CUET UG Chemistry Sample Paper - 17

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 0.1 M aqueous solutions will exhibit the largest freezing point depression?

(A) Glucose

(B) NaCl

(C) $CaCl_2$

(D) $Al_2(SO_4)_3$

Q2. The vapor pressure of pure benzene at a certain temperature is 0.850 bar. A non-volatile solute weighing 0.5 g is added to 39 g of benzene (molar mass 78). The vapor pressure of the solution is 0.845 bar. The molar mass of the solute is:

(A) 170 g/mol

(B) 180 g/mol

(C) 150 g/mol

(D) 60 g/mol

Q3. An ideal solution is formed when its components:

(A) Have zero heat of mixing ($\Delta H_{\text{mix}} = 0$)

(B) Have zero volume change ($\Delta V_{\text{mix}} = 0$)

(C) Obey Raoult's Law at all concentrations

(D) All of the above

Q4. If the Van't Hoff factor for a 0.1 M $Ba(NO_3)_2$ solution is 2.74, the degree of dissociation (α) is:

(A) 0.87

(B) 1.00

(C) 0.74

(D) 0.91

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 the same as that of a dilute solution

(D) Cannot be compared

Q6. Resistance of a 0.1 M KCl solution is 100 Ω. If the resistance of 0.02 M KCl solution in the same cell is 520 Ω, and the conductivity of 0.1 M KCl is 1.29 S/m, the molar conductivity of 0.02 M KCl is:

(A) 124×10^{-4} S m^2 mol^{-1}

(B) 12.4×10^{-4} S m^2 mol^{-1}

(C) 1.24×10^{-4} S m^2 mol^{-1}

(D) 1240×10^{-4} S m^2 mol^{-1}

Q7. The limiting molar conductivities (Λ_m^0) for $NaCl$, HCl, and CH_3COONa are 126.4, 425.9, and 91.0 S cm^2 mol^{-1} respectively. Λ_m^0 for CH_3COOH is:

(A) 540.5 S cm^2 mol^{-1}

(B) 290.5 S cm^2 mol^{-1}

(C) 390.5 S cm^2 mol^{-1}

(D) 425.9 S cm^2 mol^{-1}

Q8. In the Nernst equation, the value of the constant $\frac{2.303RT}{F}$ at 298 K is:

(A) 0.0591

(B) 0.591

(C) 0.0295

(D) 0.01

Q9. How many Faradays are required to reduce 1 mole of MnO_4^- to Mn^{2+}?

(A) 1 F

(B) 2 F

(C) 5 F

(D) 3 F

Q10. Which of the following acts as the cathode in a Leclanché (dry) cell?

(A) Zinc container

(B) Carbon (graphite) rod surrounded by MnO_2

(C) Lead plates

(D) Nickel rod

Q11. The standard Gibbs energy (ΔG^0) for the cell reaction $Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$ is related to E^0_{cell} as:

(A) $\Delta G^0 = -nFE^0_{\text{cell}}$

(B) $\Delta G^0 = nFE^0_{\text{cell}}$

(C) $\Delta G^0 = -RT \ln E^0_{\text{cell}}$

(D) $\Delta G^0 = -nF/E^0_{\text{cell}}$

Q12. The rate constant for a first-order reaction is 4.606×10^{-3} s^{-1}. The time required to reduce 2.0 g of the reactant to 0.2 g is:

(A) 200 s

(B) 500 s

(C) 1000 s

(D) 100 s

Q13. For a reaction $A + B \rightarrow$ Product, doubling the concentration of A quadruples the rate, but doubling B has no effect. The rate law is:

(A) Rate = $k[A][B]$

(B) Rate = $k[A]^2[B]^0$

(C) Rate = $k[A][B]^2$

(D) Rate = $k[A][B]$

Q14. The unit of rate constant for a zero-order reaction is:

(A) s^{-1}

(B) mol L^{-1} s^{-1}

(C) L mol^{-1} s^{-1}

(D) mol^2 L^{-2} s^{-1}

Q15. According to the Arrhenius equation, a straight line is obtained by plotting:

(A) $\log k$ vs T

(B) $\log k$ vs $1/T$

(C) k vs T

(D) $\log k$ vs $1/\log T$

Q16. The half-life of a first-order reaction is 69.3 seconds. The rate constant is:

(A) 0.1 s^{-1}

(B) 0.01 s^{-1}

(C) 1 s^{-1}

(D) 10 s^{-1}

Q17. Lanthanoid contraction is caused by:

(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 ions is colorless in aqueous solution?

(A) Ti^{3+}

(B) V^{3+}

(C) Sc^{3+}

(D) Cr^{3+}

Q19. The magnetic moment of an ion with atomic number 25 in its +2 oxidation state is:

(A) 5.92 BM

(B) 4.90 BM

(C) 3.87 BM

(D) 1.73 BM

Q20. $KMnO_4$ acts as an oxidizing agent in acidic medium. The number of electrons involved in its reduction to Mn^{2+} is:

(A) 2

(B) 3

(C) 5

(D) 7

Q21. The IUPAC name of the coordination compound $[Co(NH_3)_5Cl]Cl_2$ is:

(A) Pentaamminechloridocobalt(III) chloride

(B) Chloridopentaamminecobalt(III) chloride

(C) Pentaamminechlorocobalt(II) chloride

(D) Pentaamminechloridocobalt(II) chloride

Q22. Which of the following complexes shows linkage isomerism?

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

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

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

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

Q23. The hybridization and geometry of $[Ni(CN)_4]^{2-}$ are:

(A) sp^3, Tetrahedral

(B) dsp^2, Square Planar

(C) sp^3d^2, Octahedral

(D) d^2sp^3, Octahedral

Q24. Crystal Field Splitting Energy (Δ_o) for an octahedral complex is always higher when the ligand is:

(A) I^-

(B) F^-

(C) H_2O

(D) CN^-

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

(A) 2

(B) 3

(C) 4

(D) 0

Q26. Which of the following is an outer orbital complex?

(A) $[Fe(CN)_6]^{4-}$

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

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

(D) $[Mn(CN)_6]^{3-}$

Q27. Which of the following will react fastest by S_N1 mechanism?

(A) CH_3Br

(B) CH_3CH_2Br

(C) $(CH_3)_2CHBr$

(D) $(CH_3)_3CBr$

Q28. The conversion of an alkyl halide into an alcohol using aqueous KOH is an example of:

(A) Nucleophilic Substitution

(B) Electrophilic Substitution

(C) Elimination

(D) Addition

Q29. Finkelstein reaction is used to prepare:

(A) Alkyl Fluorides

(B) Alkyl Iodides

(C) Alkyl Chlorides

(D) Alkyl Bromides

Q30. In S_N2 reactions, the order of reactivity of alkyl halides is:

(A) $1^\circ > 2^\circ > 3^\circ$

(B) $3^\circ > 2^\circ > 1^\circ$

(C) $2^\circ > 1^\circ > 3^\circ$

(D) All react at the same rate

Q31. Lucas reagent is a mixture of:

(A) HCl + anhyd. $ZnCl_2$

(B) $HNO_3 + H_2SO_4$

(C) $Pd + BaSO_4$

(D) $Cl_2 + UV$ light

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

(A) Salicylic acid

(B) Salicylaldehyde

(C) Benzene

(D) Chlorobenzene

Q33. Which of the following is most acidic?

(A) Phenol

(B) Ethanol

(C) *p*-Nitrophenol

(D) *p*-Methylphenol

Q34. Kolbe's reaction is used for the synthesis of:

(A) Salicylaldehyde

(B) Salicylic acid

(C) Aspirin

(D) Anisole

Q35. The dehydration of ethanol to ethoxyethane (ether) occurs at:

(A) 443 K with conc. H_2SO_4

(B) 413 K with conc. H_2SO_4

(C) 300 K with dil. H_2SO_4

(D) 500 K with $NaOH$

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) Formaldehyde

(B) Acetaldehyde

(C) Acetone

(D) Propionaldehyde

Q38. The correct order of reactivity towards nucleophilic addition is:

(A) $HCHO > CH_3CHO > CH_3COCH_3$

(B) $CH_3COCH_3 > CH_3CHO > HCHO$

(C) $CH_3CHO > HCHO > CH_3COCH_3$

(D) $HCHO > CH_3COCH_3 > CH_3CHO$

Q39. Tollen's reagent is:

(A) Ammoniacal silver nitrate

(B) Ammoniacal $CuSO_4$

(C) $K_2Cr_2O_7$

(D) $FeCl_3$

Q40. Which of the following carboxylic acids is the strongest?

(A) CH_3COOH

(B) $ClCH_2COOH$

(C) $Cl_2CHCOOH$

(D) FCH_2COOH

Q41. Clemmensen reduction uses which reagent?

(A) $Zn - Hg/HCl$

(B) NH_2NH_2/KOH

(C) $LiAlH_4$

(D) H_2/Pd

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

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

(B) $(CH_3)_3N >(\mathrm{CH_3})_2NH > CH_3NH_2 > NH_3$

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

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

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

(A) Primary aliphatic amines

(B) Primary aromatic amines

(C) Secondary amines

(D) Tertiary amines

Q44. Hinsberg reagent is:

(A) Benzene sulfonyl chloride

(B) Benzene sulfonic acid

(C) Phenyl isocyanide

(D) Nitrous acid

Q45. Aniline on reaction with Br_2 water gives:

(A) *o*-Bromoaniline

(B) *p*-Bromoaniline

(C) 2,4,6-Tribromoaniline

(D) Benzene diazonium bromide

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

(A) Glucose

(B) Fructose

(C) Maltose

(D) Sucrose

Q47. The linkage present in proteins is:

(A) Glycosidic linkage
(B) Peptide linkage
(C) Phosphodiester linkage
(D) Hydrogen bond

Q48. Deficiency of Vitamin C causes:

(A) Rickets
(B) Scurvy
(C) Beri-beri
(D) Night blindness

Q49. On denaturation, which structure of protein remains intact?

(A) Primary
(B) Secondary
(C) Tertiary
(D) Quaternary

Q50. Which of the following is a ketohexose?

(A) Glucose
(B) Fructose
(C) Ribose
(D) Galactose

Detailed Solutions

Q1.

Solution

Concept: Depression of freezing point (ΔT_f) is a **colligative property**, meaning it depends on the number of solute particles in the solution rather than their identity. For electrolytic solutes, we use the **van't Hoff factor** (i) to account for dissociation.
Solution: The formula for freezing point depression is:

$$\Delta T_f = i \cdot K_f \cdot M$$

Given that the molarity ($M = 0.1$ M) and the solvent (water, so K_f is constant) are the same for all options, the depression ΔT_f is directly proportional to the **van't Hoff factor** (i).
Let's calculate i for each species assuming complete dissociation:

- **(A) Glucose:** A non-electrolyte. It does not dissociate in water.

$$\implies i = 1$$

- **(B) NaCl:** Dissociates into Na^+ and Cl^-.

$$NaCl \rightarrow Na^+ + Cl^- \implies i = 2$$

- **(C) $CaCl_2$:** Dissociates into Ca^{2+} and $2Cl^-$.

$$CaCl_2 \rightarrow Ca^{2+} + 2Cl^- \implies i = 1 + 2 = 3$$

- **(D) $Al_2(SO_4)_3$:** Dissociates into $2Al^{3+}$ and $3SO_4^{2-}$.

$$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-} \implies i = 2 + 3 = 5$$

Comparison: $Al_2(SO_4)_3$ produces the maximum number of particles ($i = 5$) per formula unit. Therefore, it will cause the **largest depression** in the freezing point.

$\boxed{\textbf{Answer: (D)}}$

Q2.

Solution

Concept: According to **Raoult's Law** for a solution containing a non-volatile solute, the relative lowering of vapor pressure is equal to the mole fraction of the solute in the solution.

Formula:

$$\frac{P^0 - P_s}{P^0} = \chi_2 = \frac{n_2}{n_1 + n_2}$$

For dilute solutions, where $n_2 \ll n_1$, the formula is simplified to:

$$\frac{P^0 - P_s}{P^0} \approx \frac{n_2}{n_1} = \frac{w_2/M_2}{w_1/M_1}$$

Where:

- P^0 = Vapor pressure of pure solvent = 0.850 bar
- P_s = Vapor pressure of solution = 0.845 bar
- w_2 = Mass of solute = 0.5 g
- M_2 = Molar mass of solute (to be found)
- w_1 = Mass of benzene = 39 g
- M_1 = Molar mass of benzene = 78 g/mol

Calculation: 1. **Find moles of benzene (n_1):**

$$n_1 = \frac{w_1}{M_1} = \frac{39}{78} = 0.5 \text{ mol}$$

2. **Apply Raoult's Law:**

$$\frac{0.850 - 0.845}{0.850} = \frac{0.5/M_2}{0.5}$$

$$\frac{0.005}{0.850} = \frac{1}{M_2}$$

$$M_2 = \frac{0.850}{0.005}$$

$$M_2 = \frac{850}{5} = 170 \text{ g/mol}$$

Solution

Analysis of options:

- **(A) 170 g/mol:** Correct based on the calculation.
- **(B) 180 g/mol:** Incorrect.
- **(C) 150 g/mol:** Incorrect.
- **(D) 60 g/mol:** Incorrect.

Conclusion: By measuring the decrease in vapor pressure upon adding a known mass of solute to a known mass of solvent, the molar mass of the unknown non-volatile solute can be precisely determined.

Answer: (A)

Q3.

Solution

Concept: An **ideal solution** is a theoretical solution that behaves perfectly according to thermodynamic principles. For a binary solution of components A and B to be ideal, the intermolecular attractive forces between the different molecules ($A - B$) must be nearly equal to those between the same molecules ($A - A$ and $B - B$).
Solution: Ideal solutions are characterized by three primary conditions:
1. **(A) Enthalpy of Mixing ($\Delta H_{mix} = 0$):** Since the strength of the new $A - B$ bonds is the same as the old $A - A$ and $B - B$ bonds, no heat is absorbed or evolved during the mixing process. 2. **(B) Volume of Mixing ($\Delta V_{mix} = 0$):** The total volume of the solution is exactly equal to the sum of the volumes of the individual components. There is no expansion or contraction upon mixing. 3. **(C) Raoult's Law Compatibility:** An ideal solution obeys **Raoult's Law** over the entire range of concentrations and temperatures. This means the partial vapor pressure of each component is directly proportional to its mole fraction: $P_A = P_A^0 \chi_A$.
Examples: Common examples of nearly ideal solutions include:

- *n*-hexane and *n*-heptane
- Bromoethane and chloroethane
- Benzene and toluene

Analysis of options: Since an ideal solution must satisfy all three criteria listed (obeying Raoult's Law, having no enthalpy change, and having no volume change), **All of the above** is the correct answer.

Answer: (D)

Q4.

Solution

Concept: The **van't Hoff factor** (i) relates the actual number of particles in a solution after dissociation (or association) to the number of formula units initially dissolved. The relationship between the degree of dissociation (α) and the van't Hoff factor (i) for an electrolyte is given by the formula:

$$i = 1 + (n - 1)\alpha$$

Where:

- i = van't Hoff factor
- n = Number of ions produced per formula unit
- α = Degree of dissociation

Solution: 1. **Identify the number of ions (n):** Barium nitrate, $Ba(NO_3)_2$, dissociates in aqueous solution as follows:

$$Ba(NO_3)_2 \rightleftharpoons Ba^{2+} + 2NO_3^-$$

Total number of ions produced $(n) = 1(Ba^{2+}) + 2(NO_3^-) = 3$.
2. **Apply the formula:** Given $i = 2.74$ and $n = 3$.

$$2.74 = 1 + (3 - 1)\alpha$$

$$2.74 = 1 + 2\alpha$$

$$2\alpha = 2.74 - 1$$

$$2\alpha = 1.74$$

$$\alpha = \frac{1.74}{2} = 0.87$$

Analysis of options:

- **(A) 0.87:** Correct. This represents an 87% dissociation of the salt.
- **(B) 1.00:** Incorrect (This would imply $i = 3.0$).
- **(C) 0.74:** Incorrect.
- **(D) 0.91:** Incorrect.

Conclusion: The degree of dissociation indicates that at 0.1 M concentration, barium nitrate is not completely dissociated, resulting in a van't Hoff factor less than the theoretical maximum of 3.

Answer: (A)

Q5.

Solution

Concept: Osmotic pressure (π) is a colligative property of a solution. It is defined as the minimum pressure that must be applied to a solution to prevent the inward flow of its pure solvent across a semi-permeable membrane.

Solution: According to the **van't Hoff equation** for dilute solutions:

$$\pi = CRT$$

Where:

- π = Osmotic pressure
- C = Molar concentration (molarity) of the solution
- R = Gas constant
- T = Temperature in Kelvin

From the equation, it is evident that at a constant temperature (T), the osmotic pressure (π) is **directly proportional** to the molar concentration (C) of the solute:

$$\pi \propto C$$

Analysis: 1. A **concentrated solution** has a higher number of solute particles per unit volume (higher C). 2. A **dilute solution** has a lower number of solute particles per unit volume (lower C). 3. Therefore, the osmotic pressure of a concentrated solution will be **higher** than that of a dilute solution at the same temperature.

Analysis of options:

- **(A) Is higher than that of a dilute solution:** Correct. Higher concentration leads to higher osmotic pressure.
- **(B) Is lower than that of a dilute solution:** Incorrect.
- **(C) Is the same as that of a dilute solution:** Incorrect (Only true if concentrations were equal).
- **(D) Cannot be compared:** Incorrect.

Conclusion: Osmotic pressure is a direct measure of solute particle density; hence, more concentrated solutions exert greater pressure.

$\boxed{\textbf{Answer: (A)}}$

Q6.

Solution

Concept: The relationship between conductivity (κ), resistance (R), and the cell constant (G^*) is given by:

$$\kappa = \frac{G^*}{R} \implies G^* = \kappa \cdot R$$

Molar conductivity (Λ_m) is calculated using the formula:

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

where C is the concentration in mol m^{-3}.

Step 1: Calculate the Cell Constant (G^*) Using the data for the 0.1 M KCl solution:

- $R_1 = 100\ \Omega$
- $\kappa_1 = 1.29$ S/m

$$G^* = \kappa_1 \times R_1 = 1.29 \times 100 = 129\ \text{m}^{-1}$$

Step 2: Calculate Conductivity (κ_2) **for 0.02 M** KCl Using the cell constant G^* (which remains the same for the same cell) and the new resistance ($R_2 = 520\ \Omega$):

$$\kappa_2 = \frac{G^*}{R_2} = \frac{129}{520} \approx 0.248\ \text{S/m}$$

Step 3: Calculate Molar Conductivity (Λ_m) First, convert the concentration from M (mol/L) to mol/m^3:

$$C = 0.02\ \text{mol/L} = 0.02 \times 1000\ \text{mol/m}^3 = 20\ \text{mol/m}^3$$

Now, calculate Λ_m:

$$\Lambda_m = \frac{\kappa_2}{C} = \frac{0.248}{20}$$

$$\Lambda_m = 0.0124\ \text{S m}^2\ \text{mol}^{-1}$$

$$\Lambda_m = 124 \times 10^{-4}\ \text{S m}^2\ \text{mol}^{-1}$$

Analysis of options: Matching the calculated value with the given options: (A) 124×10^{-4} S m^2 mol^{-1} fits our result.

Conclusion: By first determining the geometric property of the cell (cell constant), we can find the conductivity and subsequent molar conductivity of any other solution placed in that same cell.

Answer: (A)

Q7.

Solution

Concept: According to **Kohlrausch's Law of Independent Migration of Ions**, the limiting molar conductivity of an electrolyte (Λ_m^0) is the sum of the individual contributions of its constituent anions and cations. This principle allows the calculation of Λ_m^0 for weak electrolytes, which cannot be determined directly by extrapolation, using the values of strong electrolytes.

Solution: To find the limiting molar conductivity for acetic acid (CH_3COOH), we express it in terms of its ions:

$$\Lambda_m^0(CH_3COOH) = \lambda^0_{CH_3COO^-} + \lambda^0_{H^+}$$

Using the given strong electrolytes: 1. $\Lambda_m^0(HCl) = \lambda^0_{H^+} + \lambda^0_{Cl^-} = 425.9 \text{ S cm}^2 \text{ mol}^{-1}$ 2. $\Lambda_m^0(CH_3COONa) = \lambda^0_{CH_3COO^-} + \lambda^0_{Na^+} = 91.0 \text{ S cm}^2 \text{ mol}^{-1}$ 3. $\Lambda_m^0(NaCl) = \lambda^0_{Na^+} + \lambda^0_{Cl^-} = 126.4 \text{ S cm}^2 \text{ mol}^{-1}$

By applying the following algebraic combination:

$$\Lambda_m^0(CH_3COOH) = \Lambda_m^0(CH_3COONa) + \Lambda_m^0(HCl) - \Lambda_m^0(NaCl)$$

Substituting the given values:

$$\Lambda_m^0(CH_3COOH) = 91.0 + 425.9 - 126.4$$

$$\Lambda_m^0(CH_3COOH) = 516.9 - 126.4$$

$$\Lambda_m^0(CH_3COOH) = 390.5 \text{ S cm}^2 \text{ mol}^{-1}$$

Conclusion: The calculated value matches option (C). This demonstrates how the additive property of ionic conductivities overcomes the experimental limitations of measuring weak electrolytes at infinite dilution.

Answer: (C)

Q8.

Solution

Concept: The **Nernst equation** relates the reduction potential of an electrochemical cell (or half-cell) to the standard electrode potential, temperature, and activities of the chemical species involved. The general form is:

$$E = E^0 - \frac{RT}{nF} \ln Q = E^0 - \frac{2.303RT}{nF} \log Q$$

Solution: To find the value of the constant factor $\frac{2.303RT}{F}$ at standard temperature (298 K), we substitute the known physical constants:

- R (Universal gas constant) = 8.314 J K^{-1} mol^{-1}
- T (Temperature in Kelvin) = 298 K
- F (Faraday constant) $\approx$ 96485 C mol^{-1}

Calculation:

$$\text{Constant} = \frac{2.303 \times 8.314 \times 298}{96485}$$

$$\text{Constant} = \frac{5705.8}{96485} \approx 0.05913\ldots$$

In chemistry problems, this value is rounded to **0.0591** for convenience. When this constant is used, the Nernst equation simplifies to:

$$E = E^0 - \frac{0.0591}{n} \log Q$$

Analysis of options:

- **(A) 0.0591:** Correct. This is the standard value used at 25°C (298 K).
- **(B) 0.591:** Incorrect (Decimal error).
- **(C) 0.0295:** Incorrect (This is 0.0591/2).
- **(D) 0.01:** Incorrect.

Conclusion: The factor 0.0591 is a shortcut constant that incorporates the gas constant, temperature, and Faraday's constant, allowing for quick calculations of cell potentials at room temperature.

Answer: (A)

Q9.

Solution

Concept: According to Faraday's Laws of Electrolysis, the quantity of electricity required for the reduction or oxidation of 1 mole of a substance depends on the number of electrons (n) involved in the balanced half-reaction. The charge required is given by:

$$Q = nF$$

where F is the Faraday constant (charge of 1 mole of electrons).

Solution: To find the number of Faradays required, we determine the change in the oxidation state of Manganese (Mn):

1. **In MnO_4^- (Permanganate ion):** Let the oxidation state of Mn be x. $x + 4(-2) = -1$ $x - 8 = -1 \implies x = +7$

2. **In Mn^{2+} (Manganous ion):** The oxidation state of Mn is +2.

3. **Balanced Half-Reaction:** The reduction of MnO_4^- to Mn^{2+} in an acidic medium is represented as:

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

Calculation: Since 5 moles of electrons are required to reduce 1 mole of MnO_4^- to Mn^{2+}, and the charge of 1 mole of electrons is equal to 1 F:

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

Analysis of options:

- **(A) 1 F:** Incorrect.
- **(B) 2 F:** Incorrect.
- **(C) 5 F:** Correct, as the oxidation state changes from +7 to +2.
- **(D) 3 F:** Incorrect (this occurs in neutral/faintly alkaline media where MnO_4^- reduces to MnO_2).

Answer: (C)

Q10.

Solution

Concept: The **Leclanché cell**, commonly known as the **dry cell**, is a primary cell (non-rechargeable) used in low-drain devices like flashlights and clocks. It consists of a specific arrangement of an anode, a cathode, and an electrolyte.

Solution: Let's look at the components of a typical dry cell:

1. **Anode (Negative Electrode):** The **zinc container** itself acts as the anode.

$$\mathrm{Zn(s)} \longrightarrow \mathrm{Zn^{2+}(aq)} + 2e^-$$

2. **Cathode (Positive Electrode):** A **carbon (graphite) rod** is placed in the center. This rod is surrounded by a powdered mixture of **manganese dioxide (MnO_2)** and carbon black. The reduction reaction occurs at the surface of the MnO_2.

$$\mathrm{MnO_2(s)} + \mathrm{NH_4^+(aq)} + e^- \longrightarrow \mathrm{MnO(OH)(s)} + \mathrm{NH_3(g)}$$

3. **Electrolyte:** A moist paste of ammonium chloride (NH_4Cl) and zinc chloride ($ZnCl_2$).

Analysis of options:

- **(A) Zinc container:** This is the **anode**.
- **(B) Carbon (graphite) rod surrounded by MnO_2:** This is the **cathode**.
- **(C) Lead plates:** These are used in **Lead-acid storage batteries**, not dry cells.
- **(D) Nickel rod:** This is not a standard component of a Leclanché cell.

Conclusion: In a dry cell, the carbon rod serves as the electrical conductor for the cathode, where manganese dioxide is reduced.

Answer: (B)

Q11.

Solution

Concept: The relationship between the **Standard Gibbs Free Energy Change (ΔG^0)** and the **Standard Cell Potential (E^0_{cell})** is a fundamental equation in electrochemistry. It bridges the gap between chemical thermodynamics and electrical work.

Solution: 1. **Thermodynamic Relation:** The electrical work done by a galvanic cell is equal to the decrease in Gibbs free energy.

$$W_{\text{elec}} = -\Delta G$$

2. **Electrical Work:** Electrical work is calculated as the product of the total charge passed (nF) and the potential difference (E_{cell}).

$$W_{\text{elec}} = nFE_{cell}$$

3. **Standard Conditions:** At standard states (concentration 1 M, pressure 1 bar, temperature 298 K), the relationship is:

$$\Delta G^0 = -nFE^0_{cell}$$

Where:

- n = number of moles of electrons exchanged in the balanced reaction.
- F = Faraday constant ($\approx$ 96485 C mol^{-1}).
- E^0_{cell} = Standard electrode potential of the cell.

Reaction Specifics: For the given reaction: $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$, the number of electrons transferred (n) is **2**. Thus, $\Delta G^0 = -2FE^0_{cell}$.

Analysis of options:

- **(A)** $\Delta G^0 = -nFE^0_{cell}$**:** Correct. The negative sign indicates that for a spontaneous reaction ($E^0_{cell} > 0$), the Gibbs energy must decrease ($\Delta G^0 < 0$).
- **(B)** $\Delta G^0 = nFE^0_{cell}$**:** Incorrect (Missing the negative sign).
- **(C)** $\Delta G^0 = -RT \ln E^0_{cell}$**:** Incorrect (This confuses the relation with the equilibrium constant K).
- **(D)** $\Delta G^0 = -nF/E^0_{cell}$**:** Incorrect (Mathematical form is wrong).

Conclusion: The standard Gibbs energy change is directly proportional to the standard cell potential, with the negative sign reflecting the spontaneous nature of electrochemical work.

Answer: (A)

Q12.

Solution

Concept: For a **first-order reaction**, the integrated rate equation relates the rate constant (k), time (t), initial concentration ($[R]_0$), and final concentration ($[R]$) as follows:

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

Alternatively, rearranged to solve for time (t):

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

Solution: Given data:

- Rate constant (k) = 4.606×10^{-3} s^{-1}
- Initial mass ($[R]_0$) = 2.0 g
- Final mass ($[R]$) = 0.2 g

Calculation: Substitute the values into the integrated rate equation:

$$t = \frac{2.303}{4.606 \times 10^{-3}} \log \left(\frac{2.0}{0.2}\right)$$

$$t = \frac{2.303}{4.606 \times 10^{-3}} \log(10)$$

Since $\log(10) = 1$:

$$t = \frac{2.303}{4.606 \times 10^{-3}} \times 1$$

$$t = \frac{1}{2 \times 10^{-3}}$$

$$t = \frac{1000}{2} = 500 \text{ s}$$

Analysis of options:

- **(A) 200 s:** Incorrect.
- **(B) 500 s:** Correct.
- **(C) 1000 s:** Incorrect.
- **(D) 100 s:** Incorrect.

Conclusion: For a first-order reaction, the time taken for the concentration to reduce by a factor of 10 (one decade) is constant and depends only on the rate constant k.

Answer: (B)

Q13.

Solution

Concept: The **Rate Law** expresses the relationship between the rate of a chemical reaction and the concentration of its reactants. The general form for the reaction $A + B \longrightarrow$ Product is:

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

Where:

- k = Rate constant.
- x = Order of reaction with respect to A.
- y = Order of reaction with respect to B.

Solution: We determine the exponents x and y based on the experimental observations provided:
1. **Effect of [A]:** Doubling the concentration of A ($2[A]$) quadruples the rate ($4 \times$ Rate).

$$(2)^x = 4 \implies (2)^x = 2^2 \implies \mathbf{x = 2}$$

The reaction is **second-order** with respect to A.
2. **Effect of [B]:** Doubling the concentration of B ($2[B]$) has no effect on the rate ($1 \times$ Rate).

$$(2)^y = 1 \implies (2)^y = 2^0 \implies \mathbf{y = 0}$$

The reaction is **zero-order** with respect to B.
Rate Law Construction: Substituting $x = 2$ and $y = 0$ into the general rate law:

$$\text{Rate} = k[A]^2[B]^0$$

Since $[B]^0 = 1$, the rate can also be written simply as Rate $= k[A]^2$.
Analysis of options:

- **(A)** $k[A][B]$**:** Incorrect (implies first-order in both).
- **(B)** $k[A]^2[B]^0$**:** Correct.
- **(C)** $k[A][B]^2$**:** Incorrect (implies second-order in B).
- **(D)** $k[A][B]$**:** Incorrect (duplicate of A).

Conclusion: The dependence of the rate on concentration allows us to identify that reactant A is part of the rate-determining step in a second-order capacity, while reactant B does not influence the speed of the reaction at all.

Answer: (B)

Q14.

Solution

Concept: The units of a **rate constant (k)** vary depending on the overall order of the reaction. For a general reaction of n^{th} order, the units can be derived from the rate law:

$$\text{Rate} = k[\text{Concentration}]^n$$

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

Solution: For a **zero-order reaction**, $n = 0$. Substituting this value into the general unit formula:

$$k = \frac{\text{mol L}^{-1}\ \text{s}^{-1}}{(\text{mol L}^{-1})^0}$$

Since any number raised to the power of zero is 1:

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

Alternative Derivation: In a zero-order reaction, the rate is independent of the concentration of reactants:

$$\text{Rate} = k[A]^0 = k$$

Therefore, the units of the rate constant are identical to the units of the **rate of reaction**, which is the change in concentration over time.

$$\text{Unit of Rate} = \frac{\text{Concentration}}{\text{Time}} = \frac{\text{mol/L}}{\text{s}} = \text{mol L}^{-1}\ \text{s}^{-1}$$

Analysis of options:

- **(A) $\mathbf{s^{-1}}$:** This is the unit for a **first-order** reaction.
- **(B) mol $\mathbf{L^{-1}\ s^{-1}}$:** Correct. This matches the unit for a **zero-order** reaction.
- **(C) L $\mathbf{mol^{-1}\ s^{-1}}$:** This is the unit for a **second-order** reaction.
- **(D) $\mathbf{mol^{2}\ L^{-2}\ s^{-1}}$:** Incorrect.

Conclusion: Because the rate of a zero-order reaction does not change as the reactant is consumed, its rate constant must carry the same units as the speed of the reaction itself.

Answer: (B)

Q15.

Solution

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

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

Where:

- k = Rate constant
- A = Arrhenius factor (Pre-exponential factor)
- E_a = Activation energy
- R = Gas constant (8.314 J K^{-1} mol^{-1})
- T = Absolute temperature (in Kelvin)

Solution: To linearize the equation, we take the natural logarithm (ln) of both sides:

$$\ln k = \ln A - \frac{E_a}{RT}$$

Converting natural log (ln) to common log ($\log_{10}$ or simply log):

$$2.303 \log k = 2.303 \log A - \frac{E_a}{RT}$$

Dividing by 2.303:

$$\log k = \log A - \left(\frac{E_a}{2.303R}\right)\frac{1}{T}$$

Analysis: The linearized form matches the equation of a straight line ($y = mx + c$):

- **y-axis** (y)**:** $\log k$
- **x-axis** (x)**:** $1/T$
- **Slope** (m)**:** $-E_a/2.303R$
- **Intercept** (c)**:** $\log A$

Therefore, a plot of **$\log k$ vs $1/T$** yields a straight line with a negative slope.

Solution

Analysis of options:

- **(A)** $\log k$ **vs** T**:** Incorrect (yields a curve).
- **(B)** $\log k$ **vs** $1/T$**:** Correct.
- **(C)** k **vs** T**:** Incorrect (yields an exponential curve).
- **(D)** $\log k$ **vs** $1/\log T$**:** Incorrect.

Conclusion: The Arrhenius plot is a vital tool in kinetics, as the slope of the straight line allows for the experimental determination of a reaction's activation energy.

Answer: (B)

Q16.

Solution

Concept: For a **first-order reaction**, the half-life ($t_{1/2}$) is the time required for the concentration of a reactant to decrease to half of its initial value. A unique characteristic of first-order kinetics is that the half-life is constant and independent of the initial concentration.

Formula: The relationship between the rate constant (k) and the half-life ($t_{1/2}$) for a first-order reaction is derived from the integrated rate law:

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

Rearranging to solve for the rate constant (k):

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

Solution: Given:

- Half-life ($t_{1/2}$) = 69.3 s

Substituting the value into the formula:

$$k = \frac{0.693}{69.3}$$

$$k = \frac{693 \times 10^{-3}}{69.3}$$

$$k = 10 \times 10^{-3} = 10^{-2}\ \text{s}^{-1}$$

$$k = 0.01\ \text{s}^{-1}$$

Analysis of options:

- **(A)** 0.1 **s^{-1}:** Incorrect.
- **(B)** 0.01 **s^{-1}:** Correct.
- **(C)** 1 **s^{-1}:** Incorrect.
- **(D)** 10 **s^{-1}:** Incorrect.

Conclusion: The rate constant is inversely proportional to the half-life; a longer half-life indicates a smaller rate constant, reflecting a slower reaction.

Answer: (B)

Q17.

Solution

Concept: Lanthanoid contraction refers to the steady decrease in the atomic and ionic radii of lanthanoid elements (from Lanthanum to Lutetium) as the atomic number increases. This phenomenon significantly impacts the chemistry of the third transition series ($5d$ elements).

Solution: Two main factors contribute to this contraction:

1. **Poor Shielding Effect:** As we move across the lanthanoid series, electrons are added to the $4f$ **subshell**. Because $4f$ orbitals are large and diffused, they provide very **poor shielding** to the outer electrons from the pull of the nucleus. 2. **Increasing Nuclear Charge:** With each successive element, the atomic number (number of protons) increases by one. This increase in **nuclear charge** (Z) exerts a stronger electrostatic pull on the entire electron cloud.

Mechanism: Since the $4f$ electrons cannot effectively "shield" or block the increasing nuclear charge, the effective nuclear charge (Z_{eff}) experienced by the outer electrons increases. This causes the electron shells to shrink toward the nucleus, resulting in a decrease in size.

Analysis of options:

- **(A) Perfect shielding:** Incorrect. f-orbitals have the poorest shielding power $(s > p > d > f)$.
- **(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. The contraction is the cumulative result of both the increasing charge and the failure of $4f$ electrons to counter it.

Conclusion: Lanthanoid contraction is the direct result of the ineffective shielding by $4f$ electrons, which allows the steadily increasing nuclear charge to pull the electron cloud inward.

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 be colored, it must possess at least one unpaired electron in its d-orbitals (d^1 to d^9 configuration). When light falls on such an ion, an electron from a lower energy d-orbital can be excited to a higher energy d-orbital by absorbing a specific wavelength of visible light.

If an ion has a **d^0** (completely empty d-subshell) or a **d^{10}** (completely filled d-subshell) configuration, d-d transitions are impossible, and the ion will be **colorless**.

Solution: Let's examine the electronic configurations of the given ions:

- **(A)** Ti^{3+}**:** Atomic number of $Ti = 22$. Configuration of $Ti = [Ar]3d^24s^2$. Configuration of $Ti^{3+} = [Ar]3d^1$. (Contains 1 unpaired electron $\implies$ **Colored**, usually purple/violet).
- **(B)** V^{3+}**:** Atomic number of $V = 23$. Configuration of $V = [Ar]3d^34s^2$. Configuration of $V^{3+} = [Ar]3d^2$. (Contains 2 unpaired electrons $\implies$ **Colored**, usually green).
- **(C)** Sc^{3+}**:** Atomic number of $Sc = 21$. Configuration of $Sc = [Ar]3d^14s^2$. Configuration of $Sc^{3+} = [Ar]3d^0$. (Contains no d-electrons $\implies$ **Colorless**).
- **(D)** Cr^{3+}**:** Atomic number of $Cr = 24$. Configuration of $Cr = [Ar]3d^54s^1$. Configuration of $Cr^{3+} = [Ar]3d^3$. (Contains 3 unpaired electrons $\implies$ **Colored**, usually violet/green).

Analysis of options:

- **(A), (B), and (D)** all have partially filled d-orbitals, allowing for light absorption and color.
- **(C)** Sc^{3+} has a d^0 configuration, making it incapable of d-d transitions.

Conclusion: Scandium (III) is colorless because the absence of electrons in the d-subshell prevents the electronic transitions necessary to absorb visible light.

$\boxed{\textbf{Answer: (C)}}$

Q19.

Solution

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

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

Where:

- n = Number of unpaired electrons.
- BM = Bohr Magneton (unit of magnetic moment).

Solution: 1. **Identify the element:** The atomic number (Z) is 25, which corresponds to **Manganese (Mn)**. 2. **Electronic configuration of Mn (Ground state):** $[Ar]3d^5 4s^2$. 3. **Electronic configuration of Mn^{2+} (+2 oxidation state):** To form the +2 ion, two electrons are removed from the outermost $4s$ orbital.

$$Mn^{2+} = [Ar]3d^5$$

4. **Count unpaired electrons (n):** According to **Hund's Rule**, the five electrons in the $3d$ subshell will occupy the five d-orbitals singly with parallel spins.

$$\text{Number of unpaired electrons } (n) = 5$$

Calculation: Substitute $n = 5$ into the magnetic moment formula:

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

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

$$\mu = \sqrt{35}$$

Calculating the square root:

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

Analysis of options:

- **(A) 5.92 BM:** Correct (corresponds to $n = 5$).
- **(B) 4.90 BM:** Incorrect (corresponds to $n = 4$).
- **(C) 3.87 BM:** Incorrect (corresponds to $n = 3$).
- **(D) 1.73 BM:** Incorrect (corresponds to $n = 1$).

Conclusion: The Mn^{2+} ion has a maximum of five unpaired electrons in its d-subshell, resulting in a high magnetic moment of 5.92 BM.

Answer: (A)

Q20.

Solution

Concept: The oxidizing power of potassium permanganate ($KMnO_4$) depends on the pH of the medium. In an **acidic medium**, the permanganate ion (MnO_4^-) is a powerful oxidizing agent and is reduced to the manganous ion (Mn^{2+}). The number of electrons involved is determined by the change in the oxidation state of Manganese.

Solution: 1. **Determine the Oxidation State of Mn in $KMnO_4$:** In $KMnO_4$, K is $+1$ and O is -2. Let the oxidation state of Mn be x.

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

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

2. **Determine the Oxidation State of Mn in the Product:** The product is Mn^{2+}, so its oxidation state is **+2**.

3. **Calculate the Change in Oxidation State:** The change in oxidation state represents the number of electrons gained per Manganese atom during reduction:

$$\text{Change} = (+7) - (+2) = 5 \text{ electrons}$$

Balanced Half-Reaction: The complete reduction half-reaction in acidic medium is:

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

Analysis of options:

- **(A) 2:** Incorrect.
- **(B) 3:** Incorrect (this occurs in neutral or weakly alkaline media where $MnO_4^- \rightarrow MnO_2$).
- **(C) 5:** Correct.
- **(D) 7:** Incorrect (this is the total oxidation state, not the change).

Conclusion: In acidic conditions, each mole of permanganate ions accepts 5 moles of electrons to form Mn^{2+}, making it a highly effective oxidant.

$\boxed{\textbf{Answer: (C)}}$

Q21.

Solution

Concept: To name a coordination compound according to IUPAC nomenclature, the following rules are applied:

(a) Name the cation first, then the anion.

(b) Within the coordination sphere, name ligands in alphabetical order.

(c) Use prefixes (di, tri, tetra, penta, hexa) to indicate the number of ligands.

(d) Name the central metal atom followed by its oxidation state in Roman numerals in parentheses.

(e) For the ligands: NH_3 is "ammine" (note the double 'm') and Cl^- inside the sphere is "chlorido".

Solution: 1. **Identify the counter ions and coordination sphere:** In $[Co(NH_3)_5Cl]Cl_2$, the coordination sphere is $[Co(NH_3)_5Cl]^{2+}$ (cation) and the counter ions are $2Cl^-$ (anions).
2. **Calculate the Oxidation State of Cobalt** (Co)**:** Let the oxidation state of Co be x. NH_3 is a neutral ligand (charge = 0). Cl is an anionic ligand (charge = -1). The total charge of the complex must equal the charge balanced by the counter ions (+2):

$$x + 5(0) + 1(-1) = +2$$

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

So, the metal is **Cobalt(III)**.
3. **Name the Ligands (Alphabetical Order):**

- Five NH_3 groups $\implies$ **Pentaammine**
- One Cl^- group $\implies$ **Chlorido**

"Ammine" comes before "chlorido" alphabetically.
Cl2 showing coordination sphere and counter ions]
4. **Assemble the full name:** Cation: **Pentaamminechloridocobalt(III)** Anion: **chloride** Full Name: **Pentaamminechloridocobalt(III) chloride**
Analysis of options:

- **(A):** Correct. Matches all IUPAC rules.
- **(B):** Incorrect. "Chlorido" should not come before "pentaammine" alphabetically.
- **(C) & (D):** Incorrect. They list the oxidation state as (II), but it is (III).

Conclusion: Following alphabetical priority for ligands and determining the correct +3 charge on the central metal leads to the name Pentaamminechloridocobalt(III) chloride.

$\boxed{\textbf{Answer: (A)}}$

Q22.

Solution

Concept: Linkage isomerism occurs in coordination compounds containing **ambidentate ligands**. These are ligands that possess two or more different donor atoms but coordinate to the central metal atom through only one of them at a time. Common examples of ambidentate ligands include:

- **NO_2^-:** Can coordinate via Nitrogen (-NO_2, nitrito-N) or Oxygen (-ONO, nitrito-O).
- **SCN^-:** Can coordinate via Sulfur (-SCN, thiocyanato-S) or Nitrogen (-NCS, isothiocyanato-N).
- **CN^-:** Can coordinate via Carbon (-CN) or Nitrogen (-NC).

Solution: Let's analyze the given options to identify the presence of an ambidentate ligand:

- **(A)** $[Co(NH_3)_5(NO_2)]Cl_2$**:** This complex contains the **nitro (NO_2^-)** ligand. Since NO_2^- is ambidentate, it can form two isomers: one where Co is linked to N ($[Co(NH_3)_5(NO_2)]^{2+}$) and another where Co is linked to O ($[Co(NH_3)_5(ONO)]^{2+}$). **Therefore, it shows linkage isomerism.**
- **(B)** $[Co(NH_3)_5Cl]SO_4$**:** This complex contains NH_3 (monodentate) and Cl^- (monodentate). Neither is ambidentate. It shows **ionization isomerism** with $[Co(NH_3)_5SO_4]Cl$.
- **(C)** $[Co(en)_3]Cl_3$**:** This complex contains "en" (ethylenediamine), which is a didentate ligand but not ambidentate. It shows **optical isomerism**.
- **(D)** $[Pt(NH_3)_2Cl_2]$**:** This complex contains NH_3 and Cl^-. It shows **geometrical isomerism** (cis and trans isomers).

Analysis of options:

- **(A):** Contains NO_2^- (ambidentate). Correct.
- **(B):** Ionization isomerism. Incorrect.
- **(C):** Optical isomerism. Incorrect.
- **(D):** Geometrical isomerism. Incorrect.

Conclusion: Linkage isomerism is uniquely associated with the mode of attachment of a ligand; because the nitrite ion can bond through either nitrogen or oxygen, option (A) is the only complex capable of this type of isomerism.

$\boxed{\textbf{Answer: (A)}}$

Q23.

Solution

Concept: According to **Valence Bond Theory (VBT)**, the geometry and magnetic properties of a coordination complex depend on the hybridization of the central metal ion, which is influenced by the nature of the ligands. Ligands like CN^- are **strong field ligands** that cause the pairing of unpaired electrons in the d-orbitals.

2-]

Solution: To determine the hybridization of $[Ni(CN)_4]^{2-}$, we follow these steps:

1. **Oxidation State of Ni:** Let the oxidation state of Ni be x. CN has a charge of -1. $x + 4(-1) = -2 \implies x = +2$. The central metal ion is Ni^{2+}.

2. **Electronic Configuration:** Atomic number of $Ni = 28$. Ni (ground state) $= [Ar]3d^8 4s^2$
$Ni^{2+} = [Ar]3d^8 4s^0$

3. **Effect of Ligand (CN^-):** CN^- is a **strong field ligand**. It forces the 8 electrons in the $3d$ subshell to pair up as much as possible. In Ni^{2+} ($3d^8$), the electrons pair up in four d-orbitals, leaving **one** $3d$ **orbital vacant**.

4. **Hybridization:** With 4 cyanide ligands, the metal needs 4 vacant hybrid orbitals. It uses: One $3d$ + One $4s$ + Two $4p$ orbitals $\implies$ dsp^2 **hybridization**.

5. **Geometry:** The dsp^2 hybridization corresponds to a **Square Planar** geometry. Since all electrons are paired, the complex is also diamagnetic.

Analysis of options:

- **(A)** sp^3**, Tetrahedral:** This occurs in $[NiCl_4]^{2-}$ where Cl^- is a weak field ligand.
- **(B)** dsp^2**, Square Planar:** Correct.
- **(C) & (D) Octahedral:** Incorrect, as these require a coordination number of 6.

Conclusion: The strong field nature of the cyanide ligand forces electron pairing, allowing the use of an inner d-orbital for dsp^2 hybridization, resulting in a square planar shape.

Answer: (B)

Q24.

Solution

Concept: In coordination chemistry, the **Crystal Field Splitting Energy (Δ_o)** is the energy difference between the two sets of d-orbitals (t_{2g} and e_g) in an octahedral field. The magnitude of this splitting depends on the strength of the ligand, as defined by the **Spectrochemical Series**.

Solution: The Spectrochemical Series is an experimentally determined order of ligands based on their ability to split d-orbitals. The general order of increasing field strength (and thus increasing Δ_o) is:

$$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH_3 < en < NO_2^- < \mathbf{CN}$$

Classification of Ligands:

- **Weak Field Ligands (WFL):** Halides (I^-, Cl^-, F^-) and water (H_2O). They cause small splitting, resulting in a low Δ_o.
- **Strong Field Ligands (SFL):** Cyanide (CN^-), Carbon monoxide (CO), and Ethylene diamine (en). They cause large splitting, resulting in a high Δ_o.

Analysis of options:

- **(A)** I^-**:** A very weak field ligand; produces the lowest Δ_o among the choices.
- **(B)** F^-**:** A weak field ligand.
- **(C)** H_2O**:** A neutral ligand, stronger than halides but still considered a relatively weak field ligand.
- **(D)** CN^-**:** A very strong field ligand (pseudohalide). It has π-acceptor properties which significantly increase the orbital splitting.

Conclusion: Among the given options, CN^- is the strongest field ligand, meaning it exerts the greatest electrostatic repulsion on the d-orbitals, thereby maximizing the Crystal Field Splitting Energy (Δ_o).

Answer: (D)

Q25.

Solution

Concept: Geometrical isomerism occurs in coordination compounds due to different possible spatial arrangements of the ligands around the central metal atom. For a coordination number of 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** of the type $[MA_2B_2]$ (where M is the metal and A, B are monodentate ligands) commonly exhibit geometrical isomerism.

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Solution: The complex $[Pt(NH_3)_2Cl_2]$ (Diamminedichloridoplatinum(II)) has a **square planar** geometry because Pt^{2+} is a $5d^8$ ion, which typically forms dsp^2 hybridized square planar complexes regardless of the ligand strength.
There are two possible geometrical arrangements for this formula:
1. **Cis-isomer (Cisplatin):** The two identical ligands (NH_3 or Cl^-) are adjacent to each other (at an angle of 90°). This isomer is a well-known anti-cancer drug. 2. **Trans-isomer:** The two identical ligands are opposite to each other (at an angle of 180°).
Analysis of options:

- **(A) 2:** Correct. The complex exists as exactly two isomers: cis and trans.
- **(B) 3:** Incorrect.
- **(C) 4:** Incorrect.
- **(D) 0:** Incorrect (this would only be true if the geometry were tetrahedral).

Conclusion: Because Platinum(II) complexes favor a square planar arrangement, the relative positions of the ammine and chloride ligands result in two distinct geometrical forms.

Answer: (A)

Q26.

Solution

Concept: Outer orbital complexes are formed when weak-field ligands (WFL) are present. These ligands do not cause electron pairing in the $(n-1)d$ subshell, forcing the metal to use the outer nd orbitals for hybridization (typically sp^3d^2). Inner orbital complexes use $(n-1)d^2sp^3$ hybridization and occur with strong-field ligands (SFL).

Solution: We analyze the nature of the ligands and the electronic configuration of the central metal ions:

- **$[Fe(CN)_6]^{4-}$:** Fe^{2+} is $3d^6$. CN^- is a **SFL**, causing pairing. Hybridization: d^2sp^3 (Inner orbital).
- **$[Fe(H_2O)_6]^{3+}$:** Fe^{3+} is $3d^5$. H_2O is a **WFL**. It cannot pair the 5 unpaired electrons in the $3d$ orbital. The complex uses $4s$, $4p$, and $4d$ orbitals. Hybridization: sp^3d^2 (**Outer orbital**).
- **$[Co(NH_3)_6]^{3+}$:** Co^{3+} is $3d^6$. NH_3 acts as a **SFL** with Co^{3+}, causing pairing. Hybridization: d^2sp^3 (Inner orbital).
- **$[Mn(CN)_6]^{3-}$:** Mn^{3+} is $3d^4$. CN^- is a **SFL**, causing pairing. Hybridization: d^2sp^3 (Inner orbital).

Thus, $[Fe(H_2O)_6]^{3+}$ is the only outer orbital complex among the choices.

$\boxed{\textbf{Answer: (B)}}$

Q27.

Solution

Concept: The **S_N1 (Substitution Nucleophilic Unimolecular)** mechanism proceeds in two steps. The first and rate-determining step is the formation of a **carbocation** intermediate after the leaving group departs. The rate of the reaction depends directly on the **stability of the carbocation** formed.

Solution: We analyze the stability of the carbocation formed by each alkyl bromide after the loss of the bromide ion (Br^-):

- **(A)** CH_3Br **(Methyl bromide):** Forms a **methyl carbocation** (CH_3^+). This is the least stable carbocation.
- **(B)** CH_3CH_2Br **(Ethyl bromide):** Forms a **primary (1°) carbocation** ($CH_3CH_2^+$). It is stabilized by the inductive effect of one alkyl group.
- **(C)** $(CH_3)_2CHBr$ **(Isopropyl bromide):** Forms a **secondary (2°) carbocation** ($(CH_3)_2CH^+$). It is stabilized by the inductive effect and hyperconjugation of two alkyl groups.
- **(D)** $(CH_3)_3CBr$ **(tert-Butyl bromide):** Forms a **tertiary (3°) carbocation** ($(CH_3)_3C^+$). It is highly stabilized by the inductive effect and hyperconjugation of three methyl groups.

Conclusion: The order of reactivity for the S_N1 mechanism follows the order of carbocation stability:

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

Since $(CH_3)_3CBr$ forms the most stable tertiary carbocation, it will react the fastest.

Answer: (D)

Q28.

Solution

Concept: The reaction of an alkyl halide with aqueous KOH involves the replacement of the halogen atom (a leaving group) by a hydroxyl group (a nucleophile). This process is known as Nucleophilic Substitution (S_N1 or S_N2, depending on the structure of the alkyl group).

Solution: In aqueous medium, KOH dissociates to provide OH^- ions. These OH^- ions are strong nucleophiles. The general reaction is:

$$R-X+KOH_{(aq)} \rightarrow R-OH+KX$$

Specifically:

- The carbon atom attached to the halogen is electron-deficient ($\delta+$).
- The OH^- ion attacks this carbon and replaces the X^- ion.
- Since the attacking species is a nucleophile, the reaction is categorized as **Nucleophilic Substitution**.

Note: If *alcoholic* KOH were used, the OH^- would act as a base, leading to an *elimination* reaction to form an alkene.

Answer: (A)

Q29.

Solution

Concept: The Finkelstein reaction is a halogen exchange reaction used specifically for the synthesis of alkyl iodides. It is an S_N2 reaction where an alkyl chloride or bromide reacts with sodium iodide in the presence of dry acetone.

Solution: The general chemical equation for the Finkelstein reaction is:

$$R-X+NaI \xrightarrow{\text{dry acetone}} R-I+NaX\downarrow$$

(Where $X = Cl, Br$)

- **Reagent:** Sodium iodide (NaI) in dry acetone.
- **Driving Force:** The reaction is driven forward by the precipitation of $NaCl$ or $NaBr$ in acetone, as these salts are less soluble in the solvent than NaI.
- **Product:** The reaction specifically yields **alkyl iodides**.

Note: Alkyl fluorides are typically prepared using the *Swarts reaction*, not the Finkelstein reaction.

Answer: (B)

Q30.

Solution

Concept: The S_N2 (Substitution Nucleophilic Bimolecular) reaction occurs in a single concerted step. The nucleophile performs a backside attack on the carbon atom bonded to the leaving group. The rate of this reaction is primarily governed by **steric hindrance**.

Solution: In an S_N2 mechanism, the nucleophile must approach the central carbon atom. The ease of this approach depends on the size of the substituents attached to that carbon:

- **Primary** (1°)**:** The carbon is attached to only one alkyl group and two small hydrogens. Steric hindrance is minimal, allowing for a fast attack.
- **Secondary** (2°)**:** Two alkyl groups create moderate crowding, slowing the reaction.
- **Tertiary** (3°)**:** Three bulky alkyl groups shield the carbon atom, making backside attack nearly impossible. 3° halides generally do not react via S_N2.

Therefore, the order of reactivity is: $1^\circ > 2^\circ > 3^\circ$.

Answer: (A)

Q31.

Solution

Concept: Lucas reagent is used to distinguish between primary (1°), secondary (2°), and tertiary (3°) alcohols based on the rate of formation of alkyl chlorides, which appears as turbidity in the solution.

Solution: Lucas reagent is a mixture of **concentrated** HCl **and anhydrous** $ZnCl_2$.

- The $ZnCl_2$ acts as a Lewis acid catalyst that helps in the cleavage of the $C-O$ bond in alcohols.
- The reaction follows an S_N1 mechanism (predominantly for 3° and 2° alcohols), where the alcohol is converted to an insoluble alkyl chloride:

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

- **Tertiary alcohols** react immediately (instant turbidity).
- **Secondary alcohols** react within 5 minutes.
- **Primary alcohols** do not react at room temperature.

Thus, the correct composition is HCl + anhydrous $ZnCl_2$.

Answer: (A)

Q32.

Solution

Concept: The Reimer-Tiemann reaction is an organic reaction used for the ortho-formylation of phenols. It involves the treatment of phenol with chloroform in the presence of a strong base (like $NaOH$ or KOH), followed by acid hydrolysis.

Solution: The reaction proceeds through the following general steps:

(a) Chloroform ($CHCl_3$) reacts with KOH to generate the reactive intermediate **dichlorocarbene** ($: CCl_2$).

(b) The dichlorocarbene attacks the phenoxide ion at the ortho position.

(c) Subsequent hydrolysis of the intermediate CCl_2 group and acidification results in the formation of an aldehyde group ($-CHO$).

The chemical equation is:

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

The major product obtained is **Salicylaldehyde**. If carbon tetrachloride (CCl_4) were used instead of chloroform, Salicylic acid would be the product.

Answer: (B)

Q33.

Solution

Concept: The acidity of phenols depends on the stability of the phenoxide ion. Substituents that withdraw electrons (EWG) stabilize the phenoxide ion and increase acidity, while substituents that donate electrons (EDG) destabilize the ion and decrease acidity.

Solution: We compare the given compounds based on their conjugate base stability:

- **Ethanol:** Alcohols are less acidic than phenols because the ethoxide ion is not resonance-stabilized and the ethyl group has a $+I$ effect.
- **Phenol:** The phenoxide ion is resonance-stabilized by the benzene ring.
- **p-Methylphenol (p-Cresol):** The methyl group ($-CH_3$) is an electron-donating group ($+I$ and hyperconjugation). It increases the electron density on the oxygen, making the phenoxide ion less stable than phenol.
- **p-Nitrophenol:** The nitro group ($-NO_2$) is a strong electron-withdrawing group ($-R$ and $-I$). At the para position, it effectively delocalizes the negative charge of the phenoxide ion through resonance.

Since the p-nitrophenoxide ion is the most stable conjugate base, **p-nitrophenol** is the most acidic compound.

Answer: (C)

Q34.

Solution

Concept: Kolbe's reaction involves the electrophilic substitution of the phenoxide ion with carbon dioxide. It is a key industrial process for the synthesis of ortho-hydroxy aromatic acids.
Solution: The reaction proceeds as follows:

(a) Phenol reacts with $NaOH$ to form sodium phenoxide (C_6H_5ONa).

(b) Sodium phenoxide is treated with carbon dioxide (CO_2) at a temperature of approximately 400 K and a pressure of 4-7 atm.

(c) CO_2 acts as a weak electrophile and attacks the ortho position of the highly reactive phenoxide ring.

(d) The resulting sodium salicylate is acidified to produce **Salicylic acid**.

The overall chemical equation is:

$$C_6H_5OH \xrightarrow{NaOH} C_6H_5ONa \xrightarrow[2.H^+]{1.CO_2} C_6H_4(OH)COOH$$

While Salicylic acid can be used to synthesize Aspirin in a subsequent acetylation step, the immediate product of Kolbe's reaction is Salicylic acid.

Answer: (B)

Q35.

Solution

Concept: The dehydration of primary alcohols with concentrated H_2SO_4 is temperature-sensitive. It can result in either an alkene (via elimination) or an ether (via nucleophilic substitution), depending on the thermal energy provided to the system.
Solution: When ethanol is treated with concentrated sulfuric acid:

- At **443 K**, intramolecular dehydration occurs, leading to the formation of ethene ($CH_2 = CH_2$) through an elimination mechanism.
- At **413 K**, intermolecular dehydration occurs. Two molecules of ethanol react to form ethoxyethane ($C_2H_5OC_2H_5$) through an S_N2 mechanism.

The chemical equation for the formation of ether is:

$$2C_2H_5OH \xrightarrow{H_2SO_4, 413\,K} C_2H_5 - O - C_2H_5 + H_2O$$

Therefore, 413 K is the specific temperature required for the synthesis of ethoxyethane.

Answer: (B)

Q36.

Solution

Concept: Aldol condensation is shown by aldehydes and ketones that contain at least one α-hydrogen atom. In the presence of a dilute base, the α-hydrogen is removed to form an enolate nucleophile, which then attacks another carbonyl molecule.

Solution: We examine the structure of each option to identify the presence of α-hydrogens (hydrogens on the carbon adjacent to the $-C = O$ group):

- CH_3CHO **(Acetaldehyde):** Contains 3 α-hydrogens. It undergoes Aldol condensation.
- CH_3COCH_3 **(Acetone):** Contains 6 α-hydrogens. It undergoes Aldol condensation.
- CH_3CH_2CHO **(Propanal):** Contains 2 α-hydrogens on the second carbon. It undergoes Aldol condensation.
- $HCHO$ **(Formaldehyde):** The carbonyl carbon is not attached to any other carbon atom. Thus, it has **no α-hydrogen**.

Since Formaldehyde ($HCHO$) lacks α-hydrogens, it does not undergo Aldol condensation. Instead, it undergoes the Cannizzaro reaction when treated with a concentrated base.

Answer: (C)

Q37.

Solution

Concept: The Cannizzaro reaction is a disproportionation reaction shown by aldehydes that **lack α-hydrogen** atoms. When treated with a concentrated alkali, one molecule is oxidized to a carboxylic acid salt and another is reduced to a primary alcohol.

Solution: We evaluate the presence of α-hydrogens in the given compounds:

- **Acetaldehyde, Acetone, and Propionaldehyde:** All contain α-hydrogens (hydrogens on the carbon adjacent to the carbonyl group). In the presence of a base, these compounds undergo Aldol condensation.
- **Formaldehyde ($HCHO$):** There is no α-carbon, and thus **no α-hydrogen**.

The reaction for formaldehyde is as follows:

$$2HCHO + \text{conc. } NaOH \rightarrow CH_3OH + HCOONa$$

Here, one molecule of formaldehyde is reduced to methanol (CH_3OH) and the other is oxidized to sodium formate ($HCOONa$). Thus, formaldehyde gives the Cannizzaro reaction.

Answer: (A)

Q38.

Solution

Concept: The reactivity of carbonyl compounds towards nucleophilic addition reactions depends on the magnitude of the positive charge on the carbonyl carbon and the steric hindrance around it. Reactivity increases with a higher $\delta+$ charge and lower steric bulk.

Solution: We compare the three compounds based on electronic and steric factors:

- $HCHO$ **(Formaldehyde):** It has two small hydrogen atoms and no electron-donating alkyl groups. It has the highest partial positive charge on the carbon and the least steric hindrance. Thus, it is the **most reactive**.
- CH_3CHO **(Acetaldehyde):** It has one methyl group ($+I$ effect), which reduces the positive charge on the carbon compared to $HCHO$. It also has slightly more steric hindrance.
- CH_3COCH_3 **(Acetone):** It has two methyl groups ($+I$ effect), which significantly reduce the electrophilicity of the carbonyl carbon. Furthermore, the two bulky groups provide the **most steric hindrance**.

Therefore, the decreasing order of reactivity is: $HCHO > CH_3CHO > CH_3COCH_3$.

Answer: (A)

Q39.

Solution

Concept: Tollen's reagent is a mild oxidizing agent used to distinguish aldehydes from ketones. Aldehydes reduce the reagent to metallic silver, while ketones (except α-hydroxy ketones) generally do not react.

Solution: Tollen's reagent is chemically defined as **ammoniacal silver nitrate**. It contains the diamminesilver(I) complex ion, $[Ag(NH_3)_2]^+$.

- **Reaction:** When an aldehyde is heated with Tollen's reagent, the aldehyde is oxidized to a carboxylate ion, and the silver ion is reduced to metallic silver.

$$RCHO + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow RCOO^- + 2Ag \downarrow + 4NH_3 + 2H_2O$$

- **Observation:** The silver metal deposits on the clean inner surface of the test tube, forming a **silver mirror**.
- **Other options:** Ammoniacal $CuSO_4$ is associated with Fehling's/Benedict's tests, while $FeCl_3$ is used for detecting phenols.

Thus, the correct answer is ammoniacal silver nitrate.

Answer: (A)

Q40.

Solution

Concept: The acidity of carboxylic acids is enhanced by electron-withdrawing groups (EWG) through the inductive effect ($-I$ effect). These groups stabilize the conjugate base (carboxylate ion) by delocalizing the negative charge. The effect increases with the electronegativity and the number of such groups.

Solution: We compare the given acids based on the inductive effect of their substituents:

- CH_3COOH**:** The methyl group is electron-donating ($+I$), making it the least acidic.
- $ClCH_2COOH$**:** Contains one Cl atom ($-I$ effect).
- FCH_2COOH**:** Contains one F atom. Since F is more electronegative than Cl, this is stronger than monochloroacetic acid.
- $Cl_2CHCOOH$**:** Contains **two** Cl atoms. The cumulative $-I$ effect of two chlorine atoms is greater than the effect of a single fluorine atom.

The order of acidity is: $Cl_2CHCOOH > FCH_2COOH > ClCH_2COOH > CH_3COOH$. Therefore, dichloroacetic acid is the strongest acid among the choices.

Answer: (C)

Q41.

Solution

Concept: The Clemmensen reduction is used to convert a carbonyl group ($> C = O$) of aldehydes and ketones into a methylene group ($> CH_2$). This reaction is carried out under strongly acidic conditions.

Solution: The reagent used for Clemmensen reduction is **zinc amalgam** ($Zn - Hg$) **and concentrated hydrochloric acid** (HCl).

- **Reaction:** $R - CO - R' \xrightarrow{Zn-Hg/HCl} R - CH_2 - R'$
- **Nature of Reagent:** It is a deoxygenation reaction where the oxygen of the carbonyl group is removed and replaced by two hydrogen atoms.
- **Comparison with Wolff-Kishner:** While Clemmensen reduction ($Zn - Hg/HCl$) works in *acidic* medium, the Wolff-Kishner reduction (NH_2NH_2/KOH) achieves the same result in a *basic* medium.
- **Other options:** $LiAlH_4$ reduces carbonyls to alcohols, and H_2/Pd typically reduces them to alcohols or reduces alkenes to alkanes.

Therefore, the specific reagent for Clemmensen reduction is $Zn - Hg/HCl$.

Answer: (A)

Q42.

Solution

Concept: The basicity of amines in aqueous solution depends on the stability of the substituted ammonium cation formed. This stability is influenced by:

(a) **Inductive Effect ($+I$):** Alkyl groups release electrons, increasing electron density on Nitrogen.

(b) **Solvation Effect:** Smaller cations are more extensively hydrated via hydrogen bonding, which stabilizes them.

(c) **Steric Hindrance:** Bulky alkyl groups can hinder the approach of water molecules or the proton.

Solution: For methyl-substituted amines (CH_3), the interplay of these factors results in a specific order:

- **Secondary amine** $(CH_3)_2NH$**:** It balances the $+I$ effect of two methyl groups with sufficient solvation and low steric hindrance, making it the strongest base.
- **Primary amine** CH_3NH_2**:** Although it has a lower $+I$ effect than the tertiary amine, it is highly stabilized by solvation (three H-atoms available for H-bonding in the cation).
- **Tertiary amine** $(CH_3)_3N$**:** Despite having the maximum $+I$ effect, it is the weakest among the alkyl amines because the bulky methyl groups cause significant steric hindrance and poor solvation of the resulting cation.
- **Ammonia** NH_3**:** It has no alkyl groups to provide a $+I$ effect, making it the weakest overall.

Therefore, the order for methyl amines in water is: $2^\circ > 1^\circ > 3^\circ > \mathrm{NH_3}$.

Answer: (A)

Q43.

Solution

Concept: The Gabriel Phthalimide synthesis is a specific 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, followed by hydrolysis or hydrazinolysis.**Solution:**The reaction proceeds through several stages:

(a) **Deprotonation:** Phthalimide reacts with ethanolic KOH to form potassium phthalimide.

(b) **Alkylation:** The phthalimide anion acts as a nucleophile and attacks an alkyl halide ($R-X$) via an S_N2 mechanism to form N-alkylphthalimide.

(c) **Cleavage:** The N-alkylphthalimide is treated with hydrazine (NH_2NH_2) or aqueous acid/base to yield a primary aliphatic amine ($R-NH_2$).

Limitations:

- It cannot be used for **primary aromatic amines** because aryl halides do not undergo S_N2 reactions due to the partial double-bond character of the C-X bond.
- It produces only **primary amines** because the phthalimide nitrogen can only be alkylated once.

Therefore, the method is used for the preparation of primary aliphatic amines.

Answer: (A)

Q44.

Solution

Concept: The Hinsberg test is a chemical reaction used to distinguish between primary, secondary, and tertiary amines. The reagent used for this purpose is known as the Hinsberg reagent.**Solution:**The Hinsberg reagent is Benzene sulfonyl chloride ($C_6H_5SO_2Cl$). The reaction with amines depends on the number of replaceable hydrogen atoms attached to the nitrogen:

- **Primary Amines** (1°)**:** React to form an N-alkylbenzene sulfonamide which is **soluble** in alkali due to the presence of an acidic hydrogen.
- **Secondary Amines** (2°)**:** React to form an N,N-dialkylbenzene sulfonamide which is **insoluble** in alkali because it lacks an acidic hydrogen.
- **Tertiary Amines** (3°)**:** Do not react with benzene sulfonyl chloride under standard conditions.

Therefore, the correct reagent is Benzene sulfonyl chloride.

Answer: (A)

Q45.

Solution

Concept: Aniline ($C_6H_5NH_2$) is a highly activating group toward electrophilic aromatic substitution due to the strong resonance effect ($+M$ effect) of the lone pair on the nitrogen atom. This increases the electron density at the ortho and para positions significantly.**Solution:**When aniline reacts with bromine water (Br_2/H_2O), the reaction is so vigorous that substitution occurs at all available ortho and para positions simultaneously.

- The $-NH_2$ group is a powerful activating group.
- Bromine water is a highly polar medium which facilitates the formation of the bromonium ion and further increases the reactivity.
- The product formed is a white precipitate of **2,4,6-Tribromoaniline**.

If one wishes to prepare mono-substituted products like o-bromoaniline or p-bromoaniline, the activating effect of the amino group must first be "acetylated" using acetic anhydride to reduce its reactivity.

Answer: (C)

Q46.

Solution

Concept: Sugars are classified as reducing or non-reducing based on their ability to reduce Tollen's reagent or Fehling's solution. A sugar is "reducing" if it has a free aldehyde or ketone group (or a hemiacetal/hemiketal group that can open into one).**Solution:**The reducing nature of carbohydrates depends on the status of their anomeric carbons:

- **Glucose and Fructose:** All monosaccharides are reducing sugars because they possess free (or easily available) aldehydic or ketonic groups.
- **Maltose:** A disaccharide composed of two glucose units. The anomeric carbon of the second glucose unit is free (hemiacetal), making it a reducing sugar.
- **Sucrose:** A disaccharide composed of α-D-glucose and β-D-fructose. The glycosidic linkage is formed between the anomeric carbon of glucose (C1) and the anomeric carbon of fructose (C2).

Since both reducing groups are involved in the formation of the glycosidic bond, there is no free aldehyde or ketone group available. Thus, Sucrose is a non-reducing sugar.

Answer: (D)

Q47.

Solution

Concept: Proteins are high molecular weight polymers known as polypeptides. They are formed by the condensation of α-amino acids, where the amino group ($-NH_2$) of one amino acid reacts with the carboxyl group ($-COOH$) of another.

Solution: The bond that holds amino acids together in a protein chain is known as a **Peptide linkage** (or peptide bond).

- Chemically, a peptide linkage is an amide bond represented as $-CO-NH-$.
- During the formation of this bond, a molecule of water (H_2O) is eliminated between the carboxyl group of one amino acid and the amino group of the next.

Comparison with other options:

- **Glycosidic linkage:** Found in carbohydrates (polysaccharides) connecting monosaccharide units.
- **Phosphodiester linkage:** Found in nucleic acids (DNA/RNA) connecting nucleotides.
- **Hydrogen bond:** Responsible for the secondary and tertiary folding of proteins, but it is not the primary structural linkage.

Answer: (B)

Q48.

Solution

Concept: Vitamins are essential organic compounds required in small amounts for various physiological functions. Deficiency of specific vitamins leads to characteristic deficiency diseases. Vitamin C, also known as ascorbic acid, is a water-soluble vitamin vital for collagen synthesis and immune function.

Solution: The deficiency of Vitamin C leads to **Scurvy**.

- **Scurvy:** Characterized by bleeding gums, skin spots, and delayed wound healing due to the body's inability to synthesize collagen properly.

Analysis of other options:

- **Rickets:** Caused by a deficiency of **Vitamin D**, leading to soft and weak bones in children.
- **Beri-beri:** Caused by a deficiency of **Vitamin** B_1 (Thiamine), affecting the lower limbs and cardiovascular system.
- **Night blindness:** Caused by a deficiency of **Vitamin A**, resulting in poor vision in low light.

Answer: (B)

Q49.

Solution

Concept: Denaturation is a process in which a protein loses its native conformation (biological activity) due to physical or chemical changes like heat, pH changes, or the presence of heavy metals. This process involves the disruption of the non-covalent bonds that maintain the protein's shape.

Solution: Proteins have four levels of structure: primary, secondary, tertiary, and quaternary.

- **Secondary, Tertiary, and Quaternary structures:** These are maintained by relatively weak bonds such as hydrogen bonds, disulfide bridges, hydrophobic interactions, and van der Waals forces. These bonds are easily broken during denaturation.
- **Primary structure:** This is the specific sequence of amino acids held together by strong, covalent **peptide bonds**. These covalent bonds are not broken during the denaturation process.

Therefore, when a protein is denatured, it unfolds and loses its higher-order shapes, but the linear sequence of amino acids (primary structure) remains intact.

Answer: (A)

Q50.

Solution

Concept: Monosaccharides are classified based on the number of carbon atoms they contain and the type of functional group present (aldehyde or ketone).

- **Aldose:** Contains an aldehyde group ($-CHO$).
- **Ketose:** Contains a keto group ($> C = O$).
- **Hexose:** A sugar containing six carbon atoms.

Solution: We can categorize the given options based on their structure and functional groups:

- **Glucose:** A six-carbon sugar with an aldehyde group. It is an **aldohexose**.
- **Fructose:** A six-carbon sugar with a keto group at the C2 position. It is a **ketohexose**.
- **Ribose:** A five-carbon sugar with an aldehyde group. It is an **aldopentose**.
- **Galactose:** A six-carbon sugar with an aldehyde group (a C4 epimer of glucose). It is an **aldohexose**.

Fructose is the most common example of a ketohexose found in nature, often referred to as fruit sugar.

Answer: (B)

Answer Key

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