) → Zn2+(aq) + Cu(s).

Correct Answer: $-212.27\,\text{kJ/mol}$

Solution: Concept: The relationship between the standard Gibbs free energy change ($\Delta G\circ$) and the standard electromotive force (EMF) of a cell ($E\circ_{\text{cell}}$) is given by the formula:

$$\Delta G\circ = -nFE\circ_{\text{cell}}$$

Where:

- n = Number of moles of electrons transferred in the balanced chemical equation.
- F = Faraday's constant ($\approx 96487\,\text{C/mol}$ or $96500\,\text{C/mol}$ for simplicity).
- $E\circ_{\text{cell}}$ = Standard electrode potential of the cell.

Step 1: Determine the number of electrons transferred (n). The cell reaction is:

$$\text{Zn(s)} + \text{Cu2+(aq)} \rightarrow \text{Zn2+(aq)} + \text{Cu(s)}$$

The half-reactions are:

- Oxidation: Zn(s) $\rightarrow$ Zn2+(aq) + 2$e-$
- Reduction: Cu2+(aq) + 2$e-$ $\rightarrow$ Cu(s)

Thus, the number of moles of electrons transferred, $n = 2$.

Step 2: Calculate the standard Gibbs Energy change ($\Delta G\circ$). Given: $E\circ_{\text{cell}} = 1.1\,\text{V}$ and $F = 96487\,\text{C/mol}$. Substituting the values into the formula:

$$\Delta G\circ = -2 \times 96487\,\text{C/mol} \times 1.1\,\text{V}$$

$$\Delta G\circ = -212271.4\,\text{J/mol}$$

Converting to kJ/mol:

$$\Delta G\circ \approx -212.27\,\text{kJ/mol}$$

Quick Tip

Always check the sign! A spontaneous redox reaction (like in a galvanic cell) must have a **positive** $E\circ_{\text{cell}}$ and a **negative** $\Delta G\circ$. Ensure your units are consistent—usually, the formula gives Joules, so divide by 1000 to get kiloJoules.

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8. (i) Define activation energy.

(ii) Explain the effect of catalyst on the rate of chemical reaction.

Correct Answer: (i) Activation energy is the minimum amount of extra energy required by a reacting molecule to get converted into product. (ii) A catalyst increases the rate of reaction by providing an alternative pathway with a lower activation energy.

Solution: **Concept:** According to the Collision Theory, for a chemical reaction to occur, reactant molecules must collide with a certain minimum energy called Threshold Energy.

- **Activation Energy (E_a):** The difference between the threshold energy and the average kinetic energy of the reactant molecules.
- **Catalysis:** A process where a substance (catalyst) alters the reaction speed without being consumed.

Step 1: Understanding Activation Energy. Reactants do not automatically turn into products upon contact. They must overcome an energy barrier. Mathematically:

$$\text{Activation Energy } (E_a) = \text{Threshold Energy} - \text{Average energy of reactants}$$

Step 2: Effect of Catalyst. A catalyst increases the rate of a chemical reaction by participating in the reaction mechanism to provide a new "shortcut." This new pathway has a lower activation energy (E_a') than the uncatalyzed pathway.

Because the energy barrier is lower, a larger fraction of reactant molecules possess enough energy to cross the barrier at a given temperature, thereby increasing the reaction rate. It is important to note that a catalyst does *not* change the enthalpy (ΔH) or the equilibrium constant of the reaction.

Quick Tip

Think of activation energy as a "hill" that reactants must climb. A catalyst doesn't push the reactants harder; it simply lowers the height of the hill!

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9. The initial concentration of the first order reaction, $N_2O_5(g) \rightarrow 2NO_2(g) + \frac{1}{2}O_2(g)$, was $1.24 \times 10{-}2$ mol L-1 at 300 K. The concentration of N_2O_5 after 60 minutes was $0.20 \times 10{-}2$ mol L-1. Calculate the rate constant of the reaction at 300 K.

Correct Answer: 0.0304 min-1 (or $3.04 \times 10{-}2$ min-1)

Solution: Concept: For a first-order reaction, the rate constant k is determined by the integrated rate law:

$$k = \frac{2.303}{t} \log\left(\frac{[R]_0}{[R]_t}\right)$$

Where:

Ro = Initial concentration of the reactant.

Rt = Concentration of the reactant at time t.

t = Time elapsed.

Step 1: Identify the given values. Initial concentration $[R]_0 = 1.24 \times 10{-}2$ mol L-1 Final concentration $[R]_t = 0.20 \times 10{-}2$ mol L-1 Time $t = 60$ minutes

Step 2: Apply the first-order rate equation. Substituting the values into the formula:

$$k = \frac{2.303}{60} \log\left(\frac{1.24 \times 10{-}2}{0.20 \times 10{-}2}\right)$$

$$k = \frac{2.303}{60} \log(6.2)$$

Step 3: Solve for k. Using $\log(6.2) \approx 0.7924$:

$$k = \frac{2.303 \times 0.7924}{60}$$

$$k = \frac{1.8249}{60}$$

$$k = 0.030415 \text{ min}{-}1$$

Quick Tip

The units of the rate constant for a first-order reaction are always time-1. Ensure your concentrations are in the same units so they cancel out inside the log term!

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10. Identify the products X and Y formed in the following reactions:

(i) $CH_3CH_2OH + PCl_5 \rightarrow X + POCl_3 + HCl$ (ii) $CH_3Br + AgF \rightarrow Y + AgBr$

Correct Answer: X is CH_3CH_2Cl (Ethyl chloride) and Y is CH_3F (Methyl fluoride).

Solution: **Concept:** The reactions involve the substitution of functional groups in organic compounds:

- **Reaction (i):** Conversion of alcohols to alkyl halides using Phosphorus pentachloride (PCl_5). The -OH group is replaced by a chlorine atom.
- **Reaction (ii):** The **Swarts Reaction**, which is the standard method for synthesizing alkyl fluorides. It involves the exchange of a halogen (usually Br or Cl) with a metal fluoride (like AgF, Hg_2F_2, CoF_2).

Step 1: Identifying Product X. When ethanol (CH_3CH_2OH) reacts with PCl_5, the hydroxyl group is substituted by a chloride ion. The balanced chemical equation is:

$$CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2Cl + POCl_3 + HCl$$

Thus, X is Chloroethane (Ethyl chloride).

Step 2: Identifying Product Y. Methyl bromide (CH_3Br) reacts with Silver fluoride (AgF) in a halogen exchange reaction. The fluorine atom replaces the bromine atom.

$$CH_3Br + AgF \rightarrow CH_3F + AgBr$$

Thus, Y is Fluoromethane (Methyl fluoride).

Quick Tip

To remember the Swarts reaction, think of it as the "F-exchange." It is specifically used because direct fluorination of alkanes is often too violent to control!

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11. Give two differences between S_N1 and S_N2 reactions.

Correct Answer: S_N1 is a two-step reaction involving a carbocation intermediate, while S_N2 is a single-step concerted reaction with no intermediate.

Solution: **Concept:** Nucleophilic substitution reactions (S_N) are classified based on their kinetics and mechanism:

- **S_N1** (Substitution Nucleophilic Unimolecular): The rate depends only on the concentration of the substrate.
- **S_N2** (Substitution Nucleophilic Bimolecular): The rate depends on the concentration of both the substrate and the nucleophile.

Step 1: Comparing the mechanism and kinetics. The key differences can be summarized as follows:

Feature	**S_N1 Reaction**
Two-step process.	Single-step (concerted) process. heightInter
Involves a **transition state** only. heightKinetics (Order)	First order: Rate = k[RX].
Results in **racemization**.	Results in **Walden Inversion**. height

Step 2: Reactivity order. Due to the stability of intermediates and steric hindrance:

- **S_N1 preference:** Tertiary ($3\circ$) ¿ Secondary ($2\circ$) ¿ Primary ($1\circ$).
- **S_N2 preference:** Primary ($1\circ$) ¿ Secondary ($2\circ$) ¿ Tertiary ($3\circ$).

Quick Tip

To remember which is which: S_N1 has 1 reactant in the rate-determining step but 2 steps. S_N2 has 2 reactants in the rate-determining step but only 1 step!

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12. (i) In the presence of light, chloroform is slowly oxidised by air to an extremely poisonous gas called
$.(ii) How is chlorobenzene converted into 1-chloro-2-methylbenzene?$

Correct Answer: (i) Phosgene (or Carbonyl chloride). (ii) By Friedel-Crafts Alkylation using methyl chloride (CH_3Cl) and anhydrous aluminium chloride ($AlCl_3$).

Solution: Concept: The question covers the chemical stability of haloalkanes and the electrophilic substitution of haloarenes:

- **Oxidation of Chloroform: Chloroform ($CHCl_3$) is sensitive to light and air, undergoing a radical reaction to form a toxic gas.**
- **Friedel-Crafts Alkylation: An electrophilic substitution reaction where an alkyl group is introduced into the benzene ring in the presence of a Lewis acid catalyst.**

Step 1: Oxidation of Chloroform. Chloroform reacts with atmospheric oxygen in the presence of light to produce Phosgene ($COCl_2$), which is highly toxic.

$$2\mathbf{CHCl_3} + \mathbf{O_2} \xrightarrow{\textbf{light}} 2\mathbf{COCl_2} + 2\mathbf{HCl}$$

To prevent this, chloroform is stored in dark-colored bottles and often mixed with a small amount of ethanol, which converts phosgene into harmless diethyl carbonate.
Step 2: Conversion of Chlorobenzene. To convert chlorobenzene into 1-chloro-2-methyl benzene (o-chlorotoluene), we use methyl chloride in the presence of anhydrous $AlCl_3$. Since the chlorine atom on the ring is ortho-para directing, a mixture of ortho and para isomers is formed.

$$\mathbf{C_6H_5Cl} + \mathbf{CH_3Cl} \xrightarrow{\textbf{anh. AlCl}_3} \textbf{o-chlorotoluene} + \textbf{p-chlorotoluene}$$

1-chloro-2-methyl benzene is the ortho product.

Quick Tip

Remember: Friedel-Crafts reactions require a Lewis acid catalyst like anhydrous $AlCl_3$ to generate the electrophile (CH_3+ in this case).

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13. How methanol is prepared industrially? Write the chemical equation.

Correct Answer: Methanol is prepared industrially by the catalytic hydrogenation of carbon monoxide.

Solution: Concept: The industrial production of methanol (CH_3OH), also known as wood spirit, involves a high-pressure, high-temperature reaction between synthesis gas ($CO + H_2$).
Chemical Equation. Carbon monoxide reacts with hydrogen gas in the presence of a specific catalyst:

$$CO + 2H_2 \xrightarrow[200\text{–}300\ \text{atm}]{ZnO\text{–}Cr_2O_3,\ 573\text{–}673\ K} CH_3OH$$

Quick Tip

Remember the catalyst: Zinc oxide and Chromium oxide ($ZnO–Cr_2O_3$) are essential for this reaction to proceed efficiently at industrial scales.

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14. Give one chemical test to distinguish between formaldehyde and acetaldehyde.

Correct Answer: The Iodoform Test can be used to distinguish between them.

Solution: Concept: The iodoform test is specific to compounds containing a methyl ketone group (CH_3CO-) or an alcohol that can be oxidized to one.

- **Formaldehyde (HCHO): Does not have a methyl group attached to the carbonyl carbon.**
- **Acetaldehyde (CH_3CHO): Contains the required methyl group.**

Performing the Test. When reacted with iodine (I_2) in the presence of sodium hydroxide (NaOH):

- **Acetaldehyde gives a yellow precipitate of iodoform (CHI_3).**

$$\mathbf{CH_3CHO} + 3\mathbf{I_2} + 4\mathbf{NaOH} \rightarrow \mathbf{CHI_3} \downarrow (\mathbf{yellow}) + \mathbf{HCOONa} + 3\mathbf{NaI} + 3\mathbf{H_2O}$$

- **Formaldehyde does not react and gives no precipitate.**

Quick Tip

Acetaldehyde is the only aldehyde that gives a positive iodoform test!

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15. How will you convert nitrobenzene to 2, 4, 6-Tribromo aniline?

Correct Answer: By reduction of nitrobenzene to aniline followed by bromination with bromine water.

Solution: Concept: This conversion requires two distinct chemical transformations:

1. **Reduction of the nitro group (-NO_2) to an amino group (-NH_2).**
2. **Electrophilic aromatic substitution to add three bromine atoms.**

Step 1: Reduction to Aniline. Nitrobenzene is reduced using tin and hydrochloric acid (Sn/HCl) or iron and hydrochloric acid (Fe/HCl).

$$\mathbf{C_6H_5NO_2} + 6[\mathbf{H}] \xrightarrow{\mathbf{Sn/HCl}} \mathbf{C_6H_5NH_2} + 2\mathbf{H_2O}$$

Step 2: Bromination of Aniline. Aniline is highly reactive due to the resonance effect of the -NH_2 group. Treating it with bromine water (Br_2/H_2O) results in instantaneous substitution at all available ortho and para positions.

$$\mathbf{C_6H_5NH_2} + 3\mathbf{Br_2} \xrightarrow{\mathbf{H_2O}} \mathbf{2,4,6\text{-}Tribromoaniline} \downarrow (\mathbf{white\ ppt}) + 3\mathbf{HBr}$$

Quick Tip

The amino group is such a strong activator that you don't need a Lewis acid catalyst for bromination; bromine water alone is enough to triple-substitute!

16. 200 **cm**3 **of an aqueous solution of a protein contains** 1.26 **g of the protein. The osmotic pressure of such a solution at** 300 **K is found to be** $2.57 \times 10-3$ **bar. Calculate the molar mass of the protein. (**$R = 0.083$ **L bar mol**-1 **K**-1**)**

Correct Answer: $61,022 g/mol$ **approx**

Solution: Concept: Osmotic pressure (π**) is a colligative property related to the molarity of the solution. The formula is:**

$$\pi = CRT = \frac{n}{V}RT = \frac{w_2 \times R \times T}{M_2 \times V}$$

Where:

- w_2 **= mass of solute (**1.26 **g)**
- V **= volume of solution in Litres**
- M_2 **= molar mass of solute**
- R **= gas constant (**0.083 **L bar mol**-1 **K**-1**)**
- T **= temperature (**300 **K)**

Step 1: Convert units to match the Gas Constant. Volume $V = 200$ **cm**$3 = 0.200$ **L Pressure** $\pi = 2.57 \times 10-3$ **bar**

Step 2: Calculate Molar Mass (M_2**). Rearranging the formula:** $M_2 = \frac{w_2 \times R \times T}{\pi \times V}$

$$M_2 = \frac{1.26 \times 0.083 \times 300}{2.57 \times 10-3 \times 0.200}$$

$$M_2 = \frac{31.374}{0.000514} \approx 61,038.9 \text{ g/mol}$$

Quick Tip

Osmotic pressure is the preferred method for determining the molar mass of macromolecules like proteins because the pressure changes are measurable even at very low molar concentrations.

17. Briefly explain the electrochemical processes involved in the rusting of iron.

Correct Answer: Rusting is an electrochemical phenomenon where iron acts as an anode and oxygen in the presence of water acts as a cathode.

Solution: Concept: Rusting occurs at the surface of iron when it comes into contact with moisture and oxygen, forming an electrochemical cell.
Step 1: At the Anode. Iron atoms lose electrons and are oxidized to ferrous ions:

$$\textbf{Anode: Fe}(s) \rightarrow \textbf{Fe}2+(aq) + 2e- \quad (E\circ = -0.44\ \textbf{V})$$

Step 2: At the Cathode. Electrons move through the metal to another spot where they reduce oxygen in the presence of $H+$ ions (from $\mathbf{H_2CO_3}$ formed by dissolved $\mathbf{CO_2}$):

$$\textbf{Cathode: O}_2(g) + 4H + (aq) + 4e- \rightarrow 2\textbf{H}_2\textbf{O}(l) \quad (E\circ = 1.23\ \textbf{V})$$

Step 3: Formation of Rust. The ferrous ions are further oxidized by atmospheric oxygen to ferric ions, which deposit as hydrated ferric oxide (rust):

$$2\textbf{Fe}2+ + 2\textbf{H}_2\textbf{O} + \frac{1}{2}\textbf{O}_2 \rightarrow \textbf{Fe}_2\textbf{O}_3 + 4H+$$

$$\textbf{Rust: Fe}_2\textbf{O}_3 \cdot x\textbf{H}_2\textbf{O}$$

Quick Tip

Rusting is accelerated by the presence of electrolytes (like salt in seawater) because they increase the conductivity of the aqueous film on the metal surface.

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18. (i) Write any two differences between order and molecularity. (ii) What do you mean by pseudo order reaction?

Correct Answer: (i) Order is experimental and can be fractional/zero, while molecularity is theoretical and must be a whole number. (ii) A reaction that is higher order but behaves as first order due to one reactant being in large excess.

Solution: Concept: Order and molecularity describe different aspects of a reaction's mechanism. Pseudo-order reactions occur when the concentration of one reactant remains effectively constant.

Step 1: Differences between Order and Molecularity.

Order of Reaction	**Molecularity** hei
Number of reacting species in elementary step. heightDetermined experimentally.	Theoretical conce
Always a natural whole number $(1, 2, 3)$. height	

Step 2: Pseudo First Order Reaction. Consider the hydrolysis of cane sugar:

$$\mathbf{C_{12}H_{22}O_{11} + H_2O \xrightarrow{H+} C_6H_{12}O_6 + C_6H_{12}O_6}$$

Although the molecularity is 2, water is present in such large excess that its concentration does not change significantly. The rate depends only on the sugar concentration:

$$\mathbf{Rate} = k[\mathbf{C_{12}H_{22}O_{11}}]$$

Such reactions are called pseudo first order reactions.

Quick Tip

Molecularity is only defined for elementary (single-step) reactions, whereas order applies to both elementary and complex reactions.

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19. Give reasons for the following:

(i) Zn, Cd and Hg are not considered transition elements.

(ii) Transition metals form complex compounds.

(iii) Sc(3+) is colourless, but Ti(3+) is coloured.

Correct Answer: (i) They have completely filled d-orbitals in their ground and common oxidation states. (ii) Due to small size, high ionic charge, and availability of vacant d-orbitals. (iii) Sc(3+) has a $d0$ configuration (no $d - d$ transition), while Ti(3+) has a $d1$ configuration.

Solution: **Concept: Transition elements are defined as elements which have incompletely filled d-orbitals in their ground state or in any of their oxidation states. The presence of unpaired electrons in d-orbitals governs their color and complex-forming ability.**

Step 1: Electronic configuration of Group 12 elements. Zn, Cd, and Hg have the general electronic configuration $(n-1)d10ns2$. Since their d-orbitals are completely filled in both their atomic state and their common ionic state ($M2+$), they do not fit the definition of transition elements.

Step 2: Complex formation. Transition metals form complexes because:

- **They have small ionic sizes and high nuclear charges, which attract ligands.**
- **They possess vacant d-orbitals of appropriate energy to accept lone pairs of electrons from ligands.**

Step 3: Color in Sc$3+$ vs Ti$3+$. The color of transition metal ions is typically due to **$d-d$ transitions. When ligands approach the central metal ion, the degenerate d-orbitals split into different energy levels (typically t_{2g} and e_g in octahedral fields).**

- **Sc$3+$: The electronic configuration is $[Ar]3d0$. Since there are no electrons in the d-orbitals, no electron can be promoted to a higher energy d-level. Therefore, no light is absorbed in the visible region, making the ion colourless.**
- **Ti$3+$: The electronic configuration is $[Ar]3d1$. The single electron occupies a lower energy d-orbital. It can absorb a photon of visible light and be excited to a higher energy d-orbital. This absorption of specific wavelengths (green and yellow) results in the transmitted light appearing purple or violet.**

Quick Tip

To have a colored ion via $d-d$ transitions, the metal must have a partially filled d-subshell ($d1$ to $d9$). Ions with $d0$ (like Sc$3+$, Ti$4+$) or $d10$ (like Zn$2+$, Cu$+$) configurations are generally colourless.

20. How do you prepare K$(_2)Cr(_2)O(_7)fromchromiteore?$

Correct Answer: By the fusion of chromite ore with sodium carbonate, followed by conversion to sodium dichromate and finally to potassium dichromate.

Solution: Concept: The industrial preparation involves three main steps:

1. **Preparation of Sodium Chromate.**
2. **Conversion of Sodium Chromate to Sodium Dichromate.**
3. **Conversion of Sodium Dichromate to Potassium Dichromate.**

Step 1: Preparation of Sodium Chromate. Chromite ore ($FeCr_2O_4$) is fused with sodium carbonate in free access of air:

$$4\mathbf{FeCr}\_2\mathbf{O}\_4 + 8\mathbf{Na}\_2\mathbf{CO}\_3 + 7\mathbf{O}\_2 \rightarrow 8\mathbf{Na}\_2\mathbf{CrO}\_4 + 2\mathbf{Fe}\_2\mathbf{O}\_3 + 8\mathbf{CO}\_2$$

Step 2: Conversion to Sodium Dichromate. The yellow solution of sodium chromate is filtered and acidified with sulphuric acid:

$$2\mathbf{Na}\_2\mathbf{CrO}\_4 + \mathbf{H}\_2\mathbf{SO}\_4 \rightarrow \mathbf{Na}\_2\mathbf{Cr}\_2\mathbf{O}\_7 + \mathbf{Na}\_2\mathbf{SO}\_4 + \mathbf{H}\_2\mathbf{O}$$

Step 3: Conversion to Potassium Dichromate. Sodium dichromate is treated with potassium chloride. Potassium dichromate, being less soluble, crystallizes out:

$$\mathbf{Na}\_2\mathbf{Cr}\_2\mathbf{O}\_7 + 2\mathbf{KCl} \rightarrow \mathbf{K}\_2\mathbf{Cr}\_2\mathbf{O}\_7 + 2\mathbf{NaCl}$$

Quick Tip

Remember the color changes as a guide for the steps:

- **Chromite Ore (Brown/Black) $\rightarrow$ Chromate (Yellow) $\rightarrow$ Dichromate (Orange).**

Also, note that the conversion of chromate to dichromate is a reversible pH-dependent process: chromate is stable in basic medium, while dichromate is stable in acidic medium.

21. (i) [suspicious link removed] and [Ni(CO)$_4$]$have different structures, but do not differ in their magn$

Correct Answer: (i) Both are diamagnetic because they have no unpaired electrons, despite being square planar ($dsp2$) and [Ni(CO)$_4$]$being tetrahedral$(sp3). (ii)[Co(NH$_3$)$_4$(H$_2$O)Cl]Cl$_2$.

Solution: Concept: Valence Bond Theory (VBT) explains the geometry and magnetic properties based on hybridization. Strong field ligands (CN(-), CO) cause pairing of electrons.

Step 1: Analyzing [suspicious link removed]. 2-] Ni is in +2 state ($3d8$). CN(-) is a strong field ligand and pairs the $3d$ electrons, leaving one $3d$ orbital vacant. Hybridization is $dsp2$ (Square Planar). Since all electrons are paired, it is diamagnetic.

Step 2: Analyzing [Ni(CO)$_4$].]$Ni is in 0 oxidation state$(3d8 4s2)$. Strong field ligand CO forces$4s$elect$

Step 3: Writing the Coordination Formula.

- **Central metal: Cobalt (Co)**
- **Ligands: 4 Ammine (NH$_3$), 1 Aqua (H$_2$O), 1 Chlorido (Cl)**
- **Oxidation state of Co is +3. Total charge inside bracket:** $+3+4(0)+1(0)+1(-1) = +2$**.**
- **To balance $+2$, we need 2 Chloride ions outside.**

Formula: [Co(NH$_3$)$_4$(H$_2$O)Cl]Cl$_2$

Quick Tip

Strong field ligands like CN(-) and CO almost always result in diamagnetic complexes with Nickel by forcing electron pairing!

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22. (i) Draw the diagram which indicates the splitting of d-orbitals in tetrahedral field. (ii) Write any one limitation of valence bond theory.

Correct Answer:

(i) In a tetrahedral field, the five d-orbitals split into two groups: lower energy e set ($d_{x^2-y^2}, d_{z^2}$) and higher energy t_2 set (d_{xy}, d_{yz}, d_{zx}).

(ii) One limitation of Valence Bond Theory is that it fails to explain the colour exhibited by coordination compounds.

Solution:

Concept:

According to Crystal Field Theory (CFT), when ligands approach a metal ion, the degeneracy of the d-orbitals is removed due to electrostatic interactions between ligands and the d-electrons. In a tetrahedral complex, ligands approach between the coordinate axes, resulting in a specific pattern of orbital splitting.

Step 1: Splitting of d-orbitals in Tetrahedral Field.

In a tetrahedral field, the orbitals pointing between the axes experience greater repulsion and therefore have higher energy.

$$\begin{array}{c} t_2\,(d_{xy}, d_{yz}, d_{zx}) \\ \hline \Delta_t \\ \hline e\,(d_{x^2-y^2}, d_{z^2}) \end{array}$$

- **The t_2 orbitals (d_{xy}, d_{yz}, d_{zx}) experience greater repulsion and are raised in energy.**
- **The e orbitals ($d_{x^2-y^2}, d_{z^2}$) experience less repulsion and remain at lower energy.**

Thus, the splitting results in a higher energy t_2 set and a lower energy e set.

Step 2: Limitation of Valence Bond Theory (VBT).

Valence Bond Theory explains the geometry and magnetic properties of coordination compounds but has certain limitations.

One important limitation is:

- **It cannot explain the colour of coordination compounds.**

This limitation arises because VBT does not account for the splitting of d-orbitals and electronic transitions responsible for colour.

Quick Tip

Key Points:

- **Tetrahedral splitting: e (lower energy) and t_2 (higher energy).**
- **In tetrahedral complexes: $\Delta_t < \Delta_o$.**
- **VBT explains geometry and magnetism but fails to explain colour and spectra of complexes.**

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23. Name the products formed when phenol is treated with the following reagents: (i) Bromine water (ii) Zinc dust (iii) Conc. HNO_3

Correct Answer:

(i) 2,4,6-Tribromophenol
(ii) Benzene
(iii) 2,4,6-Trinitrophenol (Picric acid)

Solution:

Concept:
Phenol is highly reactive towards electrophilic substitution reactions because the hydroxyl group activates the benzene ring and directs incoming groups to the ortho and para positions.

Step 1: Reaction with Bromine Water.

Phenol reacts readily with bromine water at room temperature to form a white precipitate of 2,4,6-tribromophenol.

$$\mathbf{C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr}$$

Thus, the product formed is 2,4,6-tribromophenol.

Step 2: **Reaction with Zinc Dust.**

When phenol is heated with zinc dust, the oxygen atom is removed and phenol is reduced to **benzene**.

$$C_6H_5OH + Zn \xrightarrow{\Delta} C_6H_6 + ZnO$$

Hence, the product formed is **benzene**.

Step 3: Reaction with Concentrated Nitric Acid.

Phenol undergoes nitration with concentrated nitric acid to form **2,4,6-trinitrophenol**, commonly known as **picric acid**.

$$C_6H_5OH + 3HNO_3 \rightarrow C_6H_2(NO_2)_3OH + 3H_2O$$

Thus, the product obtained is **2,4,6-trinitrophenol (picric acid)**.

Quick Tip

Important Reactions of Phenol:

- Bromine water $\rightarrow$ 2,4,6-Tribromophenol (white precipitate)
- Zinc dust $\rightarrow$ Benzene
- Conc. $HNO_3 \rightarrow$ 2,4,6-Trinitrophenol (Picric acid)

The **–OH group activates the benzene ring** and directs substitution mainly to **ortho and para positions**.

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24. Complete the following table:

Sl. No	Reactant	Reagent	Major product	Name of reaction
1	RCOCl	H_2, Pd/$BaSO_4$	RCHO	Rosenmund Reduction
2	CH_3COOH	Cl_2/Red P	Cl-CH_2COOH	HVZ Reaction
3	CH_3CHO	Zn-Hg/conc. HCl	CH_3CH_3	Clemmensen Reduction

Correct Answer: The completed reactions correspond to Rosenmund Reduction, HVZ Reaction, and Clemmensen Reduction.

Solution:

Concept:

Several named reactions are used in organic chemistry to convert functional groups into other useful compounds. The given reactions represent important transformations of carboxylic acid derivatives and carbonyl compounds.

Step 1: Rosenmund Reduction.

In this reaction, an **acid chloride** is reduced to an **aldehyde** using hydrogen gas in the presence of a poisoned palladium catalyst (Pd/$BaSO_4$).

$$\text{RCOCl} \xrightarrow{\text{H}_2,\text{Pd/BaSO}_4} \text{RCHO}$$

Step 2: Hell–Volhard–Zelinsky (HVZ) Reaction.

Carboxylic acids containing an α-hydrogen react with chlorine in the presence of red phosphorus to form α-halogenated carboxylic acids.

$$\text{CH}_3\text{COOH} \xrightarrow{\text{Cl}_2/\text{Red P}} \text{Cl-CH}_2\text{COOH}$$

Step 3: Clemmensen Reduction.

In this reaction, aldehydes or ketones are reduced to hydrocarbons using zinc amalgam (Zn-Hg) and concentrated hydrochloric acid.

$$CH_3CHO \xrightarrow{\text{Zn-Hg/conc. HCl}} CH_3CH_3$$

Quick Tip

Important Named Reactions:

- Rosenmund Reduction: Acid chloride $\rightarrow$ Aldehyde
- HVZ Reaction: α-Halogenation of carboxylic acids
- Clemmensen Reduction: Aldehyde/Ketone $\rightarrow$ Hydrocarbon

These reactions are widely used in organic synthesis to modify functional groups.

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25. (i) The reaction in which an amide is converted into a primary amine by the action of Br_2 and alcoholic NaOH is known as $(ii) How is a primary amine distinguished from a secondary amine using Hinsberg test?$

Correct Answer: (i) Hoffmann Bromamide Degradation reaction. (ii) The product formed by a primary amine is soluble in alkali, whereas the product from a secondary amine is insoluble.

Solution: Step 1: Hinsberg Test Principle. Amines react with benzenesulphonyl chloride ($C_6H_5SO_2Cl$).

- **Primary Amines: Form N-alkylbenzenesulphonamide. The hydrogen attached to nitrogen is strongly acidic due to the electron-withdrawing sulphonyl group, making it soluble in alkali.**
- **Secondary Amines: Form N,N-dialkylbenzenesulphonamide. There is no acidic hydrogen on the nitrogen, so it remains insoluble in alkali.**

Quick Tip

In Hoffmann Bromamide Degradation, the resulting amine always has one carbon atom less than the starting amide!

26. (i) Differentiate between globular and fibrous proteins. (ii) What is meant by denaturation of protein?

Correct Answer:

(i) Fibrous proteins are long, thread-like and generally insoluble in water, whereas globular proteins are spherical and usually soluble in water.

(ii) Denaturation of protein is the process in which a protein loses its native structure and biological activity due to physical or chemical changes.

Solution:

Concept:

Proteins are macromolecules made up of amino acids linked by peptide bonds. Based on their molecular shape and structure, proteins are mainly classified into fibrous proteins and globular proteins. The biological activity of proteins depends on their specific three-dimensional structure called the native structure.

Step 1: **Difference between Fibrous and Globular Proteins.**

Feature	**Fibrous Proteins**	**Globular Proteins**
Shape	Long, thread-like structure	Spherical or globular structure
Solubility	Insoluble in water	Usually soluble in water
Function	Structural role	Functional or metabolic role
Examples	Keratin, Collagen, Myosin	Insulin, Albumin, Hemoglobin

Step 2: Denaturation of Proteins.

Denaturation refers to the loss of the natural structure and biological activity of a protein when it is subjected to physical or chemical changes such as:

- High temperature

- Change in pH
- Presence of chemicals or heavy metal ions

During denaturation:

- The **secondary and tertiary structures** of the protein are destroyed.
- The **primary structure remains intact**.
- The protein loses its biological activity.

Example: Coagulation of egg white when heated.

Quick Tip

Key Points:

- Fibrous proteins → Structural and insoluble.
- Globular proteins → Functional and soluble.
- Denaturation destroys secondary and tertiary structures but not the primary structure.

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27. (i) State Henry's Law. Give two applications of it. (ii) Draw the vapour pressure-mole fraction curve for a non-ideal solution having positive deviation, if A and B are the two volatile components.

Correct Answer: (i) The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid. (ii) A curve where the total vapour pressure is higher than predicted by Raoult's Law.

Solution: Step 1: Henry's Law Definition and Formula. Henry's Law states that at a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of the liquid or solution.

$$p = K_H \cdot x$$

Where p is the partial pressure, x is the mole fraction of the gas in solution, and K_H is the Henry's law constant.

Step 2: Applications of Henry's Law.

1. Soft Drinks: To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
2. Scuba Diving: To avoid "the bends" (painful nitrogen bubbles in blood), scuba divers use tanks filled with air diluted with Helium, which is less soluble in blood.

Step 3: Positive Deviation Curve. In solutions showing positive deviation, A-B interactions are weaker than A-A or B-B interactions. This causes the vapour pressure of each component, and the total vapour pressure, to be higher than that expected from Raoult's Law.

Quick Tip

Positive deviation usually leads to the formation of a minimum boiling azeotrope, where the solution boils at a lower temperature than either pure component!

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28. (i) Write the cell reaction and Nernst equation for a Daniel cell. (ii) Explain the variation of conductivity and molar conductivity of a solution with dilution.

Correct Answer:

(i) Cell reaction:

$$\mathrm{Zn}(s) + \mathrm{Cu}^{2+}(aq) \rightarrow \mathrm{Zn}^{2+}(aq) + \mathrm{Cu}(s)$$

(ii) Conductivity decreases with dilution, whereas molar conductivity increases with dilution.

Solution:

Concept:

A Daniell cell is a galvanic cell in which chemical energy is converted into electrical energy

through a redox reaction between zinc and copper ions. The Nernst equation helps determine the cell potential under non-standard conditions. Conductivity and molar conductivity describe how well an electrolyte solution conducts electricity and how they change with dilution.

Step 1: Daniell Cell Reaction and Nernst Equation.

A Daniell cell consists of a zinc electrode in $ZnSO_4$ solution and a copper electrode in $CuSO_4$ solution.

Anode (Oxidation):

$$\text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2e^-$$

Cathode (Reduction):

$$\text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s)$$

Overall Cell Reaction:

$$\text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s)$$

The Nernst equation for the Daniell cell at $298\,K$ is:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0591}{2} \log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]}$$

Step 2: Variation of Conductivity and Molar Conductivity with Dilution.

- **Conductivity (κ):** It is the conductance of ions present in a unit volume of solution. When a solution is diluted, the number of ions per unit volume decreases, therefore **conductivity decreases**.
- **Molar Conductivity (Λ_m):** It is defined as the conductance of all the ions produced by one mole of electrolyte in solution.

$$\Lambda_m = \frac{\kappa \times 1000}{C}$$

On dilution, the ions move more freely and the volume containing one mole increases. Hence **molar conductivity increases with dilution**.

Quick Tip

Key Points:

- Daniell cell reaction: $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$
- Nernst equation: $E = E^\circ - \frac{0.0591}{n} \log Q$
- Conductivity decreases with dilution.
- Molar conductivity increases with dilution.

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29. (i) Write two postulates of Werner's Coordination theory. (ii) Draw the geometrical isomers of $[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$ and give their structures.

Correct Answer:

(i) According to Werner's coordination theory, metals exhibit **primary valency** and **secondary valency**. Primary valency is ionizable and corresponds to oxidation state, whereas secondary valency is non-ionizable and corresponds to coordination number.

(ii) The geometrical isomers of $[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$ are **fac (facial) isomer** and **mer (meridional) isomer**.

Solution:

Concept:

Werner's coordination theory explains the bonding and structure of coordination compounds. It distinguishes between ionizable and non-ionizable valencies and also explains geometrical arrangements of ligands around the central metal ion.

Step 1: Postulates of Werner's Coordination Theory.

1. A metal atom or ion in a coordination compound exhibits two types of valencies: **primary valency** and **secondary valency**.

2. **Primary valency** corresponds to the oxidation state of the metal and is usually satisfied by negative ions. These are **ionizable**.

3. **Secondary valency** corresponds to the coordination number of the metal ion and is satisfied by neutral molecules or negative ions called **ligands**. These are **non-ionizable** and have definite spatial arrangement.

Step 2: Geometrical Isomers of MA_3B_3 Type Complex.

The complex $[Co(NH_3)_3(NO_2)_3]$ is an **octahedral** complex of the type MA_3B_3. It shows two geometrical isomers:

- **fac-isomer (Facial):** The three identical ligands occupy adjacent positions at the corners of one triangular face of the octahedron.

$$\text{fac-}[Co(NH_3)_3(NO_2)_3]$$

- **mer-isomer (Meridional):** The three identical ligands lie along a meridian of the octahedron, forming a plane that passes through the central metal atom.

$$\text{mer-}[Co(NH_3)_3(NO_2)_3]$$

Thus, the complex exhibits two geometrical arrangements known as **facial** and **meridional** isomers.

Quick Tip

Key Points:

- Werner explained coordination compounds using **primary and secondary valencies**.
- Octahedral complexes of type MA_3B_3 show two geometrical isomers: **fac (facial)** and **mer (meridional)**.
- fac $\rightarrow$ three identical ligands on one face; mer $\rightarrow$ arranged along a meridian.

30. (i) Predict the products A and B in the hydroboration-oxidation reaction. (ii) Explain the preparation of phenol from cumene.

Correct Answer:

(i) $A = (CH_3CH_2CH_2)_3B, \quad B = CH_3CH_2CH_2OH.$

(ii) Cumene is oxidized to **cumene hydroperoxide**, which on acid cleavage produces **phenol** and **acetone**.

Solution:

Concept:

Hydroboration–oxidation is an important reaction of alkenes that gives alcohols through **anti-Markovnikov addition**. Phenol can also be prepared industrially from cumene (isopropyl benzene) through oxidation followed by acid cleavage.

Step 1: Hydroboration–Oxidation Reaction.

In the first step, propene reacts with diborane $(BH_3)_2$ to form **tripropylborane (A)**.

$$3CH_3CH{=}CH_2 \xrightarrow{(BH_3)_2} (CH_3CH_2CH_2)_3B$$

In the second step, oxidation with alkaline hydrogen peroxide (H_2O_2/OH^-) converts it into **propan-1-ol (B)**.

$$(CH_3CH_2CH_2)_3B \xrightarrow{H_2O_2/OH^-} 3CH_3CH_2CH_2OH$$

This reaction follows **anti-Markovnikov rule**, where the OH group attaches to the less substituted carbon atom.

Step 2: Preparation of Phenol from Cumene.

Cumene (isopropyl benzene) is oxidized with oxygen from air to form **cumene hydroperoxide**.

$$\text{Cumene} \xrightarrow{O_2} \text{Cumene Hydroperoxide}$$

The hydroperoxide undergoes acid-catalysed cleavage to give **phenol and acetone**.

$$\text{Cumene Hydroperoxide} \xrightarrow{H^+/H_2O} \text{Phenol} + \text{Acetone}$$

This method is widely used industrially for the large-scale production of phenol.

Quick Tip

Important Points:

- Hydroboration–oxidation gives alcohols by **anti-Markovnikov addition**.
- Cumene process is an important industrial method for preparing **phenol**.
- Products of cumene process: **Phenol + Acetone**.

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31. (i) Explain Aldol condensation with example. (ii) How are the following conversions achieved: (a) Benzene $\rightarrow$ Benzaldehyde, (b) Ethanoic acid $\rightarrow$ ethanol.

Correct Answer: (i) Reaction of aldehydes/ketones having α-hydrogen with dilute alkali. (ii) (a) Gatterman-Koch reaction, (b) Reduction with $LiAlH_4$.

Solution: **Step 1:** Aldol Condensation. Aldehydes or ketones containing at least one α-hydrogen undergo a reaction in the presence of dilute alkali to form β-hydroxy aldehydes (aldols). Example: $2CH_3CHO \xrightarrow{\text{dil. NaOH}} CH_3CH(OH)CH_2CHO$

Step 2: Specific Conversions. (a) **Benzene to Benzaldehyde: Gatterman-Koch reaction**. Benzene is treated with CO and HCl in the presence of anhydrous $AlCl_3$.

$$C_6H_6 + CO + HCl \xrightarrow{\text{anh. } AlCl_3} C_6H_5CHO$$

(b) **Ethanoic acid to Ethanol:** Reduction using a strong reducing agent like Lithium Aluminium Hydride.

$$CH_3COOH \xrightarrow{\text{(i) } LiAlH_4/\text{ether, (ii) } H_3O+} CH_3CH_2OH$$

Quick Tip

For the cumene process, remember that **acetone** is a valuable by-product, making this the most economical industrial route to phenol.
