# CUET UG Chemistry Sample Paper - 10

**Duration: 1 Hour** **Maximum Marks: 250**

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## Instructions

- This paper contains a total of 50 Multiple Choice Questions.
- Each correct answer carries **+5 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

**Q1.** A solution of glucose in water is labeled as 10% w/w. If the density of the solution is 1.2 g/mL, the molarity of the solution is:

(A) 0.61 M
(B) 0.67 M
(C) 0.75 M
(D) 0.55 M

**Q2.** The boiling point of a 0.2 mol/kg solution of $X$ in water is greater than that of a 0.2 mol/kg solution of $Y$ in water. Which of the following statements is true in this case?

(A) $X$ is undergoing dissociation in water.
(B) Molecular mass of $X$ is greater than the molecular mass of $Y$.
(C) Molecular mass of $X$ is less than the molecular mass of $Y$.
(D) $Y$ is undergoing dissociation in water while $X$ is not.

**Q3.** The limiting molar conductivities for $NaCl$, $KBr$, and $KCl$ are 126, 152, and 150 S cm$^2$ mol$^{-1}$ respectively. The limiting molar conductivity for $NaBr$ is:

(A) 128 S cm$^2$ mol$^{-1}$

(B) 176 S $cm^2$ $mol^{-1}$

(C) 278 S $cm^2$ $mol^{-1}$

(D) 302 S $cm^2$ $mol^{-1}$

**Q4.** In a hydrogen-oxygen fuel cell, combustion of hydrogen occurs to:

(A) Produce high purity water.

(B) Create a potential difference between two electrodes.

(C) Generate heat.

(D) Remove adsorbed oxygen from electrode surfaces.

**Q5.** For a first-order reaction, the time required for 99% completion is how many times the time required for the completion of 90% of the reaction?

(A) 2

(B) 3

(C) 10

(D) 4

**Q6.** The rate constant of a reaction is $k = 3.4 \times 10^{-4}$ $mol^{-1}$ L $s^{-1}$. The order of the reaction is:

(A) 0

(B) 1

(C) 2

(D) 3

**Q7.** Which of the following lanthanoid ions is diamagnetic? (At. Nos. $Ce = 58, Sm = 62, Eu = 63, Yb = 70$)

(A) $Ce^{2+}$

(B) $Sm^{2+}$

(C) $Eu^{2+}$

(D) $Yb^{2+}$

**Q8.** Transition metals exhibit high enthalpies of atomization because:

(A) Of the presence of large number of valence electrons.

(B) Of high identification energy.

(C) Of large number of unpaired electrons and strong metallic bonding.

(D) They are malleable and ductile.

**Q9.** The correct IUPAC name for the complex $[Co(NH_3)_5(CO_3)]Cl$ is:

(A) Pentaamminecarbonatocobalt(III) chloride

(B) Pentaamminecarbonatocobalt(II) chloride

(C) Carbonatopentaamminecobalt(III) chloride

(D) Pentaamminecobalt(III) carbonate chloride

**Q10.** Which of the following complexes will show the maximum intensity of color?

(A) $[CoF_6]^{3-}$

(B) $[Co(H_2O)_6]^{3+}$

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

(D) $[Co(en)_3]^{3+}$

**Q11.** The major product of the reaction between tert-butyl bromide and sodium ethoxide is:

(A) 2-Butene

(B) 2-Methylpropene

(C) tert-Butyl ethyl ether

(D) 1-Butene

**Q12.** Arrange the following in increasing order of $S_N1$ reactivity: (I) Benzyl chloride, (II) Isopropyl chloride, (III) Ethyl chloride, (IV) Methyl chloride.

(A) IV < III < II < I

(B) I < II < III < IV

(C) IV < III < I < II

(D) III < IV < II < I

**Q13.** Propan-1-ol and Propan-2-ol can be best distinguished by:

(A) Oxidation with acidic $KMnO_4$ followed by reaction with Fehling's solution.

(B) Oxidation with $K_2Cr_2O_7$.

(C) Lucas Test.

(D) Reaction with Sodium metal.

**Q14.** Reimer-Tiemann reaction involves the intermediate formation of:

(A) Carbene

(B) Carbanion

(C) Carbocation

(D) Free radical

**Q15.** Which of the following will not undergo Aldol condensation?

(A) Acetaldehyde

(B) Propanaldehyde

(C) Benzaldehyde

(D) Acetone

**Q16.** The correct order of acid strength of the following substituted phenols is:

(A) p-Nitrophenol > p-Chlorophenol > Phenol > p-Cresol

(B) p-Nitrophenol > Phenol > p-Chlorophenol > p-Cresol

(C) p-Cresol > Phenol > p-Chlorophenol > p-Nitrophenol

(D) Phenol > p-Cresol > p-Chlorophenol > p-Nitrophenol

**Q17.** The strongest base among the following in aqueous solution is:

(A) Methylamine

(B) Dimethylamine

(C) Trimethylamine

(D) Aniline

**Q18.** Gabriel Phthalimide synthesis is used for the preparation of:

(A) Primary aromatic amines

(B) Primary aliphatic amines

(C) Secondary amines

(D) Tertiary amines

**Q19.** Which of the following vitamins is water-soluble?

(A) Vitamin A

(B) Vitamin D

(C) Vitamin C

(D) Vitamin E

**Q20.** Complete hydrolysis of cellulose gives:

(A) L-Glucose

(B) D-Fructose

(C) D-Glucose

(D) D-Ribose

**Q21.** A zero-order reaction is 50% complete in 20 minutes. The time required for 75% completion is:

(A) 30 min

(B) 40 min

(C) 25 min

(D) 60 min

**Q22.** The spin-only magnetic moment of $Fe^{2+}$ ion (At. No. 26) is approximately:

(A) 4.90 BM

(B) 5.92 BM

(C) 3.87 BM

(D) 2.84 BM

**Q23.** When $S_N2$ reaction occurs at a chiral center in an optically active halide, the product shows:

(A) Retention of configuration

(B) Inversion of configuration

(C) Racemization

(D) Partial racemization

**Q24.** Among the following, the most reactive towards nucleophilic addition is:

(A) $CH_3CHO$

(B) $PhCHO$

(C) $PhCOPh$

(D) $CH_3COCH_3$

**Q25.** Denaturation of proteins leads to the loss of its biological activity by affecting:

(A) Primary structure only

(B) Secondary and Tertiary structures

(C) Quaternary structure only

(D) All levels of structure

**Q26.** An azeotropic solution of two liquids has a boiling point lower than either of them when it:

(A) Shows a negative deviation from Raoult's law.

(B) Shows a positive deviation from Raoult's law.

(C) Is an ideal solution.

(D) Is saturated.

**Q27.** Resistance of a conductivity cell filled with 0.1 mol $L^{-1}$ $KCl$ solution is 100 Ω. If the resistance of the same cell when filled with 0.02 mol $L^{-1}$ $KCl$ solution is 520 Ω, calculate the conductivity of 0.02 mol $L^{-1}$ $KCl$ solution. (Conductivity of 0.1 mol $L^{-1}$ $KCl$ is 1.29 S/m):

(A) 0.248 S/m

(B) 0.124 S/m

(C) 1.24 S/m

(D) 2.48 S/m

**Q28.** The value of $\Lambda_m^\circ$ for $NH_4OH$ is equal to:

(A) $\Lambda_m^\circ(NH_4Cl) + \Lambda_m^\circ(NaOH) - \Lambda_m^\circ(NaCl)$

(B) $\Lambda_m^\circ(NH_4Cl) + \Lambda_m^\circ(NaCl) - \Lambda_m^\circ(NaOH)$

(C) $\Lambda_m^\circ(NaOH) + \Lambda_m^\circ(NaCl) - \Lambda_m^\circ(NH_4Cl)$

(D) $\Lambda_m^\circ(NH_4OH) + \Lambda_m^\circ(NH_4Cl) - \Lambda_m^\circ(HCl)$

**Q29.** For the reaction $2A + B \rightarrow 3C + D$, which of the following does not express the reaction rate?

(A) $-\frac{d[B]}{dt}$

(B) $\frac{d[D]}{dt}$

(C) $-\frac{1}{2}\frac{d[A]}{dt}$

(D) $-\frac{1}{3}\frac{d[C]}{dt}$

**Q30.** In the Arrhenius equation $k = Ae^{-E_a/RT}$, the fraction of molecules having energy equal to or greater than activation energy is:

(A) $A$

(B) $e^{-E_a/RT}$

(C) $\ln k$

(D) $E_a/RT$

**Q31.** Which of the following ions has the highest magnetic moment?

(A) $V^{3+}$

(B) $Cr^{3+}$

(C) $Fe^{3+}$

(D) $Co^{3+}$

**Q32.** The catalyst used in the manufacture of sulphuric acid by the Contact process is:

(A) $Fe$

(B) $V_2O_5$

(C) $Pt$

(D) $PdCl_2$

**Q33.** Which of the following ligands is an ambidentate ligand?

(A) $EDTA^{4-}$

(B) $CO_3^{2-}$

(C) $SCN^-$

(D) $H_2O$

**Q34.** The number of ions produced from the complex $[Co(NH_3)_6]Cl_2$ in water is:

(A) 6

(B) 4

(C) 3

(D) 2

**Q35.** Chlorobenzene is less reactive than ethyl chloride towards nucleophilic substitution because:

(A) Resonance stabilization in chlorobenzene.

(B) $sp^2$ hybridized carbon in $C-Cl$ bond of chlorobenzene.

(C) Partial double bond character of $C-Cl$ bond.

(D) All of the above.

**Q36.** $C-H$ bond is shortest in:

(A) $CH_3Cl$

(B) $CH_2Cl_2$

(C) $CHCl_3$

(D) $CH_4$

**Q37.** The dehydration of alcohols to form alkenes is catalyzed by:

(A) $NaOH$

(B) $H_2SO_4$

(C) $KMnO_4$

(D) $LiAlH_4$

**Q38.** Phenol reacts with $Br_2$ in $CS_2$ at low temperature to give:

(A) 2,4,6-Tribromophenol

(B) p-Bromophenol

(C) o-Bromophenol

(D) A mixture of o- and p-Bromophenol

**Q39.** Cannizzaro reaction is not given by:

(A) Formaldehyde

(B) Benzaldehyde

(C) Acetaldehyde

(D) Trimethylacetaldehyde

**Q40.** Carboxylic acids have higher boiling points than aldehydes of comparable molecular masses due to:

(A) Formation of intermolecular hydrogen bonding.

(B) Formation of intramolecular hydrogen bonding.

(C) High polarity of carbonyl group.

(D) None of the above.

**Q41.** Hofmann Bromamide degradation reaction is used to prepare:

(A) Primary amine with one carbon more than parent amide.
(B) Primary amine with one carbon less than parent amide.
(C) Secondary amine.
(D) Tertiary amine.

**Q42.** In the reaction $C_6H_5NH_2 + NaNO_2 + 2HCl \xrightarrow{273-278K} X$, the product $X$ is:

(A) Benzene
(B) Chlorobenzene
(C) Benzene diazonium chloride
(D) Nitrobenzene

**Q43.** Which of the following is a non-reducing sugar?

(A) Glucose
(B) Maltose
(C) Lactose
(D) Sucrose

**Q44.** Helical structure of proteins is stabilized by:

(A) Dipeptide bonds
(B) Hydrogen bonds
(C) Ether bonds
(D) Van der Waals forces

**Q45.** The van't Hoff factor $i$ for a dilute aqueous solution of the strong electrolyte $Ba(OH)_2$ is:

- (A) 0
- (B) 1
- (C) 2
- (D) 3

**Q46.** The unit of rate constant for a second-order reaction is:

- (A) $s^{-1}$
- (B) $\text{mol L}^{-1}\ \text{s}^{-1}$
- (C) $\text{L mol}^{-1}\ \text{s}^{-1}$
- (D) $\text{L}^2\ \text{mol}^{-2}\ \text{s}^{-1}$

**Q47.** Lanthanoid contraction is responsible for the fact that:

- (A) $Zr$ and $Y$ have about the same radius.
- (B) $Zr$ and $Nb$ have similar oxidation states.
- (C) $Zr$ and $Hf$ have about the same radius.
- (D) $Zr$ and $Zn$ have the same oxidation state.

**Q48.** The geometry of $[Ni(CN)_4]^{2-}$ is:

- (A) Tetrahedral
- (B) Square planar
- (C) Octahedral
- (D) Trigonal bipyramidal

**Q49.** Finkelstein reaction is a/an:

- (A) Electrophilic substitution reaction
- (B) Nucleophilic substitution reaction
- (C) Addition reaction

(D) Elimination reaction

**Q50.** Which base is present in RNA but not in DNA?

(A) Adenine

(B) Guanine

(C) Cytosine

(D) Uracil

## Detailed Solutions

## Q1.

### Solution

**Concept:** Molarity ($M$) is the number of moles of solute per liter of solution. To calculate it from weight percentage ($w/w$) and density ($d$), we use:

$$M = \frac{\%(w/w) \times d \times 10}{\text{Molar mass of solute}}$$

Alternatively, assume 100 g of solution:

- Mass of glucose = 10 g
- Volume of solution = $\frac{\text{Mass}}{\text{Density}} = \frac{100\text{ g}}{1.2\text{ g/mL}} = 83.33$ mL

**Solution:** 1. **Moles of Glucose:** Molar mass of $C_6H_{12}O_6 = (6 \times 12) + (12 \times 1) + (6 \times 16) = 180$ g/mol.

$$n = \frac{10}{180} = 0.0555 \text{ moles}$$

2. **Molarity Calculation:**

$$M = \frac{n}{\text{Volume (L)}} = \frac{0.0555}{0.08333}$$

$$M \approx 0.666 \text{ M} \approx 0.67 \text{ M}$$

**Answer: (B)**

## Q2.

### Solution

**Concept:** Elevation in boiling point ($\Delta T_b$) is a colligative property defined by:

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

Where:

- $i$ is the van't Hoff factor (number of particles after dissociation/association).
- $m$ is the molality of the solution.

**Solution:** Given that both solutions $X$ and $Y$ have the same molality (0.2 mol/kg), the difference in boiling point elevation depends solely on the van't Hoff factor ($i$).

$$\text{If } \Delta T_b(X) > \Delta T_b(Y), \text{ then } i_X > i_Y$$

Dissociation increases the number of particles ($i > 1$), which leads to a higher boiling point. Therefore, $X$ must be undergoing dissociation in water compared to $Y$.

**Answer: (A)**

## Q3.

### Solution

**Concept:** **Kohlrausch's Law of Independent Migration of Ions** states that the limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anions and cations.

$$\Lambda_m^\circ(AB) = \lambda^\circ(A^+) + \lambda^\circ(B^-)$$

**Solution:** To find $\Lambda_m^\circ(NaBr)$, we use the given electrolytes:

$$\Lambda_m^\circ(NaBr) = \Lambda_m^\circ(NaCl) + \Lambda_m^\circ(KBr) - \Lambda_m^\circ(KCl)$$

Substituting the values:

$$\Lambda_m^\circ(NaBr) = 126 + 152 - 150$$

$$\Lambda_m^\circ(NaBr) = 278 - 150 = 128 \text{ S cm}^2 \text{ mol}^{-1}$$

**Answer: (A)**

## Q4.

### Solution

**Concept: The Hydrogen-Oxygen ($H_2 - O_2$) Fuel Cell**
A fuel cell is a galvanic cell designed to convert the chemical energy from a fuel (hydrogen) and an oxidizing agent (oxygen) directly into electrical energy through a continuous chemical reaction. Unlike a standard battery, which eventually "dies" as its internal chemicals are consumed, a fuel cell produces electricity as long as fuel and oxygen are supplied.
**1. Structural Design:** The cell consists of two porous carbon electrodes impregnated with finely divided platinum or palladium, which act as catalysts to speed up the redox reactions. The electrolyte is typically a concentrated aqueous solution of $KOH$ (Potassium Hydroxide).
[Image of hydrogen fuel cell]
**2. Electrochemical Mechanism:** The operation of the cell is based on the separation of the oxidation and reduction halves of the combustion of hydrogen.

- **At the Anode (Oxidation):** Hydrogen gas is bubbled through the anode. It reacts with $OH^-$ ions from the electrolyte to release electrons.

$$2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$$

- **At the Cathode (Reduction):** Oxygen gas is bubbled through the cathode. It accepts the electrons coming from the external circuit and reacts with water.

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$

**3. Overall Cell Reaction:** By adding the two half-reactions, we get the net reaction, which is essentially the combustion of hydrogen to form water:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

**Solution:** The thermodynamic driving force of this reaction is the change in Gibbs Free Energy ($\Delta G$). In a fuel cell, this energy is not released as heat (as it would be in a flame); instead, the spatial separation of the oxidation and reduction sites forces the electrons to travel through an external circuit.
This flow of electrons **creates a potential difference** (Voltage) between the two electrodes. This potential difference is what allows the cell to perform electrical work, such as powering an electric motor or spacecraft systems. While high-purity water is a beneficial byproduct and heat is generated, the *primary functional intent* of the combustion occurring within the cell architecture is the generation of this electrical potential.

**Answer: (B)**

## Q5.

### Solution

**Concept:** For a first-order reaction, the integrated rate equation is:

$$t = \frac{2.303}{k} \log \frac{[A]_0}{[A]_t}$$

**Solution:** 1. **For 99% completion:** $[A]_t = 100 - 99 = 1\%$ of $[A]_0$.

$$t_{99\%} = \frac{2.303}{k} \log \frac{100}{1} = \frac{2.303}{k} \times 2$$

2. **For 90% completion:** $[A]_t = 100 - 90 = 10\%$ of $[A]_0$.

$$t_{90\%} = \frac{2.303}{k} \log \frac{100}{10} = \frac{2.303}{k} \times 1$$

3. **Comparison:**

$$\frac{t_{99\%}}{t_{90\%}} = \frac{2}{1} = 2$$

**Answer: (A)**

## Q6.

### Solution

**Concept:** The order of a reaction can be determined from the units of the rate constant ($k$). The general unit is:

$$(\text{mol L}^{-1})^{1-n}\ \text{s}^{-1}$$

where $n$ is the order.

**Solution:** Given $k = 3.4 \times 10^{-4}$ mol$^{-1}$ L s$^{-1}$, which is equivalent to L mol$^{-1}$ s$^{-1}$. Equating units:

$$(\text{mol L}^{-1})^{1-n} = \text{mol}^{-1}\ \text{L}$$

$$1 - n = -1 \implies n = 2$$

The reaction is of the **second order**.

**Answer: (C)**

## Q7.

### Solution

**Concept:** A species is diamagnetic if all its electrons are paired. This usually occurs with $f^0$ or $f^{14}$ configurations in lanthanoids.
**Solution:** Check configurations:

- $Ce^{2+}(Z = 58)$: $[Xe]4f^2$ (2 unpaired electrons)
- $Yb(Z = 70)$: $[Xe]4f^{14}6s^2$
- $Yb^{2+}$: $[Xe]4f^{14}$

In $Yb^{2+}$, the $4f$ orbital is completely filled. Since there are no unpaired electrons, it is **diamagnetic**.

**Answer: (D)**

## Q8.

### Solution

**Concept: Enthalpy of Atomization in Transition Metals**
The enthalpy of atomization ($\Delta_a H°$) is the enthalpy change that occurs when one mole of a substance is completely dissociated into its constituent atoms in the gaseous state. In the context of metals, it is a direct measure of the strength of the metallic bond in the crystal lattice.
**1. Metallic Bonding Factors:** Metallic bond strength depends on the number of electrons that contribute to the "sea of electrons" and the extent of covalent character within the metallic lattice. Transition metals are unique because they involve both $ns$ and $(n-1)d$ electrons in bonding.
**2. The Role of Unpaired Electrons:** Transition metals (except Zinc, Cadmium, and Mercury) have partially filled $d$-subshells. The unpaired electrons in these $(n-1)d$ orbitals can overlap with $d$-orbitals of neighboring atoms, forming covalent-like bonds within the metallic structure.
**3. Trend Analysis:** As the number of unpaired electrons increases (up to the middle of the series, e.g., Chromium or Molybdenum), the interatomic attraction becomes stronger. Stronger interatomic forces result in:

- Higher Melting and Boiling points.
- Increased Hardness.
- **Higher Enthalpy of Atomization.**

**Solution:** The high enthalpy of atomization is primarily due to the **large number of unpaired electrons** which facilitate strong interatomic metallic and covalent-like bonding. While valence electrons (Option A) are involved, it is specifically the "unpaired" nature and the resulting "metallic bonding" strength that defines this property.

**Answer: (C)**

## Q9.

### Solution

**Concept: IUPAC Nomenclature of Coordination Compounds**

The naming of the complex $[Co(NH_3)_5(CO_3)]Cl$ follows a specific set of rules established by IUPAC to ensure a unique name for every structural arrangement.

**1. Ligand Identification and Alphabetical Order:**

- $NH_3$: Named as **ammine**. There are five, so the prefix is **pentaammine**.
- $CO_3^{2-}$: Named as **carbonato** (anionic ligands end in '-o').
- Alphabetical order: 'a' in ammine comes before 'c' in carbonato.

**2. Central Metal and Oxidation State:** The metal is Cobalt ($Co$). Since the coordination sphere is a cation (indicated by $Cl$ being outside), the metal name remains "Cobalt". To find the oxidation state ($x$):

$$x + 5(\text{charge of } NH_3) + 1(\text{charge of } CO_3) = \text{charge of complex ion}$$

Since $Cl$ is $-1$, the complex ion is $+1$.

$$x + 5(0) + 1(-2) = +1 \implies x - 2 = +1 \implies x = +3$$

The oxidation state is written in Roman numerals as (III).

**3. Anion:** The counter-ion $Cl^-$ is named as **chloride**.

**Solution:** Combining these parts: **Pentaamminecarbonatocobalt(III) chloride**. Note: "Pentaammine" has two 'm's. Alphabetical order determines the sequence of ligands, not their quantity.

**Answer: (A)**

# Q10.

## Solution

**Concept: Color and Intensity in Coordination Complexes**

The color of coordination compounds arises from $d - d$ electronic transitions. When white light falls on a complex, it absorbs a specific wavelength to promote an electron from a lower energy $d$-orbital to a higher one. The intensity of this color is governed by the **Laporte Selection Rule** and the **Symmetry** of the complex.

**1. Crystal Field Splitting ($\Delta_o$):** Ligands like $F^-$, $H_2O$, $NH_3$, and $en$ (ethylenediamine) create different magnitudes of splitting. $en$ is a strong field ligand and a **chelating ligand**.

**2. Chelating Effect and Symmetry:**

Monodentate ligands (like $H_2O$ or $NH_3$) form complexes that are often more centrosymmetric. Chelating ligands like "en" (bidentate) create a five-membered ring structure with the metal. This "chelation" causes:

- Higher distortion in the octahedral geometry.
- Significant reduction in the center of inversion (centrosymmetry).

**3. Molar Absorptivity:** When a complex lacks a center of symmetry (is non-centrosymmetric), the $d - d$ transitions become "partially allowed" rather than "forbidden" (Laporte Rule). This results in a much higher molar absorptivity ($\epsilon$), which translates to a **maximum intensity of color**.

**Solution:** $[Co(en)_3]^{3+}$ is a tris-chelated complex. Due to the chelate effect and the resulting lack of perfect centrosymmetry, it exhibits the highest intensity of color among the given options.

**Answer: (D)**

# Q11.

## Solution

**Concept: Competition between $S_N2$ and $E2$ Mechanisms**

When an alkyl halide reacts with a nucleophile/base, two main pathways are possible: Substitution and Elimination. The outcome depends heavily on the structure of the alkyl halide and the strength of the base.

**1. Reactant Analysis:**

- **Alkyl Halide:** tert-Butyl bromide, $(CH_3)_3C - Br$. This is a **tertiary (3°)** alkyl halide. The central carbon is heavily shielded by three bulky methyl groups.
- **Reagent:** Sodium ethoxide, $NaOCH_2CH_3$. This is a **strong base** and a strong nucleophile.

**2. Steric Hindrance:** In a tertiary halide, the $S_N2$ mechanism (backside attack) is virtually impossible because the nucleophile cannot reach the electrophilic carbon due to the bulk of the methyl groups.

**3. The $E2$ Pathway:** Since substitution is blocked, the ethoxide ion acts as a **strong base**. It abstracts a proton ($\beta$-hydrogen) from one of the nine equivalent hydrogens on the methyl groups. This happens in a single concerted step:

- The base attacks a $\beta$-H.
- The $C - H$ bond electrons shift to form a $C = C$ double bond.
- The leaving group ($Br^-$) departs.

**4. Product Identification:** The elimination of $HBr$ from 2-bromo-2-methylpropane results in the formation of an alkene:

$$(CH_3)_3C - Br + C_2H_5ONa \rightarrow CH_2 = C(CH_3)_2 + C_2H_5OH + NaBr$$

The IUPAC name for $CH_2 = C(CH_3)_2$ is **2-Methylpropene** (also known as isobutylene).

**Solution:** Because of the high steric hindrance of the 3° carbon and the presence of a strong base, elimination ($E2$) is the exclusive pathway, yielding **2-Methylpropene**.

**Answer: (B)**

# Q12.

## Solution

**Concept: $S_N1$ Reactivity and Carbocation Stability**

The $S_N1$ (Substitution Nucleophilic Unimolecular) reaction occurs in two steps. The first and rate-determining step (RDS) is the ionization of the alkyl halide to form a **carbocation**. Therefore, the reactivity is directly proportional to the stability of the intermediate carbocation.

**1. Carbocation Formation:**

- **Benzyl chloride (I):** Forms $C_6H_5CH_2^+$. This cation is highly stabilized by **resonance** with the pi-electrons of the benzene ring.
- **Isopropyl chloride (II):** Forms $(CH_3)_2CH^+$. This is a **secondary (2°)** carbocation stabilized by the inductive effect $(+I)$ and hyperconjugation of two methyl groups.
- **Ethyl chloride (III):** Forms $CH_3CH_2^+$. This is a **primary (1°)** carbocation stabilized by only one methyl group.
- **Methyl chloride (IV):** Forms $CH_3^+$. This is the least stable carbocation as it has no stabilizing groups.

**2. Stability Order:** Resonance stabilization is generally much stronger than inductive effects or hyperconjugation.

$$\text{Benzyl } (I) > \text{Secondary } (II) > \text{Primary } (III) > \text{Methyl } (IV)$$

**Solution:** Since the $S_N1$ reactivity follows the stability of the carbocation, the increasing order (slowest to fastest) is: **IV < III < II < I**.

**Answer: (A)**

## Q13.

### Solution

**Concept: Chemical Differentiation of Alcohols**

Propan-1-ol is a **primary (1°) alcohol**, while Propan-2-ol is a **secondary (2°) alcohol**. Distinguishing them requires reactions that yield different observable products based on the position of the $-OH$ group.

**1. Oxidation Mechanism:** Using an oxidizing agent like acidic $KMnO_4$ or $K_2Cr_2O_7$:

- **Propan-1-ol** (1°)**:** Oxidizes first to **Propanal** (an aldehyde, $CH_3CH_2CHO$).
- **Propan-2-ol** (2°)**:** Oxidizes to **Propanone** (a ketone, $CH_3COCH_3$).

**2. Functional Group Testing:** Aldehydes and Ketones react differently with **Fehling's solution**:

- **Propanal:** Being an aldehyde, it reduces Fehling's solution to form a **red precipitate** of Cuprous oxide ($Cu_2O$).
- **Propanone:** Being a ketone, it does **not** react with Fehling's solution.

**Solution Analysis:** While the Lucas test (Option C) can distinguish them (Secondary gives turbidity in 5 mins, Primary only on heating), the sequence of oxidation followed by a Fehling's test (Option A) provides a definitive chemical "fingerprint" for the aldehyde produced by the 1° alcohol.

**Answer: (A)**

## Q14.

### Solution

**Concept: Mechanism of the Reimer-Tiemann Reaction**

The Reimer-Tiemann reaction is used to ortho-formylate phenols (converting Phenol to Salicylaldehyde) using Chloroform ($CHCl_3$) and aqueous $NaOH$.

**1. Generation of the Electrophile:** The reaction begins with the deprotonation of chloroform by the base:

$$CHCl_3 + OH^- \rightarrow : CCl_3^- + H_2O$$

The trichloromethyl anion ($: CCl_3^-$) then undergoes **$\alpha$-elimination** of a chloride ion to form a neutral, highly reactive species:

$$: CCl_3^- \rightarrow : CCl_2 \text{ (Dichlorocarbene)} + Cl^-$$

[Image of dichlorocarbene structure]

**2. Electrophilic Attack:** The **Dichlorocarbene ($: CCl_2$)** acts as an electrophile. Even though it is neutral, the carbon atom has only six valence electrons (an incomplete octet). It attacks the electron-rich phenoxide ring at the ortho position.

**Solution:** The key reactive intermediate that characterizes the Reimer-Tiemann mechanism is the **Carbene**.

**Answer: (A)**

## Q15.

### Solution

**Concept: Requirements for Aldol Condensation**

Aldol condensation occurs in aldehydes or ketones that possess at least one **$\alpha$-hydrogen** atom. The reaction requires a dilute base to abstract this hydrogen to form a resonance-stabilized **enolate ion**.

**1. Structural Examination:**

- **Acetaldehyde ($CH_3CHO$):** Has 3 $\alpha$-hydrogens on the methyl group. (Possible)
- **Propanaldehyde ($CH_3CH_2CHO$):** Has 2 $\alpha$-hydrogens on the $CH_2$ group. (Possible)
- **Acetone ($CH_3COCH_3$):** Has 6 $\alpha$-hydrogens. (Possible)
- **Benzaldehyde ($C_6H_5CHO$):** The carbonyl group is attached to a benzene ring carbon that is already bonded to three other carbons. There is **no hydrogen** on that $\alpha$-carbon.

**2. Reaction Outcome:** Because Benzaldehyde lacks $\alpha$-hydrogens, it cannot form an enolate ion. Instead, when treated with a concentrated base, it undergoes the **Cannizzaro reaction** (disproportionation into benzyl alcohol and sodium benzoate).

**Solution:** **Benzaldehyde** will not undergo Aldol condensation.

**Answer: (C)**

## Q16.

### Solution

**Concept: Acidity of Substituted Phenols**

The acidity of phenol depends on the stability of the **phenoxide ion** formed after losing a proton ($H^+$). Any factor that delocalizes the negative charge on the oxygen atom increases the stability of the ion and, consequently, the acidity of the parent phenol.

**1. Substituent Effects:**

- **Electron Withdrawing Groups (EWG):** Groups like $-NO_2$ and $-Cl$ withdraw electron density through inductive ($-I$) and resonance ($-R$) effects. This stabilizes the phenoxide ion.
- **Electron Donating Groups (EDG):** Groups like $-CH_3$ (in p-cresol) donate electron density through inductive ($+I$) and hyperconjugation effects. This destabilizes the phenoxide ion by increasing the electron density on the already negative oxygen.

**2. Comparing the Options:**

- **p-Nitrophenol:** The $-NO_2$ group is a very strong EWG ($-R$ and $-I$). It is the most acidic.
- **p-Chlorophenol:** The $-Cl$ group is an EWG through the $-I$ effect. It is more acidic than phenol but less than p-nitrophenol.
- **Phenol:** The reference molecule.
- **p-Cresol:** The $-CH_3$ group is an EDG. It makes the molecule less acidic than phenol.

**Solution:** The correct order of decreasing acid strength is: **p-Nitrophenol > p-Chlorophenol > Phenol > p-Cresol**.

**Answer: (A)**

## Q17.

### Solution

**Concept: Basicity of Amines in Aqueous Solution**

The basic strength of amines in water is not determined by the inductive effect ($+I$) alone. It is a complex balance of three competing factors:

(a) **Inductive Effect ($+I$):** Alkyl groups donate electrons, increasing the electron density on Nitrogen. (Order: $3^\circ > 2^\circ > 1^\circ$).

(b) **Solvation Effect (Hydration):** Protonated amines form hydrogen bonds with water. Smaller ions with more hydrogens ($H$) are better solvated and more stable. (Order: $1^\circ > 2^\circ > 3^\circ$).

(c) **Steric Hindrance:** Bulky alkyl groups hinder the approach of water molecules or protons. (Order: $1^\circ > 2^\circ > 3^\circ$).

**Solution Analysis:** For **methyl-substituted amines**, experimental data shows that the **secondary amine (Dimethylamine)** provides the perfect balance between the $+I$ effect and hydration stability. The observed order in water is:

$$(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$$

Dimethylamine is the strongest base among the choices provided.

**Answer: (B)**

## Q18.

### Solution

**Concept: Gabriel Phthalimide Synthesis**

This is a specific method for preparing **primary amines** while avoiding the formation of secondary or tertiary amines (over-alkylation).

**1. The Mechanism Steps:**

- **Step 1:** Phthalimide reacts with $KOH$ to form potassium phthalimide.
- **Step 2:** Potassium phthalimide acts as a nucleophile and undergoes an **$S_N2$ reaction** with an alkyl halide ($R - X$).
- **Step 3:** The $N$-alkylphthalimide is hydrolyzed (usually with hydrazine or $NaOH$) to release the primary amine.

**2. Limitations:** Aromatic primary amines (like aniline) cannot be prepared this way because the starting material would require an aryl halide ($Ar - X$). Aryl halides do not undergo the $S_N2$ reaction necessary in Step 2 because the $C - X$ bond has partial double bond character due to resonance.

**Solution:** The method is used exclusively for the preparation of **Primary aliphatic amines**.

**Answer: (B)**

## Q19.

### Solution

**Concept: Classification of Vitamins**

Vitamins are organic compounds required in small amounts for biological functions. They are classified based on their solubility:

**1. Fat-Soluble Vitamins:** These are stored in the liver and adipose (fat) tissues. They include Vitamins **A, D, E, and K**. Because they are stored, excessive intake can lead to toxicity (hypervitaminosis).

**2. Water-Soluble Vitamins:** These must be supplied regularly in the diet because they are not stored in the body (except $B_{12}$) and are readily excreted in urine. They include:

- **Vitamin C** (Ascorbic Acid)
- **Vitamin B-complex** (B1, B2, B6, etc.)

**Solution:** Among the given options, **Vitamin C** is the water-soluble vitamin.

**Answer: (C)**

## Q20.

### Solution

**Concept: Structure and Hydrolysis of Polysaccharides**

Cellulose is the most abundant organic polymer on Earth, acting as the structural component of the primary cell wall of green plants.

**1. Molecular Structure:** Cellulose is a straight-chain polysaccharide (unlike starch, which is branched). It consists of thousands of **$\beta$-D-glucose** units. These units are linked by **$\beta$-1,4-glycosidic bonds**.

[Image of cellulose molecular structure]

**2. Hydrolysis:** When cellulose is treated with concentrated acids or specific enzymes (cellulases), the glycosidic linkages are broken.

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$$

Since the entire chain is made of glucose, the only product of complete hydrolysis is **D-Glucose**.

**Solution:** Complete hydrolysis of cellulose yields **D-Glucose**.

**Answer: (C)**

## Q21.

### Solution

**Concept:** For a **zero-order reaction**, the rate of reaction is independent of the concentration of reactants. The integrated rate equation is:

$$[A]_t = [A]_0 - kt \quad \text{or} \quad k = \frac{[A]_0 - [A]_t}{t}$$

In zero-order kinetics, the time taken for a specific percentage of completion is directly proportional to the amount of reactant reacted ($\Delta[A]$).

**Solution:** 1. **Case 1 (50% completion):** Let $[A]_0 = 100$. For 50% completion, the amount reacted is 50.

$$50 = k \times 20 \implies k = \frac{50}{20} = 2.5 \text{ units/min}$$

2. **Case 2 (75% completion):** The amount to be reacted is 75% of 100, which is 75.

$$75 = k \times t_{75\%}$$

Substituting the value of $k$:

$$75 = 2.5 \times t_{75\%}$$

$$t_{75\%} = \frac{75}{2.5} = 30 \text{ minutes}$$

**Answer: (A)**

# Q22.

## Solution

**Concept: Spin-only Magnetic Moment ($\mu_s$)**
The magnetic properties of transition metal ions are primarily due to the presence of unpaired electrons in their $d$-orbitals. The "spin-only" formula is used to calculate the magnetic moment based on the number of these unpaired electrons ($n$).

**1. Electronic Configuration of $Fe^{2+}$:**

- Iron ($Fe$) has atomic number 26. Ground state: $[Ar]3d^6 4s^2$.
- To form the $Fe^{2+}$ ion, two electrons are removed from the outermost $4s$ orbital.
- $Fe^{2+}$ configuration: $[Ar]3d^6 4s^0$.

**2. Number of Unpaired Electrons ($n$):** According to Hund's Rule, we fill the five $d$-orbitals ($d_{xy}, d_{yz}, d_{xz}, d_{x^2-y^2}, d_{z^2}$) by placing one electron in each first before pairing.

- Orbital 1: $\uparrow\downarrow$ (Paired)
- Orbital 2: $\uparrow$ (Unpaired)
- Orbital 3: $\uparrow$ (Unpaired)
- Orbital 4: $\uparrow$ (Unpaired)
- Orbital 5: $\uparrow$ (Unpaired)

Total unpaired electrons ($n$) = 4.

**3. Calculation:** Using the formula $\mu_s = \sqrt{n(n+2)}$ BM:

$$\mu_s = \sqrt{4(4+2)} = \sqrt{4 \times 6} = \sqrt{24}$$

Since $\sqrt{25} = 5$, $\sqrt{24}$ must be slightly less than 5.

$$\mu_s \approx 4.898 \text{ BM} \approx 4.90 \text{ BM}$$

**Answer: (A)**

## Q23.

### Solution

**Concept: Stereochemistry of $S_N2$ Reactions**
The $S_N2$ (Substitution Nucleophilic Bimolecular) reaction is a concerted mechanism, meaning bond-breaking and bond-making happen simultaneously in a single transition state.
**1. Transition State Dynamics:** The nucleophile ($Nu^-$) attacks the electrophilic carbon from the side exactly opposite to the leaving group ($L$) to minimize electronic repulsion.
**2. Spatial Rearrangement:** As the new $C - Nu$ bond begins to form and the $C - L$ bond begins to break, the three other groups attached to the carbon atom "umbrella" over to the other side.
**3. Walden Inversion:** If the starting material is optically active (chiral), the product will have a spatial arrangement of groups that is the mirror image of what it would have been if the nucleophile had attacked from the front. This 100% change in configuration is known as **Walden Inversion**.
**Solution:** An $S_N2$ reaction at an asymmetric carbon always results in the **inversion of configuration**.

**Answer: (B)**

## Q24.

### Solution

**Concept: Reactivity in Nucleophilic Addition**
The reactivity of aldehydes and ketones toward nucleophilic attack (like $HCN$ addition or Grignard reaction) is governed by two main factors:
**1. Electronic Factor (Inductive effect):** Alkyl groups are electron-donating ($+I$ effect). They donate electron density to the carbonyl carbon, reducing its partial positive charge ($\delta+$). A less positive carbon is less attractive to a nucleophile.

- Aldehydes (one alkyl group) are more reactive than ketones (two alkyl groups).

**2. Steric Factor:** Bulky groups around the carbonyl carbon hinder the approach of the nucleophile.
**3. Comparison of Options:**

- $CH_3CHO$ **(Acetaldehyde):** One methyl group ($+I$) and one small Hydrogen. (Most reactive)
- $PhCHO$ **(Benzaldehyde):** The Phenyl group is bulky and reduces reactivity via resonance ($+R$ effect).
- $CH_3COCH_3$ **(Acetone):** Two methyl groups ($+I$) increase electron density and steric bulk.
- $PhCOPh$ **(Benzophenone):** Two bulky phenyl groups make it the least reactive.

**Solution:** **Acetaldehyde** is the most reactive due to the least steric hindrance and the highest electrophilicity of the carbonyl carbon.

**Answer: (A)**

# Q25.

## Solution

**Concept: Denaturation of Proteins**

Proteins are complex polymers of amino acids folded into specific three-dimensional shapes required for biological activity. Denaturation is the process where this shape is disrupted.

**1. Levels of Protein Structure:**

- **Primary:** The linear sequence of amino acids (peptide bonds).
- **Secondary:** Local folding like $\alpha$-helices and $\beta$-pleated sheets (hydrogen bonds).
- **Tertiary:** Overall 3D folding (disulfide bridges, hydrophobic interactions).

**2. The Process of Denaturation:** When a protein is subjected to physical or chemical changes (heating, extreme pH, or urea), the relatively weak bonds maintaining the **secondary and tertiary structures** are broken. The protein "uncoils" into a random, disordered string.

[Image of protein denaturation process]

**3. What remains intact?** The **Primary structure** is held together by strong, covalent peptide bonds. These bonds are not broken during standard denaturation. However, because the 3D shape is lost, the protein loses its biological function (e.g., an enzyme can no longer bind its substrate).

**Solution:** During denaturation, the **Secondary and Tertiary structures** are destroyed, but the primary structure remains intact.

**Answer: (B)**

## Q26.

### Solution

**Concept: Azeotropes and Deviations from Raoult's Law**
An azeotrope is a mixture of two or more liquids whose proportions cannot be altered or changed by simple distillation. This happens because when an azeotrope is boiled, the vapor has the same proportions of constituents as the unboiled mixture.

**1. Vapor Pressure and Boiling Point Relationship:** The boiling point of a liquid is the temperature at which its vapor pressure equals the external (atmospheric) pressure. There is an inverse relationship between vapor pressure and boiling point:

- **Higher Vapor Pressure** $\implies$ **Lower Boiling Point**
- **Lower Vapor Pressure** $\implies$ **Higher Boiling Point**

**2. Minimum Boiling Azeotropes:** When a solution shows a **large positive deviation** from Raoult's Law, the vapor pressure of the mixture is higher than the vapor pressure of either pure component.

- This occurs because the $A - B$ intermolecular interactions are **weaker** than the $A - A$ and $B - B$ interactions.
- Since the molecules can escape into the vapor phase more easily, the total vapor pressure reaches atmospheric pressure at a **lower temperature**.

**3. Examples and Analysis:** A classic example is a mixture of Ethanol and Water (95% ethanol).

- Ethanol-Water interactions are weaker than the hydrogen bonding in pure water or pure ethanol.
- This results in a "Minimum Boiling Azeotrope" because the boiling point of the mixture is lower than that of both pure ethanol and pure water.

**Solution:** Since the question describes a "Minimum Boiling Azeotrope" (boiling point lower than its components), it must correspond to a solution that shows a **positive deviation from Raoult's Law**.

**Answer: (B)**

## Q27.

### Solution

**Concept:** Conductivity ($\kappa$) is related to resistance ($R$) and cell constant ($G^*$) by:

$$\kappa = \frac{1}{R} \times G^* \quad \Longrightarrow \quad G^* = \kappa \times R$$

**Solution:** 1. **Find Cell Constant ($G^*$):** Using 0.1 M $KCl$ data: $\kappa = 1.29$ S/m, $R = 100\ \Omega$.

$$G^* = 1.29 \times 100 = 129\ \text{m}^{-1}$$

2. **Find conductivity of 0.02 M $KCl$:** Using $R = 520\ \Omega$ and the same cell constant $G^*$:

$$\kappa = \frac{G^*}{R} = \frac{129}{520}$$

$$\kappa \approx 0.248\ \text{S/m}$$

**Answer: (A)**

## Q28.

### Solution

**Concept:** Kohlrausch's Law allows the calculation of $\Lambda_m^\circ$ for weak electrolytes using $\Lambda_m^\circ$ values of strong electrolytes.

**Solution:** To isolate the ions $NH_4^+$ and $OH^-$, we combine strong electrolytes such that the unwanted ions cancel out:

$$\Lambda_m^\circ(NH_4OH) = \lambda^\circ(NH_4^+) + \lambda^\circ(OH^-)$$

By using $NH_4Cl$, $NaOH$, and $NaCl$:

$$\Lambda_m^\circ(NH_4Cl) + \Lambda_m^\circ(NaOH) - \Lambda_m^\circ(NaCl)$$

$$= [\lambda^\circ(NH_4^+) + \lambda^\circ(Cl^-)] + [\lambda^\circ(Na^+) + \lambda^\circ(OH^-)] - [\lambda^\circ(Na^+) + \lambda^\circ(Cl^-)]$$

$$= \lambda^\circ(NH_4^+) + \lambda^\circ(OH^-)$$

**Answer: (A)**

## Q29.

### Solution

**Concept: Differential Rate Expressions**

The rate of a chemical reaction is defined as the change in the molar concentration of a reactant or product per unit time. For a general reaction:

$$aA + bB \rightarrow cC + dD$$

The rate of the reaction is expressed by dividing the rate of disappearance of reactants or the rate of appearance of products by their respective stoichiometric coefficients.

**1. Mathematical Representation:**

- **Reactants** $(A, B)$**:** Their concentration decreases over time, so we use a negative sign $(-)$.
- **Products** $(C, D)$**:** Their concentration increases over time, so we use a positive sign $(+)$.

**2. Application to the Given Reaction:** For the reaction: $2A + B \rightarrow 3C + D$ The stoichiometric coefficients are $a = 2, b = 1, c = 3, d = 1$. The unified rate expression is:

$$\text{Rate} = -\frac{1}{2}\frac{d[A]}{dt} = -\frac{d[B]}{dt} = +\frac{1}{3}\frac{d[C]}{dt} = +\frac{d[D]}{dt}$$

**3. Analyzing the Options:**

- **Option A:** $-\frac{1}{2}\frac{d[A]}{dt}$ — Correct (Rate of disappearance of $A$ per 2 moles).
- **Option B:** $-\frac{d[B]}{dt}$ — Correct (Rate of disappearance of $B$ per 1 mole).
- **Option C:** $\frac{d[D]}{dt}$ — Correct (Rate of appearance of $D$ per 1 mole).
- **Option D:** $-\frac{1}{3}\frac{d[C]}{dt}$ — **Incorrect**. Since $C$ is a product, its concentration is increasing. Therefore, the sign must be positive $(+)$.

**Solution:** The expression $-\frac{1}{3}\frac{d[C]}{dt}$ is not a correct representation of the reaction rate.

**Answer: (D)**

# Q30.

## Solution

**Concept: The Arrhenius Equation and Collision Theory**

According to the Collision Theory of chemical kinetics, a reaction occurs only when reactant molecules collide with sufficient energy and proper orientation. The Arrhenius equation mathematically relates the rate constant ($k$) to temperature and energy:

$$k = Ae^{-E_a/RT}$$

**1. Component Breakdown:**

- $A$: The **Pre-exponential factor** (or frequency factor). It represents the total frequency of collisions between molecules.
- $E_a$: The **Activation Energy**. This is the minimum kinetic energy required for a collision to result in a chemical reaction.
- $R$: The Gas Constant ($8.314\ \text{J K}^{-1}\ \text{mol}^{-1}$).
- $T$: Absolute Temperature (in Kelvin).

**2. The Exponential Term ($e^{-E_a/RT}$):** The term $e^{-E_a/RT}$ is known as the **Boltzmann Factor**. In statistical mechanics, this exponential function represents the probability that a molecule (or a pair of colliding molecules) will have a kinetic energy equal to or greater than $E_a$.

**3. Logical Interpretation:** As temperature ($T$) increases, the value of the negative exponent becomes smaller (less negative), making the term $e^{-E_a/RT}$ larger. This indicates that a greater **fraction of molecules** now possess enough energy to overcome the activation barrier, leading to a higher rate constant $k$.

**Solution:** In the Arrhenius equation, the term $e^{-E_a/RT}$ specifically represents the **fraction of collisions with energy greater than $E_a$**.

**Answer: (B)**

## Q31.

### Solution

**Concept: Magnetic Properties and Unpaired Electrons**

The magnetic moment of a transition metal ion is calculated using the "spin-only" formula:

$$\mu_s = \sqrt{n(n+2)}\ \text{BM}$$

where $n$ is the number of unpaired electrons. A higher value of $n$ directly leads to a higher magnetic moment.

**1. Electronic Configuration of Ions ($3d$ series):**

- $V^{3+}$ **(Vanadium, $Z = 23$):** Neutral $V$ is $[Ar]3d^3 4s^2$. $V^{3+}$ is $[Ar]3d^2$. Config: $\uparrow | \uparrow | \ | \ | \quad \Longrightarrow \ n = 2$.
- $Cr^{3+}$ **(Chromium, $Z = 24$):** Neutral $Cr$ is $[Ar]3d^5 4s^1$. $Cr^{3+}$ is $[Ar]3d^3$. Config: $\uparrow | \uparrow | \uparrow | \ | \quad \Longrightarrow \ n = 3$.
- $Fe^{3+}$ **(Iron, $Z = 26$):** Neutral $Fe$ is $[Ar]3d^6 4s^2$. $Fe^{3+}$ is $[Ar]3d^5$. Config: $\uparrow | \uparrow | \uparrow | \uparrow | \uparrow \Longrightarrow \ n = 5$.
- $Co^{3+}$ **(Cobalt, $Z = 27$):** Neutral $Co$ is $[Ar]3d^7 4s^2$. $Co^{3+}$ is $[Ar]3d^6$. Config: $\uparrow\downarrow | \uparrow | \uparrow | \uparrow | \uparrow \Longrightarrow \ n = 4$.

**2. Calculation for $Fe^{3+}$:**

$$\mu_s = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92\ \text{BM}$$

**Solution:** Since $Fe^{3+}$ has the highest number of unpaired electrons ($n = 5$), it exhibits the maximum magnetic moment among the given ions.

**Answer: (C)**

## Q32.

### Solution

**Concept: Catalysis in the Contact Process**

The Contact Process is the industrial method used to manufacture high-purity sulfuric acid ($H_2SO_4$). The most critical step is the reversible, exothermic oxidation of sulfur dioxide ($SO_2$) to sulfur trioxide ($SO_3$).

**1. The Reaction:**

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -196.6 \text{ kJ/mol}$$

**2. The Role of the Catalyst:** To achieve a high yield of $SO_3$ at a reasonably fast rate, a catalyst is employed.

- **Historical Context:** Finely divided Platinum ($Pt$) was originally used. However, it is very expensive and highly susceptible to "catalytic poisoning" by arsenic impurities present in the sulfur.
- **Modern Choice:** **Vanadium Pentoxide ($V_2O_5$)** is used today. It is significantly cheaper, more robust, and less prone to poisoning, making the process economically viable.

**Solution:** The catalyst used in the manufacture of $H_2SO_4$ by the Contact Process is **Vanadium pentoxide ($V_2O_5$)**.

**Answer: (B)**

# Q33.

## Solution

**Concept: Ambidentate Ligands**

Ligands are species that donate a pair of electrons to a central metal ion. Most ligands have a single donor atom (monodentate). However, some monodentate ligands possess two or more different atoms that *could* potentially donate electrons, but they only use one at a time. These are called **ambidentate ligands**.

**1. Analyzing $SCN^-$ (Thiocyanate):** The thiocyanate ion has two potential donor atoms:

- **Sulfur ($S$):** When it bonds via Sulfur, the complex is named "thiocyanato-$S$".
- **Nitrogen ($N$):** When it bonds via Nitrogen, it is named "isothiocyanato" or "thiocyanato-$N$".

**2. Comparison with other options:**

- $EDTA^{4-}$: Polydentate (Hexadentate), not ambidentate.
- $CO_3^{2-}$: Monodentate or didentate, but bonds through Oxygen.
- $H_2O$: Monodentate, bonds only through Oxygen.

**Solution:** **$SCN^-$** is the ambidentate ligand because it can coordinate through either the $S$ or $N$ atom.

**Answer: (C)**

## Q34.

### Solution

**Concept: Ionization of Coordination Compounds**

When a coordination compound dissolves in a polar solvent like water, the chemical species are divided by the **coordination sphere** (the part inside the square brackets).

- **Coordination Sphere:** Remains intact as a single, large complex ion due to the strong coordinate covalent bonds between the metal and ligands.
- **Ionization Sphere:** The ions outside the brackets (counter-ions) dissociate completely.

**1. Dissociation Equation:** For $[Co(NH_3)_6]Cl_2$:

$$[Co(NH_3)_6]Cl_2(s) \xrightarrow{H_2O} [Co(NH_3)_6]^{2+}(aq) + 2Cl^-(aq)$$

**2. Counting the Ions:**

- **One** complex cation: $[Co(NH_3)_6]^{2+}$
- **Two** chloride anions: $Cl^-$ and $Cl^-$

Total number of ions = 1 + 2 = 3.

**Solution:** One mole of $[Co(NH_3)_6]Cl_2$ yields **3 ions** upon dissolution in water.

**Answer: (C)**

## Q35.

### Solution

**Concept: Reactivity of Haloarenes in Nucleophilic Substitution**

Haloarenes (like chlorobenzene) are significantly less reactive toward nucleophilic substitution reactions compared to haloalkanes (like ethyl chloride). This is due to several combined factors:

**1. Resonance Effect:** The lone pair of electrons on the halogen atom is in conjugation with the $\pi$-electrons of the benzene ring. This gives the $C - X$ bond a **partial double bond character**, making it much stronger and harder to break than a single bond.

**2. Hybridization of Carbon:** In haloarenes, the halogen is attached to an **$sp^2$ hybridized** carbon, which is more electronegative than the $sp^3$ carbon in haloalkanes. This results in a shorter and stronger bond.

**3. Instability of Phenyl Cation:** In an $S_N1$ mechanism, a phenyl cation ($C_6H_5^+$) would need to form. However, the phenyl cation is highly unstable because the positive charge cannot be effectively delocalized, preventing $S_N1$ from occurring.

**Solution:** All the mentioned factors (Resonance, Hybridization, and Cation instability) contribute to the low reactivity of haloarenes.

**Answer: (D)**

## Q36.

### Solution

**Concept:** $C - H$ **Bond Length and Electronegativity**

The length of a $C - H$ bond is determined by the hybridization of the carbon atom and the electronic environment created by neighboring substituents.

**1. Electronegativity Effect:** In the series $CH_4, CH_3Cl, CH_2Cl_2, CHCl_3$, the number of highly electronegative Chlorine atoms increases. Chlorine withdraws electron density from the Carbon atom ($-I$ effect).

- As Carbon becomes more electron-deficient, it exerts a stronger pull on the remaining bonding electrons, including the $C - H$ bond.
- This "contraction" of the electron cloud results in a shorter $C - H$ bond distance.

**2. Hybridization and $s$-character:** Increasing the number of halogen atoms slightly increases the $s$-character of the $C - H$ hybrid orbital. Since $s$-orbitals are closer to the nucleus than $p$-orbitals, higher $s$-character leads to a shorter, stronger bond.

**3. Comparison:** Chloroform ($CHCl_3$) has three Chlorine atoms pulling electron density away from the Carbon, making the $C - H$ bond the shortest and most acidic in this series.

**Solution:** Due to the maximum inductive effect of three Chlorine atoms, **$CHCl_3$** has the shortest $C - H$ bond.

**Answer: (C)**

# Q37.

## Solution

**Concept: Acid-Catalyzed Dehydration of Alcohols**

The conversion of an alcohol to an alkene is an elimination reaction ($E1$ or $E2$). Because the hydroxyl group ($-OH$) is a poor leaving group, the reaction requires a catalyst to facilitate its departure.

**1. Role of the Catalyst ($H_2SO_4$):**

- **Protonation:** The acid ($H^+$) protonates the oxygen of the alcohol, converting $-OH$ into $-H_2O^+$.
- **Leaving Group:** Water ($H_2O$) is a much better leaving group than the hydroxide ion ($OH^-$).
- **Carbocation Formation:** In 1° or 2° alcohols, the $C-O$ bond breaks to form a carbocation intermediate (in $E1$) or the proton is abstracted simultaneously (in $E2$).

[Image of dehydration of ethanol mechanism]

**2. Reaction Conditions:** Ethanol is typically dehydrated using **concentrated $H_2SO_4$** at 443 K. At lower temperatures (413 K), the reaction favors the formation of ethers.

**3. Why not others?**

- $NaOH$: A base; would not protonate the alcohol.
- $KMnO_4$: An oxidizing agent; would convert ethanol to acetic acid.
- $LiAlH_4$: A reducing agent; usually used to convert carbonyls back to alcohols.

**Solution:** **Concentrated $H_2SO_4$** is the essential catalyst for the dehydration of alcohols to alkenes.

**Answer: (B)**

# Q38.

## Solution

**Concept: Electrophilic Substitution of Phenol**

Phenol is highly reactive toward electrophilic aromatic substitution because the $-OH$ group is a strong activating group (due to the $+R$ effect of the lone pairs on Oxygen).

**1. Solvent Effect (Polar vs. Non-polar):**

- **In Water ($H_2O$):** Phenol ionizes to form the phenoxide ion ($C_6H_5O^-$). The negative charge on Oxygen is even more activating, leading to rapid trisubstitution (2,4,6-tribromophenol).
- **In $CS_2$ or $CHCl_3$:** These are non-polar solvents. Phenol does not ionize significantly, and its reactivity is moderated.

**2. Regioselectivity:** The $-OH$ group is **ortho/para directing**. At low temperatures in a non-polar solvent, monosubstitution occurs.

- **Ortho-bromophenol:** Formed in smaller amounts.
- **Para-bromophenol:** Formed as the **major product** because the para position is less sterically hindered by the hydroxyl group.

**Solution:** In $CS_2$ at low temperature, the reaction yields a mixture of **ortho- and para-bromophenols**.

**Answer: (D)**

## Q39.

### Solution

**Concept: The Cannizzaro Reaction**

The Cannizzaro reaction is a base-induced disproportionation (self-redox) of aldehydes. It is specifically undergone by aldehydes that **lack $\alpha$-hydrogens**.

**1. Mechanism Requirements:** If an aldehyde has $\alpha$-hydrogens, it will undergo the **Aldol Condensation** because the base will abstract the acidic $\alpha$-proton. Without $\alpha$-hydrogens, the base is forced to attack the carbonyl carbon directly.

**2. Analyzing the Options:**

- **Formaldehyde ($HCHO$):** No $\alpha$-carbon, so no $\alpha$-H. (Gives Cannizzaro)
- **Benzaldehyde ($C_6H_5CHO$):** The $\alpha$-carbon is in the benzene ring and has no hydrogen attached. (Gives Cannizzaro)
- **Trimethylacetaldehyde ($(CH_3)_3CCHO$):** The $\alpha$-carbon is bonded to three methyl groups; no $\alpha$-H. (Gives Cannizzaro)
- **Acetaldehyde ($CH_3CHO$):** Has three $\alpha$-hydrogens on the methyl group.

**Solution:** **Acetaldehyde** will not give the Cannizzaro reaction; it undergoes Aldol condensation instead.

**Answer: (C)**

## Q40.

### Solution

**Concept: Intermolecular Forces in Carbonyl Compounds**

The boiling point of an organic compound is a physical property that reflects the strength of the intermolecular forces holding the molecules together in the liquid phase.

**1. Carboxylic Acids ($R - COOH$):** These contain both a carbonyl group ($C = O$) and a hydroxyl group ($-OH$). This allows for very strong **intermolecular hydrogen bonding**. In fact, carboxylic acids often exist as **stable dimers** even in the vapor phase, effectively doubling their molecular weight.

**2. Aldehydes ($R - CHO$):** Aldehydes are polar molecules, but they lack a hydrogen atom bonded to an electronegative atom (like O or N). Therefore, they can only interact through **dipole-dipole interactions**, which are much weaker than hydrogen bonds.

**3. Comparison:** Because breaking hydrogen bonds requires significantly more thermal energy than breaking dipole-dipole attractions, carboxylic acids have much higher boiling points than aldehydes of comparable molecular mass.

**Solution:** Carboxylic acids have higher boiling points due to **intermolecular hydrogen bonding**.

**Answer: (A)**

## Q41.

### Solution

**Concept: Hofmann Bromamide Degradation Reaction**

The Hofmann bromamide reaction is a specialized method used to convert a primary amide into a primary amine. It is classified as a "degradation" because the product contains one fewer carbon atom than the starting material.

**1. Reagents and Conditions:** The reaction requires an amide ($R - CONH_2$), Bromine ($Br_2$), and a strong base (usually aqueous or alcoholic $NaOH$ or $KOH$).

**2. Step-by-Step Mechanism:**

- **N-Bromination:** The base abstracts a proton from the amide nitrogen, followed by reaction with $Br_2$ to form an N-bromoamide ($R - CONHBr$).
- **Isocyanate Formation:** Further deprotonation and loss of $Br^-$ leads to a rearrangement (the alkyl group $R$ migrates from Carbon to Nitrogen), forming an **Isocyanate** ($R - N = C = O$).
- **Hydrolysis:** The intermediate isocyanate is hydrolyzed by the base to form a primary amine and a carbonate ion ($CO_3^{2-}$).

**3. Structural Change:** The carbonyl carbon ($C = O$) of the amide is removed entirely as sodium carbonate ($Na_2CO_3$). Therefore, the resulting amine has **one carbon atom less** than the parent amide.

**Solution:** The primary amine obtained by Hofmann bromamide degradation contains **one carbon atom less** than the starting amide.

**Answer: (B)**

## Q42.

### Solution

**Concept: Diazotization of Primary Aromatic Amines**

Diazotization is the process of converting a primary aromatic amine into a diazonium salt. This reaction is a cornerstone of synthetic organic chemistry because diazonium salts are highly reactive intermediates.

**1. Reaction Parameters:**

- **Reactant:** Aniline ($C_6H_5NH_2$).
- **Reagents:** Sodium nitrite ($NaNO_2$) and excess Hydrochloric acid ($HCl$). These react in situ to produce nitrous acid ($HNO_2$).
- **Temperature:** The reaction must be performed at ice-cold temperatures ($0-5$°C or $273-278$ K).

**2. Chemical Equation:**

$$C_6H_5NH_2 + NaNO_2 + 2HCl \xrightarrow{273-278\text{ K}} C_6H_5N_2^+Cl^- + NaCl + 2H_2O$$

**3. Stability:** The resulting **Benzene diazonium chloride** is relatively stable at low temperatures due to the resonance stabilization of the diazonium group with the benzene ring. If the temperature rises above 5°C, the salt decomposes to form phenol and nitrogen gas.

**Solution:** The product formed by the reaction of aniline with $NaNO_2$ and $HCl$ at $0-5$°C is **Benzene diazonium chloride**.

**Answer: (C)**

## Q43.

### Solution

**Concept: Reducing and Non-reducing Sugars**

Carbohydrates are classified as "reducing sugars" if they can reduce mild oxidizing agents like Tollen's reagent ($Ag^+$) or Fehling's solution ($Cu^{2+}$). This ability depends on the presence of a free (or potentially free) carbonyl group.

**1. Structural Requirement:** For a sugar to be reducing, it must have a **free aldehyde group** or a **hemiacetal/hemiketal group** (which can open up into an aldehyde or $\alpha$-hydroxy ketone in solution).

**2. Analyzing the Disaccharides:**

- **Maltose:** Two glucose units linked by $\alpha - 1,4$ bond. One glucose unit's anomeric carbon is free (hemiacetal). (Reducing)
- **Lactose:** Glucose and Galactose linked by $\beta - 1,4$ bond. The glucose unit's anomeric carbon is free. (Reducing)
- **Sucrose:** Glucose and Fructose linked by a glycosidic bond between **C1 of glucose and C2 of fructose**.

[Image of sucrose structure showing glycosidic linkage]

**3. Why Sucrose is Different:** In sucrose, the reducing groups (the anomeric carbons) of both monosaccharides are involved in the glycosidic linkage. Because there is no free hemiacetal or hemiketal group to open into a carbonyl form, sucrose cannot reduce Tollen's or Fehling's reagents.

**Solution:** **Sucrose** is a non-reducing sugar.

**Answer: (D)**

# Q44.

## Solution

**Concept: Secondary Structure of Proteins - The $\alpha$-Helix**

The secondary structure refers to the local spatial arrangement of the polypeptide backbone. The two most common types are the $\alpha$-helix and the $\beta$-pleated sheet.

**1. The $\alpha$-Helix Structure:** The polypeptide chain is coiled into a right-handed screw (helix). This conformation is favored because it maximizes internal stability.

**2. Hydrogen Bonding Mechanism:** The helix is held together and stabilized by **intramolecular hydrogen bonds**.

- The hydrogen bond forms between the $-NH$ group of an amino acid residue and the $-C = O$ group of a residue situated **four positions earlier** in the chain.
- Every peptide bond (except those at the very ends) participates in this hydrogen bonding, creating a rigid and stable rod-like structure.

**3. Contrast with $\beta$-sheets:** In $\beta$-pleated sheets, hydrogen bonds are formed between different adjacent chains (intermolecular) or distant segments of the same chain, whereas the $\alpha$-helix relies on local, regular, internal bonding.

**Solution:** The helical structure of protein is stabilized by **hydrogen bonds**.

**Answer: (B)**

# Q45.

## Solution

**Concept: van't Hoff Factor ($i$) and Dissociation**

The van't Hoff factor ($i$) is a measure of the effect of a solute on colligative properties. For solutes that dissociate in solution, $i$ is the ratio of the total number of moles of particles after dissociation to the moles of solute dissolved.

**1. Dissociation Process:** Barium hydroxide ($Ba(OH)_2$) is a strong base. In a dilute aqueous solution, it is considered to undergo complete (100%) ionization.

$$Ba(OH)_2(aq) \longrightarrow Ba^{2+}(aq) + 2OH^-(aq)$$

**2. Calculating the Particles:** When one formula unit of $Ba(OH)_2$ dissolves:

- It produces **one** $Ba^{2+}$ ion.
- It produces **two** $OH^-$ ions.

Total number of ions produced per formula unit = 1 + 2 = 3.

**3. Calculation of $i$:** For complete dissociation:

$$i = \frac{\text{Number of particles after dissociation}}{\text{Number of formula units initially}}$$

$$i = \frac{3}{1} = 3$$

**Solution:** The van't Hoff factor for a dilute aqueous solution of $Ba(OH)_2$ is **3**.

**Answer: (D)**

## Q46.

### Solution

**Concept: Units of the Rate Constant ($k$)**

The unit of the rate constant is not fixed; it depends on the overall order of the reaction ($n$). The rate of a reaction is defined as the change in concentration per unit time:

$$\text{Rate} = \frac{d[C]}{dt} = \text{mol L}^{-1}\ \text{s}^{-1}$$

**1. General Formula:** For a reaction of order $n$, the rate law is: $\text{Rate} = k[A]^n$

$$k = \frac{\text{Rate}}{[A]^n} = \frac{\text{mol L}^{-1}\ \text{s}^{-1}}{(\text{mol L}^{-1})^n}$$

$$\text{Unit of } k = (\text{mol L}^{-1})^{1-n}\ \text{s}^{-1}$$

**2. Calculation for Second-Order ($n = 2$):** Substitute $n = 2$ into the general formula:

$$\text{Unit} = (\text{mol L}^{-1})^{1-2}\ \text{s}^{-1}$$

$$\text{Unit} = (\text{mol L}^{-1})^{-1}\ \text{s}^{-1}$$

$$\text{Unit} = \text{mol}^{-1}\ \text{L s}^{-1}$$

**Solution:** The unit of the rate constant for a second-order reaction is **L $\text{mol}^{-1}$ $\text{s}^{-1}$** (or $\text{dm}^3$ $\text{mol}^{-1}$ $\text{s}^{-1}$).

**Answer: (C)**

## Q47.

### Solution

**Concept: Lanthanoid Contraction and Its Consequences**

Lanthanoid contraction is the steady decrease in the atomic and ionic radii of the lanthanoid elements (atomic numbers 58 to 71) as the atomic number increases.

**1. Cause:** This is due to the poor shielding effect of the $4f$ electrons. As the nuclear charge increases, the $4f$ electrons fail to protect the outer electrons effectively, causing the entire electron cloud to shrink.

**2. Effect on $5d$ Series:** The contraction occurs right before the $5d$ transition elements. As a result, the expected increase in size going from the $4d$ series to the $5d$ series (due to an additional shell) is almost exactly cancelled out by the lanthanoid contraction.

**3. Zirconium ($Zr$) and Hafnium ($Hf$):** $Zr$ (40) is in the $4d$ series and $Hf$ (72) is in the $5d$ series, positioned directly below $Zr$. Because of the intervening lanthanoids, **$Zr$ and $Hf$ have nearly identical atomic radii** ($\approx$ 160 pm) and ionic radii. This makes them "chemical twins" as they are very difficult to separate.

**Solution:** The pair of elements with nearly the same atomic radii due to lanthanoid contraction is **Zr and Hf**.

**Answer: (C)**

## Q48.

### Solution

**Concept: Geometry and Hybridization of $[Ni(CN)_4]^{2-}$**

The geometry of a coordination complex is determined by the hybridization of the central metal ion, which is influenced by the strength of the ligands.

**1. Oxidation State and Configuration:**

- In $[Ni(CN)_4]^{2-}$, the oxidation state of Nickel is +2.
- $Ni^{2+}$ electronic configuration: $[Ar]3d^8 4s^0$.

**2. Effect of Strong Field Ligand ($CN^-$):** Cyanide is a **strong field ligand**. According to Crystal Field Theory, it causes a large splitting energy, forcing the eight $3d$ electrons to pair up as much as possible.

- This leaves **one** $3d$ orbital vacant ($d_{x^2-y^2}$).
- The metal ion then hybridizes one $3d$, one $4s$, and two $4p$ orbitals.

2-]

**3. Hybridization and Geometry:** The resulting **$dsp^2$ hybridization** leads to a **Square Planar** geometry. In contrast, with a weak field ligand like $Cl^-$, the hybridization would be $sp^3$, resulting in a tetrahedral geometry.

**Solution:** The geometry of the $[Ni(CN)_4]^{2-}$ ion is **Square planar**.

**Answer: (B)**

## Q49.

### Solution

**Concept: Finkelstein Reaction Mechanism**

The Finkelstein reaction is a classic organic method for the synthesis of alkyl iodides. It is an example of a halogen exchange reaction.

**1. Reaction Conditions:** An alkyl chloride or alkyl bromide is treated with sodium iodide ($NaI$) in a solvent of **dry acetone**.

$$R - X + NaI \xrightarrow{\text{Acetone}} R - I + NaX \downarrow \quad (X = Cl, Br)$$

**2. Mechanism Type:** The reaction proceeds via an **$S_N2$ mechanism**. The iodide ion ($I^-$) acts as a nucleophile, attacking the carbon from the back side and displacing the halide ion.

- **Nucleophile:** A species that donates an electron pair ($I^-$).
- **Substitution:** One group is replaced by another.

**3. Role of Acetone:** $NaI$ is soluble in acetone, but $NaCl$ and $NaBr$ are not. Their precipitation drives the reaction forward according to Le Chatelier's principle.

**Solution:** The Finkelstein reaction is a **Nucleophilic substitution** reaction.

**Answer: (B)**

## Q50.

### Solution

**Concept: Nitrogenous Bases in Nucleic Acids**

Nucleic acids (DNA and RNA) are polymers made of nucleotides. Each nucleotide contains a sugar, a phosphate group, and a nitrogenous base.

**1. Classification of Bases:**

- **Purines:** Adenine (A) and Guanine (G). These are found in both DNA and RNA.
- **Pyrimidines:** Cytosine (C), Thymine (T), and Uracil (U).

**2. Comparison of DNA and RNA:**

- **DNA Bases:** Adenine, Guanine, Cytosine, and **Thymine**.
- **RNA Bases:** Adenine, Guanine, Cytosine, and **Uracil**.

**3. The Specific Difference:** **Uracil** is the base that is unique to RNA. During protein synthesis (translation), Uracil pairs with Adenine, performing the role that Thymine plays in the DNA double helix.

**Solution:** The base present in RNA but not in DNA is **Uracil**.

**Answer: (D)**

# Answer Key

| Q | Ans | Q | Ans | Q | Ans | Q | Ans | Q | Ans |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | A | 3 | A | 4 | B | 5 | A |
| 6 | C | 7 | D | 8 | C | 9 | A | 10 | D |
| 11 | B | 12 | A | 13 | A | 14 | A | 15 | C |
| 16 | A | 17 | B | 18 | B | 19 | C | 20 | C |
| 21 | A | 22 | A | 23 | B | 24 | A | 25 | B |
| 26 | B | 27 | A | 28 | A | 29 | D | 30 | B |
| 31 | C | 32 | B | 33 | C | 34 | C | 35 | D |
| 36 | C | 37 | B | 38 | D | 39 | C | 40 | A |
| 41 | B | 42 | C | 43 | D | 44 | B | 45 | D |
| 46 | C | 47 | C | 48 | B | 49 | B | 50 | D |