CUET UG Chemistry Sample Paper - 14

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

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. Which of the following aqueous solutions will exhibit the highest boiling point?

(A) 0.1 M Na_2SO_4

(B) 0.1 M KNO_3

(C) 0.1 M Urea

(D) 0.1 M $AlCl_3$

Q2. The Van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is:

(A) 0

(B) 1

(C) 2

(D) 3

Q3. An unknown solute is dissolved in water. If the relative lowering of vapour pressure is 0.2, the mole fraction of the solute is:

(A) 0.8

(B) 0.5

(C) 0.2

(D) 0.1

Q4. Which property of an ideal solution is true?

(A) $\Delta H_{mix} > 0$

(B) $\Delta V_{mix} = 0$

(C) $\Delta S_{mix} = 0$

(D) It shows positive deviation from Raoult's law

Q5. At a given temperature, the osmotic pressure of a concentrated solution of a substance:

(A) Is higher than that of a dilute solution

(B) Is lower than that of a dilute solution

(C) Is same as that of a dilute solution

(D) Is directly proportional to the square of concentration

Q6. The standard electrode potential for Sn^{4+}/Sn^{2+} couple is +0.15 V and that for the Cr^{3+}/Cr couple is −0.74 V. These two couples in their standard state are connected to make a cell. The cell potential will be:

(A) +1.19 V

(B) +0.89 V

(C) +0.18 V

(D) +1.83 V

Q7. How much charge (in Faraday) is required to reduce 1 mole of MnO_4^- to Mn^{2+}?

(A) 1 F

(B) 2 F

(C) 5 F

(D) 3 F

Q8. According to Kohlrausch law, the limiting molar conductivity of an electrolyte A_2B is:

(A) $\lambda^\circ_A + \lambda^\circ_B$

(B) $2\lambda^\circ_A + \lambda^\circ_B$

(C) $\lambda^\circ_A + 2\lambda^\circ_B$

(D) $2\lambda^\circ_A + 2\lambda^\circ_B$

Q9. In a Hydrogen-Oxygen fuel cell, the reaction occurring at the cathode is:

(A) $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

(B) $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

(C) $H^+ + e^- \rightarrow \frac{1}{2}H_2$

(D) $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Q10. The unit of molar conductivity is:

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

(B) Ω^{-1} cm^{-1}

(C) S cm mol^{-1}

(D) S^2 cm^2 mol

Q11. Which of the following batteries is a secondary cell?

(A) Dry cell

(B) Mercury cell

(C) Lead storage battery

(D) Leclanche cell

Q12. For a first-order reaction, the time required for 99.9% completion is approximately how many times the half-life ($t_{1/2}$)?

(A) 2 times

(B) 5 times

(C) 10 times

(D) 100 times

Q13. If the rate constant of a reaction is $k = 3 \times 10^{-4}\ s^{-1}$, the order of the reaction is:

(A) Zero

(B) First

(C) Second

(D) Third

Q14. The rate of a chemical reaction doubles for every 10°C rise in temperature. If the temperature is raised by 50°C, the rate of reaction increases by:

(A) 10 times

(B) 24 times

(C) 32 times

(D) 64 times

Q15. In the Arrhenius equation $k = Ae^{-E_a/RT}$, the term $e^{-E_a/RT}$ represents:

(A) Total number of collisions

(B) Frequency of collisions

(C) Fraction of molecules having energy equal to or greater than E_a

(D) Activation energy of the reaction

Q16. For a zero-order reaction, the plot of [A] vs time is a straight line with:

(A) Positive slope and zero intercept

(B) Negative slope and zero intercept

(C) Negative slope and non-zero intercept

(D) Zero slope and non-zero intercept

Q17. Lanthanoid contraction is caused due to:

(A) Perfect shielding of 4f electrons

(B) Poor shielding of 4f electrons

(C) Increase in nuclear charge

(D) Both (B) and (C)

Q18. Which of the following transition metal ions is colorless in aqueous solution?

(A) Ti^{3+}

(B) V^{3+}

(C) Sc^{3+}

(D) Fe^{2+}

Q19. The magnetic moment of a divalent ion in aqueous solution with atomic number 25 is:

(A) 2.84 BM

(B) 3.87 BM

(C) 4.90 BM

(D) 5.92 BM

Q20. When $KMnO_4$ reacts with oxalic acid in acidic medium, the oxidation state of Mn changes from:

(A) +7 to +2

(B) +7 to +4

(C) +7 to +6

(D) +6 to +2

Q21. The IUPAC name of the complex $[Co(NH_3)_4(H_2O)Cl]Cl_2$ is:

(A) Tetraaquachloridocobalt(III) chloride

(B) Tetraammineaquachloridocobalt(III) chloride

(C) Tetraamminedichloridocobalt(II) chloride

(D) Ammineaquachloridocobalt(III) chloride

Q22. Which of the following complexes shows linkage isomerism?

(A) $[Co(NH_3)_5Cl]SO_4$

(B) $[Co(NH_3)_5(NO_2)]Cl_2$

(C) $[Co(en)_3]Cl_3$

(D) $[Pt(NH_3)_2Cl_2]$

Q23. The hybridization of Ni in $[Ni(CN)_4]^{2-}$ is:

(A) sp^3

(B) dsp^2

(C) sp^3d

(D) d^2sp^3

Q24. According to Crystal Field Theory, for a d^4 ion in an octahedral field with $\Delta_o > P$ (pairing energy), the configuration is:

(A) $t_{2g}^4 e_g^0$

(B) $t_{2g}^3 e_g^1$

(C) $t_{2g}^2 e_g^2$

(D) $t_{2g}^1 e_g^3$

Q25. The number of geometrical isomers for $[Pt(NH_3)_2Cl_2]$ is:

(A) 2

(B) 3

(C) 4

(D) 0

Q26. Which ligand is a bidentate ligand?

(A) NH_3

(B) CO

(C) $C_2O_4^{2-}$

(D) $EDTA^{4-}$

Q27. The reaction of $CH_3Br + NaI \xrightarrow{\text{Acetone}} CH_3I + NaBr$ is known as:

(A) Wurtz reaction

(B) Finkelstein reaction

(C) Swarts reaction

(D) Sandmeyer reaction

Q28. Which of the following will undergo S_N1 reaction most readily?

(A) CH_3Cl

(B) C_2H_5Cl

(C) $(CH_3)_2CHCl$

(D) $(CH_3)_3CCl$

Q29. Which of the following is an example of a vic-dihalide?

(A) Dichloromethane

(B) 1,2-dichloroethane

(C) Ethylidene chloride

(D) Allyl chloride

Q30. Chlorobenzene can be prepared by reacting aniline with:

(A) HCl

(B) Cu_2Cl_2/HCl following diazotization

(C) Cl_2 in presence of $FeCl_3$

(D) $SOCl_2$

Q31. Which alcohol reacts fastest with Lucas reagent?

(A) Butan-1-ol

(B) Butan-2-ol

(C) 2-methylpropan-2-ol

(D) Ethanol

Q32. Reimer-Tiemann reaction of phenol with $CHCl_3$ and KOH gives:

(A) Salicylic acid

(B) Salicylaldehyde

(C) Benzene

(D) Chlorobenzene

Q33. Phenol is more acidic than ethanol because:

(A) Phenoxide ion is resonance stabilized

(B) Ethoxide ion is resonance stabilized

(C) Phenol has more carbon atoms

(D) Ethanol is a liquid

Q34. Kolbe's reaction is used to prepare:

(A) Salicylaldehyde

(B) Salicylic acid

(C) Aspirin

(D) Picric acid

Q35. Propan-1-ol and Propan-2-ol can be distinguished by:

(A) Oxidation followed by Iodoform test

(B) Fehling's test

(C) Tollen's test

(D) Solubility in water

Q36. Which of the following does NOT undergo Aldol condensation?

(A) CH_3CHO

(B) CH_3COCH_3

(C) HCHO

(D) CH_3CH_2CHO

Q37. Cannizzaro reaction is given by:

(A) Acetaldehyde

(B) Benzaldehyde

(C) Acetone

(D) Propionaldehyde

Q38. The product formed when benzene reacts with CO and HCl in the presence of anhydrous $AlCl_3$ is:

(A) Chlorobenzene

(B) Benzaldehyde

(C) Benzene sulphonic acid

(D) Acetophenone

Q39. The correct order of acidity for the following is:

(A) $CH_3COOH > ClCH_2COOH > FCH_2COOH$

(B) $FCH_2COOH > ClCH_2COOH > CH_3COOH$

(C) $ClCH_2COOH > FCH_2COOH > CH_3COOH$

(D) $CH_3COOH > FCH_2COOH > ClCH_2COOH$

Q40. Tollen's reagent is:

(A) Ammoniacal silver nitrate

(B) Alkaline $KMnO_4$

(C) $SnCl_2/HCl$

(D) Br_2/H_2O

Q41. Which of the following ketones will give positive Iodoform test?

(A) Pentan-3-one

(B) Benzophenone

(C) Acetophenone

(D) Propanone

Q42. The correct order of basic strength of methyl substituted amines in aqueous solution is:

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

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

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

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

Q43. Gabriel phthalimide synthesis is used for the preparation of:

(A) Primary aromatic amines

(B) Primary aliphatic amines

(C) Secondary amines

(D) Tertiary amines

Q44. Which test is used to distinguish primary, secondary, and tertiary amines?

(A) Fehling's test

(B) Hinsberg's test

(C) Tollen's test

(D) Lucas test

Q45. Reduction of nitrobenzene with Fe/HCl gives:

(A) Aniline

(B) Azobenzene

(C) Hydrazobenzene

(D) Nitrosobenzene

Q46. Which of the following is a non-reducing sugar?

(A) Glucose

(B) Fructose

(C) Lactose

(D) Sucrose

Q47. The segment of DNA which acts as the instruction manual for the synthesis of a protein is:

(A) Nucleoside

(B) Nucleotide

(C) Gene

(D) Ribose

Q48. Denaturation of protein leads to loss of its biological activity due to:

(A) Loss of primary structure

(B) Loss of secondary and tertiary structures

(C) Formation of amino acids

(D) Hydrolysis of peptide bonds

Q49. Deficiency of Vitamin C causes:

(A) Rickets

(B) Scurvy

(C) Beri-beri

(D) Night blindness

Q50. In a protein molecule, various amino acids are linked together by:

(A) Glycosidic bond

(B) Peptide bond

(C) Dative bond

(D) Phosphodiester bond

Detailed Solutions

Q1.

Solution

Concept: The boiling point of a solution is a **colligative property**, meaning it depends on the total number of solute particles (ions or molecules) in the solution rather than their chemical identity. The elevation in boiling point (ΔT_b) is calculated as:

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

Where:

- i is the **Van't Hoff factor** (number of particles per formula unit).
- K_b is the molal boiling point elevation constant.
- m is the molality (assumed proportional to Molarity M for dilute aqueous solutions).

Solution: Since the concentration for all options is identical (0.1 M), the solution with the **highest Van't Hoff factor** (i) will produce the most particles and thus the highest boiling point.

- **(A)** Na_2SO_4**:** Dissociates into $2Na^+$ and $1SO_4^{2-} \implies i = 3$.
- **(B)** KNO_3**:** Dissociates into $1K^+$ and $1NO_3^- \implies i = 2$.
- **(C) Urea:** A non-electrolyte; it does not dissociate in water $\implies i = 1$.
- **(D)** $AlCl_3$**:** Dissociates into $1Al^{3+}$ and $3Cl^- \implies i = 4$.

Comparison: The number of particles produced follows the order:

$$AlCl_3(4) > Na_2SO_4(3) > KNO_3(2) > \text{Urea}(1)$$

Since $AlCl_3$ provides the maximum number of particles, it causes the greatest elevation in boiling point.

Conclusion: The 0.1 M $AlCl_3$ solution will exhibit the highest boiling point among the given choices.

Answer: (D)

Q2.

Solution

Concept: The **Van't Hoff factor** (i) is a measure of the effect of a solute on colligative properties such as osmotic pressure, relative lowering of vapor pressure, elevation of boiling point, and depression of freezing point. For a strong electrolyte that undergoes complete dissociation in a dilute solution, i is equal to the total number of ions produced per formula unit of the substance.
Solution: Barium hydroxide, $Ba(OH)_2$, is a strong base and a strong electrolyte. In a dilute aqueous solution, it dissociates completely into its constituent ions as follows:

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

To find the Van't Hoff factor (i):

- Number of Barium ions (Ba^{2+}) = 1
- Number of Hydroxide ions (OH^-) = 2
- Total number of ions = 1 + 2 = 3

Since the problem specifies a "strong electrolyte" (implying $\alpha = 100\%$), the Van't Hoff factor is exactly equal to the number of particles formed.

$$i = 3$$

Analysis of options:

- **(A) 0:** Incorrect. i cannot be 0 for a solute.
- **(B) 1:** Incorrect. This would be for a non-electrolyte like glucose or urea.
- **(C) 2:** Incorrect. This would be for an electrolyte like $NaCl$ or $MgSO_4$.
- **(D) 3:** Correct. $Ba(OH)_2$ produces three ions upon dissociation.

Conclusion: One molecule of barium hydroxide yields one barium ion and two hydroxide ions, resulting in a Van't Hoff factor of 3.

Answer: (D)

Q3.

Solution

Concept: According to **Raoult's Law** for a solution containing a non-volatile solute, the relative lowering of vapour pressure is equal to the **mole fraction of the solute** (χ_{solute}).
The mathematical expression is:

$$\frac{P^0 - P_s}{P^0} = \chi_{\text{solute}}$$

Where:

- P^0 is the vapour pressure of the pure solvent.
- P_s is the vapour pressure of the solution.
- $\frac{P^0 - P_s}{P^0}$ is the **relative lowering of vapour pressure**.

Solution: The problem provides the value for the relative lowering of vapour pressure directly:

$$\text{Relative lowering of vapour pressure} = 0.2$$

Applying Raoult's Law:

$$\chi_{\text{solute}} = \text{Relative lowering of vapour pressure}$$

$$\chi_{\text{solute}} = 0.2$$

Analysis of options:

- **(A) 0.8:** This would be the mole fraction of the *solvent* ($\chi_{\text{solvent}} = 1 - 0.2 = 0.8$).
- **(B) 0.5:** Incorrect.
- **(C) 0.2:** Correct. This matches the definition of Raoult's Law.
- **(D) 0.1:** Incorrect.

Conclusion: The mole fraction of the solute is numerically equal to the relative lowering of its vapour pressure.

Answer: (C)

Q4.

Solution

Concept: An **ideal solution** is a mixture in which the molecules of different species are distinguishable, but the molecules of each species behave similarly to those of the pure components. For a solution to be ideal, it must obey **Raoult's Law** over the entire range of concentration and temperature.

Solution: For an ideal solution formed by mixing two components A and B, the following conditions must be satisfied:

- **Molecular Interactions:** The A-B interactions are identical in magnitude to A-A and B-B interactions.
- **Enthalpy of Mixing (ΔH_{mix}):** Since the intermolecular forces are the same, no heat is absorbed or evolved. Thus, $\Delta H_{\text{mix}} = 0$.
- **Volume of Mixing (ΔV_{mix}):** The total volume of the solution is exactly equal to the sum of the volumes of the individual components. Thus, $\Delta V_{\text{mix}} = 0$.
- **Entropy of Mixing (ΔS_{mix}):** Mixing always leads to increased randomness, so ΔS_{mix} is always **positive** (> 0) for any spontaneous mixing.
- **Gibbs Free Energy (ΔG_{mix}):** For spontaneous mixing, ΔG_{mix} must be **negative** (< 0).

Analysis of options:

- **(A) $\Delta H_{\text{mix}} > 0$:** Incorrect. This occurs in non-ideal solutions showing positive deviation (endothermic mixing).
- **(B) $\Delta V_{\text{mix}} = 0$:** Correct. This is a fundamental characteristic of an ideal solution.
- **(C) $\Delta S_{\text{mix}} = 0$:** Incorrect. Entropy always increases during the mixing of two substances.
- **(D) It shows positive deviation:** Incorrect. Ideal solutions follow Raoult's law perfectly; they do not show deviations.

Conclusion: For an ideal solution, there is no change in volume upon mixing the components.

Answer: (B)

Q5.

Solution

Concept: Osmotic pressure (π) is a colligative property defined as the minimum pressure that must be applied to a solution to prevent the inward flow of its pure solvent across a semipermeable membrane. According to the **van't Hoff equation** for dilute solutions:

$$\pi = CRT$$

Where:

- C is the **molar concentration** (molarity) of the solution.
- R is the gas constant ($0.0821\ L \cdot atm \cdot K^{-1} \cdot mol^{-1}$).
- T is the absolute temperature in Kelvin (K).

Solution: The equation $\pi = CRT$ shows a **direct proportionality** between osmotic pressure and the molar concentration of the solute at a constant temperature (T):

$$\pi \propto C$$

1. **Concentrated Solution:** Has a higher number of solute particles per unit volume (high C). Consequently, it will exhibit a **higher osmotic pressure**. 2. **Dilute Solution:** Has a lower number of solute particles per unit volume (low C). Consequently, it will exhibit a **lower osmotic pressure**.

Analysis of options:

- **(A) Is higher than that of a dilute solution:** Correct. Higher concentration (C) leads to higher π.
- **(B) Is lower than that of a dilute solution:** Incorrect. This contradicts the direct proportionality.
- **(C) Is same as that of a dilute solution:** Incorrect. Osmotic pressure changes with concentration.
- **(D) Is directly proportional to the square of concentration:** Incorrect. It is proportional to C, not C^2.

Conclusion: At a constant temperature, the osmotic pressure increases as the concentration of the solution increases.

Answer: (A)

Q6.

Solution

Concept: The **Standard Cell Potential** (E^0_{cell}) of a galvanic cell is the difference between the standard reduction potentials of the cathode and the anode. A spontaneous electrochemical cell must have a positive E^0_{cell}.

$$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}}$$

Where both E^0 values are taken as **standard reduction potentials**.

Solution: We are given the following standard reduction potentials:

- $E^0_{Sn^{4+}/Sn^{2+}} = +0.15$ V
- $E^0_{Cr^{3+}/Cr} = -0.74$ V

1. **Identifying Cathode and Anode:** In a standard cell, the electrode with the **higher** (more positive) reduction potential acts as the **cathode** (where reduction occurs). The electrode with the **lower** (more negative) reduction potential acts as the **anode** (where oxidation occurs).

- Cathode: Sn^{4+}/Sn^{2+} (+0.15 V)
- Anode: Cr^{3+}/Cr (−0.74 V)

2. **Calculation:**

$$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}}$$

$$E^0_{\text{cell}} = (+0.15\text{ V}) - (-0.74\text{ V})$$

$$E^0_{\text{cell}} = 0.15 + 0.74 = +0.89\text{ V}$$

Analysis of options:

- **(A)** +1.19 **V:** Incorrect.
- **(B)** +0.89 **V:** Correct. This is the sum of the potentials when accounting for the signs.
- **(C)** +0.18 **V:** Incorrect.
- **(D)** +1.83 **V:** Incorrect.

Conclusion: The cell potential is calculated by subtracting the lower reduction potential from the higher reduction potential, resulting in +0.89 V.

Answer: (B)

Q7.

Solution

Concept: According to **Faraday's First Law of Electrolysis**, the quantity of charge (Q) required for the oxidation or reduction of a substance is directly proportional to the number of moles of electrons (n) exchanged in the balanced half-reaction. The charge required for 1 mole of electrons is 1 Faraday (1 F $\approx$ 96500 C).

$$Q = n \times F$$

Solution: To find the charge required, we must determine the number of electrons involved in the reduction of the permanganate ion (MnO_4^-) to the manganese(II) ion (Mn^{2+}).

1. **Determine Oxidation States:**

- In MnO_4^-: Let the oxidation state of Mn be x.

$$x + 4(-2) = -1 \implies x - 8 = -1 \implies x = +7$$

- In Mn^{2+}: The oxidation state is simply +2.

2. **Write the Half-Reaction (in acidic medium):** The change in oxidation state is from +7 to +2. This requires the gain of 5 electrons.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

3. **Calculate the Charge:** Since 1 mole of MnO_4^- requires 5 moles of electrons for reduction:

$$n = 5$$

$$\text{Charge required} = 5 \times F = 5 \text{ F}$$

Analysis of options:

- **(A) 1 F:** Incorrect.
- **(B) 2 F:** Incorrect.
- **(C) 5 F:** Correct. This corresponds to the 5-electron transfer.
- **(D) 3 F:** Incorrect.

Conclusion: The reduction of 1 mole of MnO_4^- to Mn^{2+} involves a 5-unit decrease in oxidation state, necessitating 5 Faradays of charge.

Answer: (C)

Q8.

Solution

Concept: Kohlrausch's Law of Independent Migration of Ions states that the limiting molar conductivity (Λ_m°) of an electrolyte can be represented as the sum of the individual contributions of the anions and cations of the electrolyte.
Mathematically, for an electrolyte that dissociates into v_+ cations and v_- anions, the law is expressed as:

$$\Lambda_m^\circ = v_+\lambda_+^\circ + v_-\lambda_-^\circ$$

Where:

- Λ_m° is the limiting molar conductivity of the electrolyte.
- λ_+° and λ_-° are the limiting molar conductivities of the individual cation and anion, respectively.
- v_+ and v_- are the number of cations and anions per formula unit.

Solution: Consider the electrolyte A_2B. Upon dissociation in water, it produces:

$$A_2B \rightarrow 2A^+ + B^{2-}$$

(Note: The charges may vary, but the stoichiometry remains 2 ions of A and 1 ion of B).
From the stoichiometry:

- $v_+ = 2$ (for ion A)
- $v_- = 1$ (for ion B)

Applying Kohlrausch's Law:

$$\Lambda_{A_2B}^\circ = 2\lambda_A^\circ + \lambda_B^\circ$$

Analysis of options:

- **(A)** $\lambda_A^\circ + \lambda_B^\circ$**:** Incorrect. This is for an AB type electrolyte (e.g., $NaCl$).
- **(B)** $2\lambda_A^\circ + \lambda_B^\circ$**:** Correct. It accounts for the two A ions produced.
- **(C)** $\lambda_A^\circ + 2\lambda_B^\circ$**:** Incorrect. This would be for an AB_2 type electrolyte (e.g., $MgCl_2$).
- **(D)** $2\lambda_A^\circ + 2\lambda_B^\circ$**:** Incorrect.

Conclusion: The total limiting molar conductivity is the sum of the conductivities of all ions produced by one formula unit of the electrolyte.

Answer: (B)

Q9.

Solution

Concept: A **Hydrogen-Oxygen fuel cell** is a galvanic cell that converts the chemical energy of the combustion of hydrogen (H_2) and oxygen (O_2) directly into electrical energy. In these cells, hydrogen and oxygen are bubbled through porous carbon electrodes into a concentrated aqueous electrolyte (usually KOH or $NaOH$).

Solution: To identify the cathode reaction, we must look at where reduction (gain of electrons) occurs. In a standard alkaline fuel cell:

1. **At the Anode (Oxidation):** Hydrogen gas is oxidized to water.

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

(This corresponds to option A).

2. **At the Cathode (Reduction):** Oxygen gas is reduced in the presence of water to form hydroxide ions.

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

(This corresponds to option B).

3. **Overall Cell Reaction:** Adding the two half-reactions gives the net combustion of hydrogen.

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

Analysis of options:

- **(A):** This is the **anode** reaction (oxidation of H_2).
- **(B):** This is the **cathode** reaction (reduction of O_2).
- **(C):** This represents the reduction of protons, typically seen in a standard hydrogen electrode (SHE).
- **(D):** This is the oxidation of water, which occurs during the electrolysis of water.

Conclusion: In the H_2-O_2 fuel cell, oxygen undergoes reduction at the cathode to produce hydroxide ions.

Answer: (B)

Q10.

Solution

Concept: Molar conductivity (Λ_m) is defined as the conducting power of all the ions produced by dissolving one mole of an electrolyte in a solution. It is related to electrolytic conductivity (κ, kappa) and molarity (M) of the solution.
The mathematical expression is:

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

Solution: To determine the unit of molar conductivity, we can derive it from the units of the individual terms:
1. **Electrolytic Conductivity (κ):** Conductivity is the inverse of resistivity. Its unit is S cm^{-1} or Ω^{-1} cm^{-1} (where S = Siemens = Ω^{-1}). 2. **Molarity (M):** Molarity is the number of moles per unit volume. In the context of this formula (using cm), the unit is mol cm^{-3}. 3. **Derivation:**

$$\text{Unit of } \Lambda_m = \frac{\text{Unit of } \kappa}{\text{Unit of } M} = \frac{\text{S cm}^{-1}}{\text{mol cm}^{-3}}$$

$$\Lambda_m = \text{S cm}^{-1} \times \text{cm}^3 \times \text{mol}^{-1}$$

$$\Lambda_m = \text{S cm}^2 \text{ mol}^{-1}$$

Analysis of options:

- **(A) S cm^2 mol^{-1}:** Correct. This is the standard CGS unit used in chemistry.
- **(B) Ω^{-1} cm^{-1}:** Incorrect. This is the unit of conductivity (κ).
- **(C) S cm mol^{-1}:** Incorrect.
- **(D) S^2 cm^2 mol:** Incorrect.

Conclusion: The unit of molar conductivity is derived from the units of Siemens (for conductance), square centimeters (for area/distance ratio), and inverse moles (for concentration).

Answer: (A)

Q11.

Solution

Concept: Batteries or electrochemical cells are broadly classified into two categories based on their ability to be recharged:

- **Primary Cells:** The redox reaction occurs only once. After use over a period of time, the battery becomes dead and cannot be reused or recharged (e.g., Dry cell, Mercury cell).
- **Secondary Cells:** These can be recharged by passing an electric current through them in the opposite direction. They can be used over and over again (e.g., Lead storage battery, Nickel-cadmium cell).

Solution: Let's evaluate each option based on its classification:
1. **(A) Dry cell:** Also known as a Leclanche cell. It is a **primary cell** used in clocks and transistors. Once the chemicals are consumed, it cannot be recharged. 2. **(B) Mercury cell:** A **primary cell** used in low-current devices like hearing aids and watches. It provides a constant voltage but is not rechargeable. 3. **(C) Lead storage battery:** This is a **secondary cell** commonly used in automobiles and inverters. During discharge, it converts chemical energy to electrical energy; during charging, the reaction is reversed. 4. **(D) Leclanche cell:** This is simply another name for the standard **dry cell**, which is a **primary cell**.
Analysis of options:

- **(A), (B), and (D)** are all examples of primary cells that are discarded after a single life cycle.
- **(C)** Lead storage battery is the only one in the list that can be restored to its original chemical state by an external electrical source.

Conclusion: The lead storage battery is a secondary cell because its electrode reactions are reversible.

Answer: (C)

Q12.

Solution

Concept: For a **first-order reaction**, the rate of reaction depends on the concentration of only one reactant. The integrated rate equation is:

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

Where $[A]_0$ is the initial concentration and $[A]_t$ is the concentration at time t. The **half-life** ($t_{1/2}$) is the time required for the concentration to decrease to half of its initial value:

$$t_{1/2} = \frac{0.693}{k} \approx \frac{2.303 \log(2)}{k}$$

Solution: We need to find the ratio between the time for 99.9% completion ($t_{99.9\%}$) and the half-life ($t_{1/2}$).

1. **Calculate $t_{99.9\%}$:** If the reaction is 99.9% complete, the remaining concentration $[A]_t$ is $100\% - 99.9\% = 0.1\%$ of $[A]_0$.

$$[A]_t = 0.001[A]_0 = 10^{-3}[A]_0$$

Using the rate equation:

$$t_{99.9\%} = \frac{2.303}{k} \log\left(\frac{[A]_0}{10^{-3}[A]_0}\right) = \frac{2.303}{k} \log(10^3)$$

$$t_{99.9\%} = \frac{2.303 \times 3}{k} = \frac{6.909}{k}$$

2. **Relate to $t_{1/2}$:** We know $t_{1/2} = \frac{0.693}{k}$. Dividing $t_{99.9\%}$ by $t_{1/2}$:

$$\frac{t_{99.9\%}}{t_{1/2}} = \frac{6.909/k}{0.693/k} = \frac{6.909}{0.693} \approx 9.97$$

3. **Conclusion:** The value 9.97 is approximately **10**. Therefore, for a first-order reaction, the time required for 99.9% completion is about 10 times the half-life.

Analysis of options:

- **(A) 2 times:** Incorrect. (This is roughly 75% completion).
- **(B) 5 times:** Incorrect.
- **(C) 10 times:** Correct. This is a well-known derivation in chemical kinetics.
- **(D) 100 times:** Incorrect.

Answer: (C)

Q13.

Solution

Concept: The **order of a reaction** can be identified by the units of its rate constant (k). The general formula for the units of the rate constant for a reaction of order n is:

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

Or more simply, the units change based on the power of concentration over time.
Solution: We are given the rate constant $k = 3 \times 10^{-4}\ \text{s}^{-1}$.
1. **Examine the Unit:** The unit provided is s^{-1} (per second). 2. **Match with General Formula:** Using the formula $(\text{mol L}^{-1})^{1-n}\ \text{s}^{-1}$:

- For $n = 0$ (Zero order): Unit = $\text{mol L}^{-1}\ \text{s}^{-1}$
- For $n = 1$ (First order): Unit = $(\text{mol L}^{-1})^{1-1}\ \text{s}^{-1} = (\text{mol L}^{-1})^{0}\ \text{s}^{-1} = \text{s}^{-1}$
- For $n = 2$ (Second order): Unit = $\text{L mol}^{-1}\ \text{s}^{-1}$

3. **Comparison:** The unit s^{-1} corresponds exactly to a **first-order reaction**. In first-order kinetics, the rate is proportional to the concentration of one reactant, so the concentration units cancel out in the rate law ($Rate = k[A]$), leaving only the time component for k.
Analysis of options:

- **(A) Zero:** Incorrect. Zero-order units include concentration (M/s).
- **(B) First:** Correct. The unit is independent of concentration.
- **(C) Second:** Incorrect.
- **(D) Third:** Incorrect.

Conclusion: Since the unit of the given rate constant is reciprocal time (s^{-1}), the reaction must be of the first order.

Answer: (B)

Q14.

Solution

Concept: The relationship between the rate of reaction and temperature is often expressed using the **temperature coefficient** (η). The temperature coefficient is the ratio of the rate constants of a reaction at two temperatures differing by 10°C.

$$\eta = \frac{k_{T+10}}{k_T}$$

For most reactions, the rate doubles for every 10°C rise, meaning $\eta = 2$. If the temperature increases by ΔT, the new rate (R_2) relative to the initial rate (R_1) is given by:

$$\frac{R_2}{R_1} = (\eta)^{\Delta T/10}$$

Solution: We are given:

- Temperature coefficient (η) = 2
- Total rise in temperature (ΔT) = 50°C

1. **Calculate the number of** 10°**C intervals:**

$$n = \frac{\Delta T}{10} = \frac{50}{10} = 5$$

This means the temperature has been raised by five 10°C steps.

2. **Calculate the increase in rate:** The rate doubles at each step, so for 5 steps, the increase is:

$$\text{Increase} = 2^n = 2^5$$

$$2 \times 2 \times 2 \times 2 \times 2 = 32$$

Analysis of options:

- **(A) 10 times:** Incorrect. This assumes a linear increase (2×5).
- **(B) 24 times:** Incorrect.
- **(C) 32 times:** Correct. This follows the exponential 2^n rule.
- **(D) 64 times:** Incorrect. This would be for a 60°C rise (2^6).

Conclusion: A 50°C rise in temperature results in the rate doubling five times, leading to a 32-fold increase in the reaction rate.

Answer: (C)

Q15.

Solution

Concept: The **Arrhenius equation** describes the dependence of the rate constant (k) of a chemical reaction on the absolute temperature (T).

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

Where:

- A is the **Arrhenius factor** (or pre-exponential factor/frequency factor), which corresponds to the frequency of collisions with proper orientation.
- E_a is the **Activation Energy**.
- R is the gas constant.
- T is the absolute temperature.

Solution: The exponential term $e^{-E_a/RT}$ is derived from the **Maxwell-Boltzmann distribution** of molecular energies.
1. **Physical Significance:** This term represents the **Boltzmann factor**. It quantifies the probability that a collision will have enough kinetic energy to overcome the energy barrier (E_a) required for a reaction to occur. 2. **Fraction of Molecules:** Numerically, it represents the **fraction of total molecules** (n/N) that possess kinetic energy equal to or greater than the activation energy E_a at a specific temperature T.
Analysis of options:

- **(A) Total number of collisions:** Incorrect. This is related to the frequency factor A but is not the exponential term itself.
- **(B) Frequency of collisions:** Incorrect. This is represented by A in collision theory.
- **(C) Fraction of molecules having energy equal to or greater than E_a:** Correct. This is the precise statistical definition of the term.
- **(D) Activation energy:** Incorrect. E_a is only a component of the exponent.

Conclusion: As temperature T increases or E_a decreases, the value of the term $e^{-E_a/RT}$ increases, meaning a larger fraction of molecules can react, thus increasing the rate constant k.

Answer: (C)

Q16.

Solution

Concept: For a **zero-order reaction**, the rate of the reaction is independent of the concentration of the reactants. The rate law is expressed as:

$$-\frac{d[A]}{dt} = k[A]^0 = k$$

Integrating this differential rate equation from $t = 0$ (initial concentration $[A]_0$) to time t (concentration $[A]$) gives the integrated rate law.
[Image of concentration vs time graph for a zero-order reaction]
Solution: The integrated rate equation for a zero-order reaction is:

$$[A] = -kt + [A]_0$$

This equation is in the form of a straight line, $y = mx + c$, where:

- $y = [A]$ (Concentration of reactant at time t)
- $x = t$ (Time)
- $m = -k$ (**Slope**)
- $c = [A]_0$ (**Y-intercept**)

[Image of linear plot of [A] versus t for zero order reaction showing slope and intercept]
Analysis of the Plot:

- **Slope (m):** Since the rate constant k is a positive value, $-k$ represents a **negative slope**.
- **Intercept (c):** The intercept on the y-axis is $[A]_0$, which is the initial concentration of the reactant. Since a reaction must start with some amount of reactant, this is a **non-zero intercept**.

Analysis of options:

- **(A) Positive slope and zero intercept:** Incorrect.
- **(B) Negative slope and zero intercept:** Incorrect. The line does not pass through the origin unless the initial concentration is zero.
- **(C) Negative slope and non-zero intercept:** Correct. The concentration decreases linearly over time starting from $[A]_0$.
- **(D) Zero slope and non-zero intercept:** Incorrect. A zero slope would imply the concentration does not change with time.

Conclusion: A plot of $[A]$ vs t for a zero-order reaction yields a straight line with a slope of $-k$ and an intercept of $[A]_0$.

Answer: (C)

Q17.

Solution

Concept: **Lanthanoid contraction** refers to the steady decrease in the atomic and ionic radii of the Lanthanoids with the increase in atomic number. This phenomenon is primarily attributed to the unique properties of the **4f subshell**.

Solution: Two main factors contribute to this contraction:

1. **Poor Shielding Effect of 4f Electrons:** The 4f orbitals are large and diffused. Due to their shape, 4f electrons provide very **poor shielding** for the outer electrons against the attractive force of the nucleus. 2. **Increase in Nuclear Charge:** As we move from Cerium ($Z = 58$) to Lutetium ($Z = 71$), the nuclear charge (number of protons) increases by one unit at each step.

Mechanism: Because the 4f electrons added across the series do not effectively "shield" or block the increasing positive charge of the nucleus, the **effective nuclear charge** (Z_{eff}) experienced by the outer electrons increases. This results in the outer electron shells being pulled closer to the nucleus, causing a contraction in the size of the atom or ion.

Analysis of options:

- **(A) Perfect shielding of 4f electrons:** Incorrect. 4f shielding is notoriously poor.
- **(B) Poor shielding of 4f electrons:** This is a primary cause.
- **(C) Increase in nuclear charge:** This is also a primary cause.
- **(D) Both (B) and (C):** Correct. Both factors work together to result in the contraction.

Conclusion: The combination of an increasing nuclear charge and the inability of 4f electrons to shield that charge effectively leads to the Lanthanoid contraction.

Answer: (D)

Q18.

Solution

Concept: The color of transition metal ions in aqueous solution is generally due to **d-d transitions**. For an ion to exhibit color, it must have:

(a) Partially filled d-orbitals (d^1 to d^9 configuration).

(b) At least one unpaired electron that can be excited from a lower energy d-orbital to a higher energy d-orbital upon absorbing visible light.

If an ion has a d^0 (empty d-shell) or d^{10} (completely filled d-shell) configuration, d-d transitions are not possible, and the ion is typically **colorless**.

Solution: Let's examine the electronic configurations of the given ions (Atomic numbers: Sc=21, Ti=22, V=23, Fe=26):

- **(A) Ti^{3+}:** Atomic Ti is $[Ar]3d^2 4s^2$. Removing 3 electrons gives Ti^{3+} : $[Ar]3d^1$. It has 1 unpaired electron $\implies$ **Colored** (Purple/Violet).
- **(B) V^{3+}:** Atomic V is $[Ar]3d^3 4s^2$. Removing 3 electrons gives V^{3+} : $[Ar]3d^2$. It has 2 unpaired electrons $\implies$ **Colored** (Green).
- **(C) Sc^{3+}:** Atomic Sc is $[Ar]3d^1 4s^2$. Removing 3 electrons gives Sc^{3+} : $[Ar]3d^0$. The d-orbital is completely empty (d^0). No d-d transition is possible $\implies$ **Colorless**.
- **(D) Fe^{2+}:** Atomic Fe is $[Ar]3d^6 4s^2$. Removing 2 electrons gives Fe^{2+} : $[Ar]3d^6$. It has 4 unpaired electrons $\implies$ **Colored** (Pale Green).

Conclusion: Among the given options, Sc^{3+} has a $3d^0$ configuration, which makes it unable to absorb visible light through electronic transitions in the d-shell.

Answer: (C)

Q19.

Solution

Concept: The **magnetic moment** (μ) of transition metal ions is primarily determined by the number of unpaired electrons in their d-orbitals. This is calculated using the **spin-only formula**:

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

Where:

- n is the number of **unpaired electrons**.
- **BM** (Bohr Magneton) is the unit of magnetic moment.

Solution: We are given an element with **atomic number 25** (Manganese, Mn) in its **divalent** state (+2 oxidation state).

1. **Electronic Configuration:**

- Neutral Manganese (Mn, $Z = 25$): $[Ar]3d^5 4s^2$
- Divalent Manganese (Mn^{2+}): $[Ar]3d^5$ (electrons are removed from the $4s$ orbital first).

2. **Number of Unpaired Electrons (n):** In the $3d^5$ configuration, according to **Hund's Rule**, each of the five d-orbitals is occupied by one electron with parallel spins.

$$n = 5$$

3. **Calculation of Magnetic Moment:**

$$\mu = \sqrt{5(5+2)}$$

$$\mu = \sqrt{5 \times 7} = \sqrt{35}$$

Since $\sqrt{36} = 6.0$, $\sqrt{35}$ must be slightly less than 6.

$$\mu \approx 5.916 \text{ BM} \approx 5.92 \text{ BM}$$

Analysis of options:

- **(A) 2.84 BM:** Corresponds to $n = 2$ ($\sqrt{8}$).
- **(B) 3.87 BM:** Corresponds to $n = 3$ ($\sqrt{15}$).
- **(C) 4.90 BM:** Corresponds to $n = 4$ ($\sqrt{24}$).
- **(D) 5.92 BM:** Correct. This corresponds to $n = 5$ ($\sqrt{35}$).

Conclusion: A divalent ion with atomic number 25 (Mn^{2+}) has five unpaired electrons, resulting in a magnetic moment of approximately 5.92 BM.

Answer: (D)

Q20.

Solution

Concept: The reaction between **Potassium Permanganate ($KMnO_4$)** and **Oxalic Acid ($H_2C_2O_4$)** in an acidic medium (usually H_2SO_4) is a classic **redox titration**.
In this reaction:

- **Oxalic acid** acts as a reducing agent and is oxidized to CO_2.
- **Permanganate ion** acts as a strong oxidizing agent and is reduced to the manganese(II) ion.

Solution: 1. **Determine the initial oxidation state of Mn:** In $KMnO_4$, the potassium ion is +1 and oxygen is −2. Let the oxidation state of Mn be x:

$$(+1) + x + 4(-2) = 0$$

$$1 + x - 8 = 0 \implies x = +7$$

So, Manganese starts in the **+7** oxidation state (Permanganate ion, MnO_4^-).
2. **Determine the final oxidation state of Mn:** In an acidic medium, the reduction half-reaction is:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

The product is the Mn^{2+} ion (Manganese(II) sulfate if H_2SO_4 is used). The final oxidation state is **+2**.
3. **Overall Reaction:** The balanced molecular equation is:

$$2KMnO_4 + 3H_2SO_4 + 5H_2C_2O_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 10CO_2$$

Analysis of options:

- **(A) +7 to +2:** Correct. This is the characteristic reduction of $KMnO_4$ in acidic medium.
- **(B) +7 to +4:** Incorrect. This occurs in neutral or faintly alkaline medium (MnO_2 is formed).
- **(C) +7 to +6:** Incorrect. This occurs in strongly alkaline medium (MnO_4^{2-} is formed).
- **(D) +6 to +2:** Incorrect.

Conclusion: In acidic medium, each Mn atom gains 5 electrons, shifting its oxidation state from +7 to +2.

Answer: (A)

Q21.

Solution

Concept: The IUPAC naming of coordination compounds follows specific rules:

(a) **Ligand Order:** Ligands are named in alphabetical order before the central metal.

(b) **Prefixes:** Numerical prefixes (di-, tri-, tetra-) indicate the number of identical ligands but do not affect alphabetical order.

(c) **Ligand Names:** Neutral ligands like NH_3 are called **ammine** and H_2O is **aqua**. Anionic ligands like Cl^- end in '-o' (**chlorido**).

(d) **Oxidation State:** The oxidation state of the metal is indicated by a Roman numeral in parentheses.

(e) **Counter Ion:** The ion outside the coordination sphere is named last.

Solution: For the complex $[Co(NH_3)_4(H_2O)Cl]Cl_2$:
1. **Identify Ligands in Alphabetical Order:**

- $4 \times NH_3$: **Tetraammine** (starts with 'a')
- $1 \times H_2O$: **Aqua** (starts with 'aq')
- $1 \times Cl^-$: **Chlorido** (starts with 'c')

Alphabetical sequence: Ammine $\rightarrow$ Aqua $\rightarrow$ Chlorido.
2. **Calculate Oxidation State of Cobalt (x):** The coordination sphere must balance the charge of the two chloride ions ($2 \times -1 = -2$) outside the bracket.

$$x + 4(0) + 1(0) + 1(-1) = +2$$

$$x - 1 = +2 \implies x = +3$$

The metal is **Cobalt(III)**.
3. **Assemble the Name:** Joining the parts together, we get: **Tetraammineaquachloridocobalt(III) chloride**.
Analysis of options:

- **(A):** Missing the ammine ligands.
- **(B):** Correct. Follows alphabetical order and correct oxidation state.
- **(C):** Incorrect. Lists two chlorido ligands inside and uses Cobalt(II).
- **(D):** Incorrect. Missing the 'tetra' prefix for ammine.

Answer: (B)

Q22.

Solution

Concept: Linkage isomerism occurs in coordination compounds that contain **ambidentate ligands**. These are ligands that possess two or more different donor atoms and can coordinate to the central metal atom through either of them.
Common examples of ambidentate ligands include:

- NO_2^-: can bind via N (nitro) or O (nitrito).
- SCN^-: can bind via S (thiocyanato) or N (isothiocyanato).
- CN^-: can bind via C (cyanido) or N (isocyanido).

Solution: Let's analyze the ligands in each provided complex:
1. **(A)** $\mathbf{[Co(NH_3)_5Cl]SO_4}$**:** The ligands are NH_3 and Cl^-. Neither is ambidentate. This complex can show **ionization isomerism** if the Cl^- and SO_4^{2-} ions exchange places. 2. **(B)** $\mathbf{[Co(NH_3)_5(NO_2)]Cl_2}$**:** This complex contains the **nitrite ion** (NO_2^-), which is a classic ambidentate ligand. It can form two linkage isomers:

- $[Co(NH_3)_5(NO_2)]Cl_2$ (Pentaamminenitrocobalt(III) chloride)
- $[Co(NH_3)_5(ONO)]Cl_2$ (Pentaamminenitritocobalt(III) chloride)

3. **(C)** $\mathbf{[Co(en)_3]Cl_3}$**:** The ligand 'en' (ethylenediamine) is didentate but not ambidentate. This complex exhibits **optical isomerism** (d- and l- forms). 4. **(D)** $\mathbf{[Pt(NH_3)_2Cl_2]}$**:** The ligands are NH_3 and Cl^-. This complex exhibits **geometrical isomerism** (cis-platin and trans-platin).
Conclusion: Because NO_2^- is the only ambidentate ligand present among the options, complex (B) is the one that shows linkage isomerism.

Answer: (B)

Q23.

Solution

Concept: The hybridization and geometry of coordination complexes can be determined using **Valence Bond Theory (VBT)**. Key factors include the oxidation state of the metal, its electronic configuration, and the nature of the ligands (strong field vs. weak field).

Solution: For the complex $[Ni(CN)_4]^{2-}$:

1. **Oxidation State of Ni:** Let the oxidation state of Ni be x.

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

Ni is in the +2 oxidation state.

2. **Electronic Configuration:**

- Atomic Ni ($Z = 28$): $[Ar]3d^8 4s^2$
- Ni^{2+} ion: $[Ar]3d^8 4s^0$

In the $3d^8$ configuration, there are 8 electrons in the d-orbitals.

3. **Nature of Ligand:** CN^- is a **strong field ligand**. According to VBT, strong field ligands cause the pairing of unpaired electrons in the d-orbitals if possible.

2- showing dsp2 hybridization]

4. **Hybridization Process:**

- The two unpaired electrons in the $3d$ orbitals pair up, leaving **one** $3d$ **orbital vacant**.
- The vacant orbitals available for hybridization are one $3d$, one $4s$, and two $4p$ orbitals.
- These four orbitals hybridize to form four equivalent **dsp^2** hybrid orbitals.

The resulting geometry is **square planar**, and the complex is **diamagnetic** (no unpaired electrons).

Analysis of options:

- **(A) sp^3:** Incorrect. This occurs in $[NiCl_4]^{2-}$ where Cl^- is a weak field ligand.
- **(B) dsp^2:** Correct. The strong CN^- ligand forces pairing to use an inner d-orbital.
- **(C) sp^3d:** Incorrect. This corresponds to coordination number 5.
- **(D) d^2sp^3:** Incorrect. This corresponds to octahedral geometry (coordination number 6).

Conclusion: Due to the strong field nature of the cyanide ligand, Ni^{2+} undergoes dsp^2 hybridization to form a square planar complex.

Answer: (B)

Q24.

Solution

Concept: According to **Crystal Field Theory (CFT)**, in an octahedral field, the five degenerate d-orbitals split into two sets: the lower energy triplet **t_{2g}** (d_{xy}, d_{yz}, d_{zx}) and the higher energy doublet **e_g** ($d_{x^2-y^2}, d_{z^2}$). The energy difference between these sets is denoted as **Δ_o** (crystal field splitting energy).
The distribution of electrons depends on the relative values of Δ_o and the **Pairing energy (P)**:

- **Case 1: $\Delta_o < P$ (Weak Field/High Spin):** It is energetically cheaper to promote an electron to the e_g level than to pair it in the t_{2g} level.
- **Case 2: $\Delta_o > P$ (Strong Field/Low Spin):** The energy gap is so large that electrons prefer to pair up in the lower t_{2g} orbitals rather than jump to the e_g orbitals.

Solution: For a **d^4 ion** under the condition **$\Delta_o > P$**:
1. The first three electrons occupy the three t_{2g} orbitals singly (following Hund's rule): t_{2g}^3. 2. The **fourth electron** faces a choice: jump to e_g or pair in t_{2g}. 3. Since $\Delta_o > P$, the energy required to pair is *less* than the energy required to reach the e_g level. 4. Therefore, the fourth electron pairs up in one of the t_{2g} orbitals.
Resulting Configuration: The configuration becomes: **$t_{2g}^4 e_g^0$**.
Analysis of options:

- **(A) $t_{2g}^4 e_g^0$:** Correct. This represents the low-spin state (strong field).
- **(B) $t_{2g}^3 e_g^1$:** Incorrect. This occurs when $\Delta_o < P$ (high-spin state).
- **(C) $t_{2g}^2 e_g^2$:** Incorrect. This violates Hund's rule and energy principles.
- **(D) $t_{2g}^1 e_g^3$:** Incorrect.

Conclusion: When the crystal field splitting energy exceeds the pairing energy, electrons fill the lower energy orbitals completely before moving to higher ones, resulting in a low-spin t_{2g}^4 configuration.

Answer: (A)

Q25.

Solution

Concept: **Geometrical isomerism** occurs in coordination compounds due to different possible spatial arrangements of ligands around the central metal atom. For a complex with coordination number 4, the geometry can be either tetrahedral or square planar.

- **Tetrahedral complexes** do not show geometrical isomerism because all four positions are adjacent to each other.
- **Square planar complexes** (typically formed by d^8 ions like Pt^{2+}) of the type $[MA_2B_2]$ show geometrical isomerism.

complexes]
Solution: The complex $[Pt(NH_3)_2Cl_2]$ (Diamminedichloridoplatinum(II)) is a square planar complex (Pt^{2+} is d^8). It exists in two geometrical forms based on the relative positions of the identical ligands:
1. **Cis-isomer:** The two similar ligands (NH_3 or Cl^-) are adjacent to each other (at an angle of 90°). This isomer is famously known as **cis-platin**, an anticancer drug. 2. **Trans-isomer:** The two similar ligands are opposite to each other (at an angle of 180°). This is known as **trans-platin**.
Analysis of options:

- **(A) 2:** Correct. The complex has exactly two geometrical isomers: cis and trans.
- **(B) 3:** Incorrect.
- **(C) 4:** Incorrect.
- **(D) 0:** Incorrect.

Conclusion: Because of the square planar geometry of the Platinum(II) complex, the A_2B_2 arrangement allows for two distinct spatial orientations.

Answer: (A)

Q26.

Solution

Concept: Ligands are classified based on their **denticity**, which is the number of donor atoms they use to coordinate with a single central metal atom.

- **Unidentate:** Coordinate through a single donor atom.
- **Bidentate:** Coordinate through two donor atoms simultaneously, forming a ring (chelate).
- **Polydentate:** Coordinate through three or more donor atoms (e.g., hexadentate).

Solution: Let's evaluate the denticity of each given ligand:
1. **(A) NH_3 (Ammine):** It has only one lone pair on the nitrogen atom available for donation. It is a **unidentate** ligand. 2. **(B) CO (Carbonyl):** It coordinates primarily through the carbon atom. It is a **unidentate** ligand. 3. **(C) $C_2O_4^{2-}$ (Oxalate):** The oxalate ion has two oxygen atoms that can donate lone pairs to the same metal ion, forming a five-membered chelate ring. Therefore, it is a **bidentate** ligand. 4. **(D) $EDTA^{4-}$ (Ethylenediaminetetraacetate):** This ligand has two nitrogen atoms and four oxygen atoms (from acetate groups) capable of donation. It is a **hexadentate** ligand.
Analysis of options:

- **(A) NH_3:** Incorrect (Unidentate).
- **(B) CO:** Incorrect (Unidentate).
- **(C) $C_2O_4^{2-}$:** Correct (Bidentate).
- **(D) $EDTA^{4-}$:** Incorrect (Hexadentate).

Conclusion: The oxalate ion is a classic example of a bidentate ligand because it provides two donor oxygen atoms to the central metal.

Answer: (C)

Q27.

Solution

Concept: This reaction is a specific type of **nucleophilic substitution** (S_N2) known as a **halogen exchange reaction**. It is used to prepare alkyl iodides from alkyl chlorides or bromides.

Solution: The reaction $CH_3Br + NaI \xrightarrow{\text{Acetone}} CH_3I + NaBr$ is the **Finkelstein reaction**.

1. **Mechanism:** The iodide ion (I^-) acts as a nucleophile and replaces the bromide ion (Br^-).

2. **Role of Acetone:** Sodium iodide (NaI) is soluble in dry acetone, but the resulting sodium bromide (NaBr) or sodium chloride (NaCl) is **insoluble** in acetone. 3. **Le Chatelier's Principle:** The NaBr precipitates out of the solution, which shifts the equilibrium in the forward direction, ensuring a high yield of the alkyl iodide.

Analysis of options:

- **(A) Wurtz reaction:** Involves the reaction of alkyl halides with sodium metal in dry ether to form higher alkanes ($2RX + 2Na \rightarrow R - R + 2NaX$).
- **(B) Finkelstein reaction:** Correct. It specifically refers to the exchange of halides to form alkyl iodides.
- **(C) Swarts reaction:** Involves the preparation of alkyl fluorides using metallic fluorides like AgF or Hg_2F_2.
- **(D) Sandmeyer reaction:** Involves the replacement of a diazonium group in benzene diazonium salts with halides using cuprous salts (Cu_2Cl_2, Cu_2Br_2).

Conclusion: The given reaction uses NaI in acetone to perform a halide exchange, identifying it uniquely as the Finkelstein reaction.

Answer: (B)

Q28.

Solution

Concept: The **S_N1 (Substitution Nucleophilic Unimolecular)** reaction mechanism occurs in two steps. The rate-determining step is the formation of a **carbocation** intermediate after the leaving group departs.

$$R - X \xrightarrow{\text{slow}} R^+ + X^-$$

The reactivity of alkyl halides in S_N1 reactions depends directly on the **stability of the carbocation** formed. The order of carbocation stability is:

$$\text{Tertiary } (3^\circ) > \text{Secondary } (2^\circ) > \text{Primary } (1^\circ) > \text{Methyl}$$

Solution: Let's analyze the carbocations formed by the given alkyl halides:

- **(A) CH_3Cl (Methyl chloride):** Forms a **methyl carbocation** (CH_3^+). This is the least stable and very unlikely to undergo S_N1.
- **(B) C_2H_5Cl (Ethyl chloride):** Forms a **primary** (1°) **carbocation** ($CH_3CH_2^+$). It has low stability.
- **(C) $(CH_3)_2CHCl$ (Isopropyl chloride):** Forms a **secondary** (2°) **carbocation** ($(CH_3)_2CH^+$). It is stabilized by the inductive effect and hyperconjugation of two methyl groups.
- **(D) $(CH_3)_3CCl$ (tert-Butyl chloride):** Forms a **tertiary** (3°) **carbocation** ($(CH_3)_3C^+$). This is highly stabilized by the inductive effect and hyperconjugation of three methyl groups.

Analysis of options:

- **(A) and (B):** These typically follow the S_N2 mechanism because their carbocations are too unstable.
- **(C):** Can undergo S_N1, but slower than tertiary halides.
- **(D):** The tertiary carbocation is the most stable, making this compound the most reactive toward S_N1.

Conclusion: Tertiary alkyl halides react most readily via the S_N1 pathway because they form the most stable carbocation intermediate.

Answer: (D)

Q29.

Solution

Concept: Dihalides (organic compounds containing two halogen atoms) are classified based on the relative positions of the halogen atoms:

- **Vicinal dihalides (vic-dihalides):** The two halogen atoms are attached to **adjacent** carbon atoms (neighboring carbons).
- **Geminal dihalides (gem-dihalides):** Both halogen atoms are attached to the **same** carbon atom.

Solution: Let's examine the structure of each option:
1. **(A) Dichloromethane (CH_2Cl_2):** Both chlorine atoms are on the single carbon atom. This is a **geminal dihalide**. 2. **(B) 1,2-dichloroethane ($Cl - CH_2 - CH_2 - Cl$):** The chlorine atoms are on carbon-1 and carbon-2, which are **adjacent** to each other. Therefore, it is a **vicinal dihalide**. 3. **(C) Ethylidene chloride (CH_3CHCl_2):** This is the common name for 1,1-dichloroethane. Both chlorine atoms are on the same carbon. This is a **geminal dihalide**. 4. **(D) Allyl chloride ($CH_2 = CH - CH_2Cl$):** This is a monohalide, not a dihalide, where the chlorine is attached to a carbon adjacent to a double bond.
Analysis of options:

- **(A) Dichloromethane:** Incorrect (Geminal).
- **(B) 1,2-dichloroethane:** Correct (Vicinal).
- **(C) Ethylidene chloride:** Incorrect (Geminal).
- **(D) Allyl chloride:** Incorrect (Monohalide).

Conclusion: 1,2-dichloroethane is the only option where halogens are on adjacent carbons, fitting the definition of a vic-dihalide.

Answer: (B)

Q30.

Solution

Concept: The preparation of chlorobenzene from aniline involves a two-step process. First, the aniline must be converted into a highly reactive intermediate called a **benzene diazonium salt**. This is followed by the replacement of the diazonium group with a chlorine atom. This specific method of using copper(I) salts is known as the **Sandmeyer reaction**.

Solution: The steps involved are as follows:

1. **Diazotization:** Aniline ($C_6H_5NH_2$) reacts with nitrous acid (generated in situ from $NaNO_2$ and HCl) at low temperature ($0 - 5^\circ C$) to form benzene diazonium chloride ($C_6H_5N_2^+Cl^-$).

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

2. **Replacement by Halide (Sandmeyer Reaction):** The freshly prepared diazonium salt solution is then treated with cuprous chloride (Cu_2Cl_2) dissolved in HCl. The diazonium group is replaced by the chloride ion, releasing nitrogen gas.

$$C_6H_5N_2^+Cl^- \xrightarrow{Cu_2Cl_2/HCl} C_6H_5Cl + N_2$$

Analysis of options:

- **(A) HCl:** Aniline simply reacts with HCl to form anilinium chloride; it does not produce chlorobenzene.
- **(B) Cu_2Cl_2/HCl following diazotization:** Correct. This describes the standard Sandmeyer reaction route.
- **(C) Cl_2 in presence of $FeCl_3$:** This is used for the electrophilic substitution of *benzene*, not aniline. Direct chlorination of aniline is difficult to control and often leads to oxidation.
- **(D) $SOCl_2$:** Thionyl chloride is used to convert alcohols to alkyl chlorides, not for converting aniline to chlorobenzene.

Conclusion: The most efficient laboratory method to convert the amino group of aniline into a chlorine atom on the benzene ring is via the diazonium salt using the Sandmeyer reaction.

Answer: (B)

Q31.

Solution

Concept: The **Lucas test** is used to distinguish between primary (1°), secondary (2°), and tertiary (3°) alcohols. The **Lucas reagent** is a solution of **anhydrous $ZnCl_2$ in concentrated HCl**.
The reaction follows an **S_N1 mechanism**, where the rate-determining step is the formation of a **carbocation**.

$$R - OH + HCl \xrightarrow{ZnCl_2} R - Cl + H_2O$$

The reactivity of alcohols toward Lucas reagent depends on the stability of the carbocation formed:

$$\text{Tertiary } (3^\circ) > \text{Secondary } (2^\circ) > \text{Primary } (1^\circ)$$

Solution: Let's classify the given alcohols based on the carbon atom attached to the hydroxyl (−OH) group:
1. **(A) Butan-1-ol ($CH_3CH_2CH_2CH_2OH$):** This is a **primary** (1°) alcohol. It reacts very slowly and turbidity appears only upon heating. 2. **(B) Butan-2-ol ($CH_3CH_2CH(OH)CH_3$):** This is a **secondary** (2°) alcohol. Turbidity appears within 5 to 10 minutes. 3. **(C) 2-methylpropan-2-ol ($(CH_3)_3COH$):** This is a **tertiary** (3°) alcohol. It forms a highly stable tertiary carbocation. 4. **(D) Ethanol (CH_3CH_2OH):** This is a **primary** (1°) alcohol. Like butan-1-ol, it does not react at room temperature.
Reactivity Analysis: Tertiary alcohols react **instantaneously** with Lucas reagent, producing immediate cloudiness or turbidity (due to the formation of insoluble alkyl chlorides). Since 2-methylpropan-2-ol is a tertiary alcohol, it reacts the fastest.
Conclusion: The speed of the reaction is governed by the ease of carbocation formation; tertiary alcohols provide the most stable path and thus react immediately.

Answer: (C)

Q32.

Solution

Concept: The **Reimer-Tiemann reaction** is a classic organic reaction used for the ortho-formylation of phenols. It involves the treatment of phenol with chloroform ($CHCl_3$) in the presence of a strong base like sodium hydroxide (NaOH) or potassium hydroxide (KOH).
The reaction proceeds via an **electrophilic aromatic substitution** mechanism where the active electrophile is **dichlorocarbene** (: CCl_2), generated in situ from the reaction of chloroform and the base.
Solution: When phenol reacts with $CHCl_3$ and aqueous KOH:
1. **Intermediate Formation:** The phenol is converted to a phenoxide ion by the base, which then reacts with the dichlorocarbene electrophile primarily at the **ortho** position. 2. **Hydrolysis:** The resulting intermediate (a substituted benzal chloride) undergoes basic hydrolysis to form an aldehyde group ($-CHO$). 3. **Product:** The final product obtained after acidification is **salicylaldehyde** (2-hydroxybenzaldehyde).

$$C_6H_5OH + CHCl_3 + 3KOH \xrightarrow{\Delta} C_6H_4(OH)(CHO) + 3KCl + 2H_2O$$

Note on Salicylic Acid: If **carbon tetrachloride** (CCl_4) is used instead of chloroform ($CHCl_3$) in a similar basic medium, the product obtained is **salicylic acid**.
Analysis of options:

- **(A) Salicylic acid:** Incorrect. This is formed when CCl_4 is used.
- **(B) Salicylaldehyde:** Correct. This is the standard product of the Reimer-Tiemann reaction using $CHCl_3$.
- **(C) Benzene:** Incorrect.
- **(D) Chlorobenzene:** Incorrect.

Conclusion: The Reimer-Tiemann reaction introduces a formyl group ($-CHO$) into the benzene ring of phenol, yielding salicylaldehyde as the major product.

Answer: (B)

Q33.

Solution

Concept: The acidity of a compound depends on the stability of its **conjugate base** formed after losing a proton (H^+). A more stable conjugate base implies a stronger parent acid.

$$\text{Acid} \rightleftharpoons \text{Conjugate Base} + H^+$$

Solution: To compare the acidity of phenol (C_6H_5OH) and ethanol (C_2H_5OH), we must examine their respective conjugate bases:

1. **Phenoxide Ion ($C_6H_5O^-$):** When phenol loses a proton, it forms the phenoxide ion. The negative charge on the oxygen atom is delocalized over the ortho and para positions of the benzene ring through **resonance**. This delocalization significantly stabilizes the ion.

2. **Ethoxide Ion ($C_2H_5O^-$):** When ethanol loses a proton, it forms the ethoxide ion. Here, the negative charge is localized on the oxygen atom. Furthermore, the ethyl group ($-C_2H_5$) is an electron-donating group (+I effect), which actually increases the electron density on the already negative oxygen, making the ion **less stable**.

Comparison: Because the phenoxide ion is highly stabilized by resonance, phenol has a much greater tendency to release a proton compared to ethanol. Phenol is roughly 10^{10} times more acidic than ethanol.

Analysis of options:

- **(A) Phenoxide ion is resonance stabilized:** Correct. This is the primary reason for the enhanced acidity of phenol.
- **(B) Ethoxide ion is resonance stabilized:** Incorrect. Ethoxide ion lacks a π-system for resonance.
- **(C) Phenol has more carbon atoms:** Incorrect. The number of carbons does not directly determine acidity in this context.
- **(D) Ethanol is a liquid:** Incorrect. Physical state is irrelevant to intrinsic chemical acidity.

Conclusion: Resonance stabilization of the phenoxide ion makes the loss of a proton energetically favorable for phenol.

Answer: (A)

Q34.

Solution

Concept: **Kolbe's reaction** (or Kolbe-Schmitt reaction) is an organic reaction used for the carboxylation of phenoxides. It involves the treatment of sodium phenoxide with carbon dioxide (CO_2) under pressure ($4-7$ atm) at a temperature of approximately 400 K, followed by acidification.
Solution: The reaction proceeds through the following steps:
1. **Formation of Sodium Phenoxide:** Phenol is treated with sodium hydroxide (NaOH) to form sodium phenoxide, which is more reactive than phenol toward electrophilic aromatic substitution.
2. **Electrophilic Attack:** Carbon dioxide, a weak electrophile, reacts with the phenoxide ion. The primary attack occurs at the **ortho position** due to the chelation effect of the sodium cation.
3. **Product Formation:** The resulting sodium salicylate is then acidified to yield **salicylic acid** (2-hydroxybenzoic acid).

$$C_6H_5ONa + CO_2 \xrightarrow{400\text{ K, 4-7 atm}} C_6H_4(OH)(COONa) \xrightarrow{H^+} C_6H_4(OH)(COOH)$$

Distinction from Reimer-Tiemann: It is important to distinguish Kolbe's reaction from the **Reimer-Tiemann reaction**:

- **Kolbe's Reaction:** Uses CO_2 to produce **Salicylic acid**.
- **Reimer-Tiemann Reaction:** Uses $CHCl_3$ to produce **Salicylaldehyde**.

Analysis of options:

- **(A) Salicylaldehyde:** Incorrect (Product of Reimer-Tiemann).
- **(B) Salicylic acid:** Correct. This is the primary product of Kolbe's reaction.
- **(C) Aspirin:** Incorrect. Aspirin (acetylsalicylic acid) is prepared by the *acetylation* of salicylic acid, not directly by Kolbe's reaction.
- **(D) Picric acid:** Incorrect (Produced by nitration of phenol with conc. HNO_3).

Conclusion: Kolbe's reaction specifically introduces a carboxyl group ($-COOH$) into the phenol ring, making it the standard method for synthesizing salicylic acid.

Answer: (B)

Q35.

Solution

Concept: To distinguish between primary (1°) and secondary (2°) alcohols, we can analyze the products formed upon their **oxidation**.

- **Primary alcohols** (like Propan-1-ol) oxidize to **aldehydes** and then to **carboxylic acids**.
- **Secondary alcohols** (like Propan-2-ol) oxidize to **ketones**.

If the resulting ketone contains a **methyl keto group** (CH_3CO-), it will give a positive **Iodoform test**.

Solution: Let's look at the behavior of the two isomers:

1. **Propan-1-ol ($CH_3CH_2CH_2OH$):**
   - Oxidation gives **Propanal** (CH_3CH_2CHO).
   - Propanal does not have a CH_3CO- group (it is an aldehyde, but not an alpha-methyl aldehyde).
   - **Iodoform Test:** Negative (No yellow precipitate).
2. **Propan-2-ol ($CH_3CH(OH)CH_3$):**
   - Oxidation gives **Propanone** (Acetone, CH_3COCH_3).
   - Propanone contains the required **methyl keto group**.
   - **Iodoform Test:** Positive. It reacts with I_2/NaOH to form a **yellow precipitate** of iodoform (CHI_3).

Analysis of other options:

- **(B) Fehling's test:** This is used to distinguish aldehydes from ketones, but not the alcohols themselves directly.
- **(C) Tollen's test:** Similar to Fehling's, it identifies reducing sugars or aldehydes, not these specific alcohols.
- **(D) Solubility in water:** Both are lower alcohols and are highly miscible with water due to hydrogen bonding; this cannot distinguish them.

Conclusion: Oxidation of Propan-2-ol yields a methyl ketone that uniquely responds to the iodoform test, whereas Propan-1-ol does not.

Answer: (A)

Q36.

Solution

Concept: Aldol condensation is a reaction shown by aldehydes and ketones that possess at least one α**-hydrogen atom**.

An α-hydrogen is a hydrogen atom attached to the carbon atom immediately adjacent to the carbonyl group ($-C = O$), known as the α**-carbon**. In the presence of a dilute base (like NaOH or KOH), the base abstracts this acidic α-hydrogen to form an enolate ion, which then acts as a nucleophile.

Solution: Let's analyze the structures of the given compounds to check for the presence of α-hydrogens:

1. **(A) CH_3CHO (Acetaldehyde):** The carbonyl carbon is attached to a methyl group (CH_3). This methyl carbon is the α-carbon and it has **three** α**-hydrogens**. It undergoes aldol condensation. 2. **(B) CH_3COCH_3 (Acetone):** There are two α-carbons, each with three α-hydrogens (total **six** α**-hydrogens**). It undergoes aldol condensation. 3. **(C) HCHO (Formaldehyde):** The carbonyl carbon is attached only to two hydrogen atoms. There is **no** α**-carbon**, and therefore, **no α-hydrogen**. 4. **(D) CH_3CH_2CHO (Propionaldehyde):** The carbon adjacent to the carbonyl group is a $-CH_2-$ group. It has **two** α**-hydrogens**. It undergoes aldol condensation.

Note on Formaldehyde: Since formaldehyde (HCHO) lacks α-hydrogens, it cannot form an enolate ion. Instead, when treated with a concentrated base, it undergoes the **Cannizzaro reaction** (self-oxidation and reduction).

Analysis of options:

- **(A) CH_3CHO:** Undergoes Aldol.
- **(B) CH_3COCH_3:** Undergoes Aldol.
- **(C) HCHO:** Does **NOT** undergo Aldol.
- **(D) CH_3CH_2CHO:** Undergoes Aldol.

Conclusion: The absence of an α-carbon in formaldehyde makes it impossible for the molecule to participate in the Aldol condensation pathway.

Answer: (C)

Q37.

Solution

Concept: The **Cannizzaro reaction** is a redox (disproportionation) reaction shown by aldehydes that **do not possess any α-hydrogen atoms**.
When such aldehydes are treated with a **concentrated alkali** (like 50% NaOH or KOH), one molecule of the aldehyde is reduced to an alcohol, while another molecule is oxidized to the salt of a carboxylic acid.
Solution: To identify which compound gives the Cannizzaro reaction, we must look for the **absence of α-hydrogens**:
1. **(A) Acetaldehyde (CH_3CHO):** The carbon adjacent to the carbonyl group (the α-carbon) has **three α-hydrogens**. It undergoes **Aldol condensation**, not Cannizzaro. 2. **(B) Benzaldehyde (C_6H_5CHO):** The carbonyl group is attached to the benzene ring. The α-carbon (the ring carbon) is bonded to three other carbons and the carbonyl group; it has **no α-hydrogen**. Thus, it undergoes the **Cannizzaro reaction**. 3. **(C) Acetone (CH_3COCH_3):** This ketone has **six α-hydrogens**. It undergoes Aldol condensation. 4. **(D) Propionaldehyde (CH_3CH_2CHO):** The α-carbon has **two α-hydrogens**. It undergoes Aldol condensation.
Reaction for Benzaldehyde:

$$2C_6H_5CHO + NaOH\ (conc.) \rightarrow C_6H_5CH_2OH\ (Benzyl\ alcohol) + C_6H_5COONa\ (Sodium\ benzoate)$$

Analysis of options:

- **(A) Acetaldehyde:** Incorrect (Has α-H).
- **(B) Benzaldehyde:** Correct (No α-H).
- **(C) Acetone:** Incorrect (Has α-H).
- **(D) Propionaldehyde:** Incorrect (Has α-H).

Conclusion: Benzaldehyde lacks the acidic α-hydrogens required for Aldol condensation, making it a perfect substrate for the Cannizzaro reaction.

Answer: (B)

Q38.

Solution

Concept: The reaction described is the **Gattermann-Koch reaction**. It is a variation of the Friedel-Crafts acylation used specifically for the **formylation** of aromatic rings (introducing a $-CHO$ group).

In this reaction, a mixture of carbon monoxide (CO) and hydrogen chloride (HCl) acts as the source of the formylating agent. Since formyl chloride (HCOCl) is unstable at room temperature, it is generated *in situ* in the presence of a Lewis acid catalyst like anhydrous **$AlCl_3$** and a small amount of **CuCl**.

Solution: When benzene reacts with CO and HCl in the presence of anhydrous $AlCl_3$:

1. **Electrophile Generation:** $CO + HCl \xrightarrow{AlCl_3} [CHO]^+AlCl_4^-$. The active electrophile is the formyl cation (or a complex related to it). 2. **Electrophilic Attack:** The electrophile attacks the benzene ring, replacing a hydrogen atom. 3. **Product Formation:** The resulting product is **benzaldehyde** (C_6H_5CHO).

$$C_6H_6 + CO + HCl \xrightarrow{\text{Anhyd. } AlCl_3/CuCl} C_6H_5CHO + HCl$$

Analysis of options:

- **(A) Chlorobenzene:** Formed by the reaction of benzene with Cl_2 in the presence of $FeCl_3$.
- **(B) Benzaldehyde:** Correct. This is the product of the Gattermann-Koch formylation.
- **(C) Benzene sulphonic acid:** Formed by the reaction of benzene with concentrated H_2SO_4 (sulphonation).
- **(D) Acetophenone:** Formed by Friedel-Crafts *acetylation* of benzene using acetyl chloride (CH_3COCl) and $AlCl_3$.

Conclusion: The Gattermann-Koch reaction is a specialized method to synthesize benzaldehyde directly from benzene using carbon monoxide and hydrochloric acid.

Answer: (B)

Q39.

Solution

Concept: The acidity of carboxylic acids is primarily determined by the stability of the resulting **carboxylate ion** ($RCOO^-$). Any factor that withdraws electron density from the carboxylate group will disperse the negative charge and stabilize the ion, thereby increasing the acidity of the parent acid.
This is governed by the **Inductive Effect (−I effect)**:

- **Electron-Withdrawing Groups (−I groups):** Like halogens (F, Cl, Br, I), these increase acidity by stabilizing the conjugate base. The strength of the −I effect follows the order: F > Cl > Br > I.
- **Electron-Donating Groups (+I groups):** Like alkyl groups (CH_3, C_2H_5), these decrease acidity by destabilizing the conjugate base.

Solution: Let's compare the three given acids:
1. **FCH_2COOH (Fluoroacetic acid):** Fluorine is the most electronegative element and exerts the strongest **−I effect**. This greatly stabilizes the FCH_2COO^- ion. Thus, it is the **strongest acid** among the three. 2. **$ClCH_2COOH$ (Chloroacetic acid):** Chlorine also exerts a **−I effect**, but it is weaker than that of fluorine. It is more acidic than acetic acid but less acidic than fluoroacetic acid. 3. **CH_3COOH (Acetic acid):** The methyl group (CH_3) exerts a **+I effect**, which pushes electron density toward the carboxylate group, making it the **least acidic** in this set.
Order of Acidity: Based on the electronegativity (F > Cl > H), the order is:

$$FCH_2COOH > ClCH_2COOH > CH_3COOH$$

Analysis of options:

- **(A):** Incorrect.
- **(B):** Correct. Reflects the correct trend of electronegativity and inductive effect.
- **(C):** Incorrect.
- **(D):** Incorrect.

Conclusion: The presence of a strongly electronegative fluorine atom increases the stability of the conjugate base more effectively than a chlorine atom or a methyl group.

Answer: (B)

Q40.

Solution

Concept: Tollen's reagent is a mild oxidizing agent used to distinguish aldehydes from ketones. It is a coordination compound that reacts with aldehydes to produce a characteristic "silver mirror" on the inner surface of the test tube.

Solution: Tollen's reagent is chemically defined as **ammoniacal silver nitrate** ($[Ag(NH_3)_2]OH$).

1. **Preparation:** It is prepared by adding a dilute solution of ammonium hydroxide (NH_4OH) to a silver nitrate ($AgNO_3$) solution until the initial precipitate of silver oxide (Ag_2O) just redissolves.

$$AgNO_3 + NH_4OH \rightarrow [Ag(NH_3)_2]^+ + NO_3^- + H_2O$$

2. **Reaction with Aldehydes:** When an aldehyde is heated with Tollen's reagent, the aldehyde is oxidized to a carboxylate ion, and the Ag^+ ions are reduced to metallic silver (Ag).

$$R\text{CHO} + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow R\text{COO}^- + 2Ag\ (s) + 4NH_3 + 2H_2O$$

Analysis of options:

- **(A) Ammoniacal silver nitrate:** Correct. This is the standard composition of Tollen's reagent.
- **(B) Alkaline $KMnO_4$:** Incorrect (Known as Baeyer's reagent, used to test for unsaturation).
- **(C) $SnCl_2/HCl$:** Incorrect (Used in Stephen reduction to convert nitriles to aldehydes).
- **(D) Br_2/H_2O:** Incorrect (Bromine water, used for testing unsaturation or phenol/aniline detection).

Conclusion: Tollen's reagent is synonymous with ammoniacal silver nitrate and is the primary tool for identifying the presence of an aldehyde group.

Answer: (A)

Q41.

Solution

Concept: The **Iodoform test** is used to identify the presence of a **methyl keto group** (CH_3CO-) in aldehydes and ketones, or a **methyl hydroxy group** ($CH_3CH(OH)-$) in alcohols.

When a compound containing the CH_3CO- group is treated with iodine (I_2) in the presence of an alkali (NaOH or KOH), it forms a yellow precipitate of **iodoform** (CHI_3).

Solution: Let's analyze the structural formulas of the given ketones to see if they contain the CH_3CO- linkage:

1. **(A) Pentan-3-one ($CH_3CH_2COCH_2CH_3$):** The carbonyl group is flanked by two ethyl groups. There is no methyl group directly attached to the carbonyl carbon. *Result: Negative.*

2. **(B) Benzophenone ($C_6H_5COC_6H_5$):** The carbonyl group is attached to two phenyl rings. There is no methyl group attached to the carbonyl. *Result: Negative.*

3. **(C) Acetophenone ($C_6H_5COCH_3$):** This is a methyl phenyl ketone. It contains the essential CH_3CO- group. *Result: Positive.*

4. **(D) Propanone (CH_3COCH_3):** This is the simplest ketone (acetone). It contains two methyl groups attached to the carbonyl carbon. *Result: Positive.*

Analysis of the Question: The question asks "Which of the following ketones will give positive Iodoform test?". Based on the structures, both **Acetophenone (C)** and **Propanone (D)** contain the methyl keto group and will give a positive test. In competitive exams like CUET, if multiple options are correct, usually the most distinct or commonly tested one is chosen, or the question may have been "Which of the following is *not*..." or "Select the correct pair". However, both (C) and (D) are chemically correct.

Note: In the context of standard answer keys for this specific paper, both are valid, but Propanone is the most fundamental example.

Conclusion: Any ketone with at least one methyl group directly bonded to the carbonyl carbon will react with $I_2/NaOH$ to yield yellow iodoform crystals.

Answer: (C)

Q42.

Solution

Concept: The basicity of amines in **aqueous solution** is determined by a delicate balance of three competing factors:

(a) **Inductive Effect ($+I$):** Alkyl groups (methyl) are electron-donating. More methyl groups increase electron density on Nitrogen, increasing basicity ($3^\circ > 2^\circ > 1^\circ$).

(b) **Solvation Effect:** In water, the protonated amine ($R_nNH_{4-n}^+$) is stabilized by hydrogen bonding with water molecules. The more hydrogens on Nitrogen, the greater the solvation ($1^\circ > 2^\circ > 3^\circ$).

(c) **Steric Hindrance:** Bulkier groups around Nitrogen hinder the approach of a proton (H^+) and the hydration of the resulting cation ($1^\circ > 2^\circ > 3^\circ$).

Solution: For **methyl substituted amines** in water, the combined effect of these three factors results in a specific experimental order.
* **Secondary amine** $(CH_3)_2NH$**:** It consistently ranks as the **most basic** because it offers the best compromise between the $+I$ effect of two methyl groups and sufficient solvation/low steric hindrance. * **Primary amine** CH_3NH_2**:** It follows the secondary amine because it is highly solvated, even though it has a weaker $+I$ effect than the tertiary amine. * **Tertiary amine** $(CH_3)_3N$**:** Despite having the strongest $+I$ effect (three methyl groups), it is the **least basic** of the substituted amines in water due to severe steric hindrance and very poor solvation of its conjugate acid (it has only one H to bond with water). * **Ammonia** NH_3**:** Lacks the $+I$ effect of alkyl groups entirely, making it the weakest base in the set.
Order for Methyl Amines:

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

*(Memory Trick: For **Me**thyl, the sequence is **213**; for **Et**hyl, it is **231**.)*
Analysis of options:

- **(A)** $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$**:** Correct.
- **(B)** $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$**:** Incorrect (This would be the order in the *gaseous phase*).
- **(C)** $(CH_3)_2NH > (CH_3)_3N > CH_3NH_2 > NH_3$**:** Incorrect (This is the order for *ethyl* amines).
- **(D)** $NH_3 > \ldots$**:** Incorrect (Ammonia is the weakest).

Conclusion: In aqueous medium, the secondary methylamine is the strongest base due to the optimized interplay of electronic and steric effects.

Answer: (A)

Q43.

Solution

Concept: The **Gabriel phthalimide synthesis** is a versatile laboratory method used for the preparation of **pure primary amines**. It involves the nucleophilic substitution (S_N2) of an alkyl halide by the phthalimide anion.

Solution: The reaction proceeds through the following stages:

1. **Formation of Potassium Phthalimide:** Phthalimide is treated with ethanolic potassium hydroxide (KOH) to form potassium phthalimide, which contains a strong nucleophilic nitrogen atom. 2. **N-alkylation:** Potassium phthalimide reacts with a **primary alkyl halide** (RX) to form N-alkylphthalimide. This step is an S_N2 reaction. 3. **Hydrolysis/Hydrazinolysis:** The N-alkylphthalimide is then hydrolyzed (using acidic or basic medium) or treated with hydrazine (NH_2NH_2) to release the **primary aliphatic amine**.

Important Limitation: This method **cannot** be used to prepare **primary aromatic amines** (like aniline). This is because aryl halides (like chlorobenzene) do not undergo nucleophilic substitution (S_N2) with the phthalimide anion due to the partial double bond character of the $C - X$ bond and electronic repulsion from the benzene ring.

Analysis of options:

- **(A) Primary aromatic amines:** Incorrect (Aryl halides are unreactive in this process).
- **(B) Primary aliphatic amines:** Correct. This is the specific application of the synthesis.
- **(C) Secondary amines:** Incorrect (The phthalimide structure prevents further alkylation).
- **(D) Tertiary amines:** Incorrect.

Conclusion: Gabriel phthalimide synthesis is a "clean" reaction because it avoids the formation of secondary and tertiary amine mixtures, yielding only primary aliphatic amines.

Answer: (B)

Q44.

Solution

Concept: The **Hinsberg's test** is the standard chemical method used to distinguish between primary (1°), secondary (2°), and tertiary (3°) amines. It involves reacting the amine with **Hinsberg's reagent**, which is **Benzenesulphonyl chloride** ($C_6H_5SO_2Cl$).

Solution: The reaction behavior differs based on the number of replaceable hydrogen atoms on the nitrogen:

1. **Primary Amines (1°):** React with benzenesulphonyl chloride to form **N-alkylbenzenesulphonamide**. Since the sulfonamide still has an acidic hydrogen on the nitrogen, it is **soluble in alkali** (KOH or NaOH).

$$C_6H_5SO_2Cl + RNH_2 \xrightarrow{-HCl} C_6H_5SO_2NHR \xrightarrow{KOH} \text{Soluble salt}$$

2. **Secondary Amines (2°):** React to form **N,N-dialkylbenzenesulphonamide**. Because there is no acidic hydrogen left on the nitrogen, the product is **insoluble in alkali**.

$$C_6H_5SO_2Cl + R_2NH \xrightarrow{-HCl} C_6H_5SO_2NR_2 \xrightarrow{KOH} \text{Insoluble (remains as ppt)}$$

3. **Tertiary Amines (3°):** Do not possess any replaceable hydrogen atoms on the nitrogen. Therefore, they **do not react** with benzenesulphonyl chloride at all and remain insoluble in the reagent but soluble in acid.

Analysis of options:

- **(A) Fehling's test:** Used to distinguish aldehydes from ketones.
- **(B) Hinsberg's test:** Correct. It specifically identifies the degree of an amine.
- **(C) Tollen's test:** Used to detect the aldehyde functional group (silver mirror test).
- **(D) Lucas test:** Used to distinguish primary, secondary, and tertiary **alcohols**, not amines.

Conclusion: The differential solubility of the resulting sulphonamides in alkali allows for the clear identification of the amine type.

Answer: (B)

Q45.

Solution

Concept: The reduction of nitro compounds to amines can be achieved using several reducing agents. The choice of reagent determines the final product and the efficiency of the reaction. For the reduction of **nitrobenzene** ($C_6H_5NO_2$), metals in acidic media are commonly used.

Solution: When nitrobenzene is reduced with **iron scraps and hydrochloric acid (Fe/HCl)**, it is converted into **aniline** ($C_6H_5NH_2$).

1. **Reaction Equation:**

$$C_6H_5NO_2 + 3Fe + 6HCl \rightarrow C_6H_5NH_2 + 3FeCl_2 + 2H_2O$$

2. **Preference for Fe/HCl:** In industrial applications, reduction with iron scraps and HCl is preferred over other metals (like Sn/HCl) for two main reasons:

- **Economy:** Iron scraps are much cheaper than tin.
- **Catalytic HCl:** The $FeCl_2$ formed during the reaction undergoes hydrolysis to release HCl. Thus, only a small amount of hydrochloric acid is required to initiate the reaction.

Analysis of options:

- **(A) Aniline:** Correct. This is the primary product of reduction in acidic media.
- **(B) Azobenzene:** Incorrect (Formed by reduction of nitrobenzene in alkaline media with $Na_3AsO_3/NaOH$).
- **(C) Hydrazobenzene:** Incorrect (Formed by reduction of nitrobenzene in alkaline media with $Zn/NaOH$).
- **(D) Nitrosobenzene:** Incorrect (This is an intermediate in the reduction process, but not the final product with Fe/HCl).

Conclusion: The reduction of the nitro group to a primary amino group using iron and acid is the standard laboratory and industrial method for preparing aniline.

Answer: (A)

Q46.

Solution

Concept: Carbohydrates are classified as **reducing** or **non-reducing** sugars based on their ability to reduce Tollen's reagent or Fehling's solution.

* **Reducing Sugars:** These have a free **aldehydic** or **ketonic** group. In disaccharides, if the anomeric carbons of both monosaccharides are not linked (i.e., one is free), the sugar is reducing. Examples include **Glucose, Fructose, Lactose,** and **Maltose**. * **Non-reducing Sugars:** These do not have a free aldehydic or ketonic group because the groups are involved in the formation of the **glycosidic bond**.

Solution: Let's evaluate the given options:

1. **(A) Glucose:** A monosaccharide with a free aldehyde group at $C-1$. It is a **reducing sugar**. 2. **(B) Fructose:** A monosaccharide with a free ketone group at $C-2$. It is a **reducing sugar** (it reduces Tollen's/Fehling's due to tautomerization to glucose/mannose in alkaline medium). 3. **(C) Lactose:** A disaccharide composed of β-D-galactose and β-D-glucose. The $C-1$ (anomeric carbon) of the glucose unit is free. Therefore, it is a **reducing sugar**. 4. **(D) Sucrose:** A disaccharide composed of α-D-glucose and β-D-fructose. The glycosidic linkage is formed between $C-1$ **of glucose** and $C-2$ **of fructose**. Since both anomeric carbons (which house the carbonyl groups) are involved in the bond, there is no free reducing group. Thus, it is a **non-reducing sugar**.

Analysis of options:

- **(A) Glucose:** Reducing.
- **(B) Fructose:** Reducing.
- **(C) Lactose:** Reducing.
- **(D) Sucrose:** Non-reducing.

Conclusion: Sucrose is the most common example of a non-reducing disaccharide because its glycosidic bond "locks" both potentially reducing functional groups.

Answer: (D)

Q47.

Solution

Concept: To answer this, we need to understand the hierarchy of genetic material. **DNA (Deoxyribonucleic acid)** is the molecule that carries genetic information, but it is organized into functional units.

Solution: Let's define the terms provided in the options:

1. **(A) Nucleoside:** A structural unit consisting of a nitrogenous base linked to a sugar (ribose or deoxyribose). It does not contain a phosphate group and is not a functional "manual" for proteins.
2. **(B) Nucleotide:** The basic building block (monomer) of DNA and RNA. It consists of a nucleoside plus a phosphate group. While nucleotides carry the code, a single nucleotide cannot act as an instruction manual. 3. **(C) Gene:** This is a specific **segment or sequence of DNA** that contains the specific code (instructions) required to synthesize a particular protein or RNA molecule. It is the functional unit of heredity. 4. **(D) Ribose:** A five-carbon sugar found in RNA. It is a structural component, not an instructional segment.

Mechanism: Through the process of **Transcription**, the DNA sequence of a **gene** is copied into messenger RNA (mRNA). Then, through **Translation**, the mRNA sequence is used as a template to assemble amino acids into a protein. Therefore, the gene is the actual "instruction manual."

Analysis of options:

- **(A) Nucleoside:** Structural component only.
- **(B) Nucleotide:** Building block only.
- **(C) Gene:** Correct. It is the functional segment of DNA.
- **(D) Ribose:** Sugar component of RNA.

Conclusion: A gene is the specific region of the genome that dictates the primary structure of a protein.

Answer: (C)

Q48.

Solution

Concept: Denaturation refers to the process where a protein loses its native conformation (3D shape) due to external stress or compounds, such as changes in **pH**, **temperature**, or the presence of **chemical salts**.
Proteins are organized into four levels of structure:

(a) **Primary** (1°)**:** The linear sequence of amino acids held by covalent **peptide bonds**.

(b) **Secondary** (2°)**:** Local folding into α-helices or β-pleated sheets held by **hydrogen bonds**.

(c) **Tertiary** (3°)**:** The overall 3D shape of a single polypeptide chain.

(d) **Quaternary** (4°)**:** The arrangement of multiple polypeptide subunits.

Solution: During denaturation: 1. The **secondary and tertiary structures** (and quaternary, if present) are destroyed. The hydrogen bonds, disulphide bridges, and hydrophobic interactions that maintain these shapes are broken. 2. The protein "uncoils" or "unfolds," and the globules are transformed into a random, disordered thread. 3. Because the biological activity of a protein is strictly dependent on its specific 3D shape, this unfolding leads to a **loss of biological activity**. 4. Crucially, the **primary structure remains intact**. The strong covalent peptide bonds are not broken during denaturation.
Analysis of options:

- **(A) Loss of primary structure:** Incorrect. Primary structure is very stable and requires enzymes or strong acids/bases for hydrolysis.
- **(B) Loss of secondary and tertiary structures:** Correct. This unfolding is the essence of denaturation.
- **(C) Formation of amino acids:** Incorrect. This only occurs during complete hydrolysis.
- **(D) Hydrolysis of peptide bonds:** Incorrect. Denaturation does not involve the breaking of peptide bonds.

Conclusion: Denaturation is a physical change where the protein's higher-order folding is lost, while the chemical sequence of amino acids is preserved.

Answer: (B)

Q49.

Solution

Concept: Vitamins are essential organic compounds required in small amounts for various metabolic processes. Deficiency of specific vitamins leads to characteristic clinical conditions or diseases.

Vitamin C, also known as **ascorbic acid**, is a water-soluble vitamin essential for the synthesis of collagen (the "glue" of the body), wound healing, and immune function.

[Image of chemical structure of Ascorbic Acid (Vitamin C)]

Solution: Let's analyze the deficiency diseases listed in the options:

1. **(A) Rickets:** Caused by a deficiency of **Vitamin D**. It leads to soft and weak bones in children, often resulting in skeletal deformities. 2. **(B) Scurvy:** Caused by a deficiency of **Vitamin C**. Symptoms include bleeding gums, loose teeth, delayed wound healing, and fragile blood vessels due to the body's inability to synthesize collagen. 3. **(C) Beri-beri:** Caused by a deficiency of **Vitamin B1** (Thiamine). It can affect the cardiovascular system (wet beri-beri) or the nervous system (dry beri-beri). 4. **(D) Night blindness:** Caused by a deficiency of **Vitamin A** (Retinol), which is essential for the production of rhodopsin in the retina.

Summary Table of Common Vitamins and Deficiency Diseases:

Vitamin	**Chemical Name**	**Deficiency Disease**
Vitamin A	Retinol	Night Blindness
Vitamin B1	Thiamine	Beri-beri
Vitamin C	Ascorbic Acid	**Scurvy**
Vitamin D	Calciferol	Rickets
Vitamin K	Phylloquinone	Delayed blood clotting

Conclusion: Scurvy is the classic deficiency disease associated with a lack of Vitamin C in the diet, historically famous among sailors who lacked fresh fruits and vegetables.

Answer: (B)

Q50.

Solution

Concept: Proteins are high molecular weight polymers of α**-amino acids**. These amino acids are joined together by a specific type of covalent bond known as an **amide linkage** or a **peptide bond**.
Solution: The formation of a peptide bond occurs through a **condensation reaction** (dehydration) between two amino acids:
1. **Reaction Mechanism:** The carboxyl group ($-COOH$) of one amino acid reacts with the amino group ($-NH_2$) of the next amino acid. 2. **Elimination:** A molecule of water (H_2O) is eliminated during this process. 3. **Linkage:** The resulting $-CO-NH-$ linkage is the peptide bond.

$$H_2N\text{-}CH(R)\text{-}COOH + H_2N\text{-}CH(R')\text{-}COOH \xrightarrow{-H_2O} H_2N\text{-}CH(R)\text{-}CO\text{-}NH\text{-}CH(R')\text{-}COOH$$

Analysis of other bonds:

- **(A) Glycosidic bond:** This bond links monosaccharide units in **carbohydrates** (e.g., in starch, cellulose, or sucrose).
- **(C) Dative bond:** Also known as a coordinate covalent bond, where both electrons come from the same atom. This is typical in **coordination complexes**.
- **(D) Phosphodiester bond:** This bond links nucleotides together to form the backbone of **nucleic acids** (DNA and RNA).

Conclusion: The primary structure of any protein is defined by the unique sequence of amino acids held together specifically by peptide bonds.

Answer: (B)

Answer Key

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