CUET UG Chemistry Sample Paper - 4

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. A solution of acetone in ethanol shows:

(A) Negative deviation from Raoult's Law
(B) Positive deviation from Raoult's Law
(C) No deviation from Raoult's Law
(D) Can be positive or negative depending on composition

Q2. The value of Van't Hoff factor (i) for $K_4[Fe(CN)_6]$, assuming 100% dissociation, is:

(A) 4
(B) 5
(C) 2
(D) 1

Q3. What is the molality of a 10% (w/w) aqueous solution of glucose (Molar mass = 180 g/mol)?

(A) 0.617 m
(B) 0.555 m
(C) 0.01 m

(D) 0.72 m

Q4. The boiling point of 0.2 mol/kg solution of X in water is greater than 0.2 mol/kg solution of Y in water. Which of the following statements is true?

(A) X is undergoing dissociation

(B) Y is undergoing dissociation

(C) Molecular mass of X is greater than Y

(D) X is undergoing association

Q5. Which of the following aqueous solutions will have the highest boiling point?

(A) 0.1 M $NaCl$

(B) 0.1 M $BaCl_2$

(C) 0.1 M KNO_3

(D) 0.1 M Glucose

Q6. The unit of molar conductivity (Λ_m) is:

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

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

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

(D) $S\ cm^2\ mol$

Q7. How much charge is required for the reduction of 1 mole of MnO_4^- to Mn^{2+}?

(A) 1 F

(B) 5 F

(C) 3 F

(D) 2 F

Q8. For the cell reaction $Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$, the Nernst equation is given by:

(A) $E_{cell} = E^{\circ}_{cell} - \frac{0.059}{2} \log \frac{[Mg^{2+}]}{[Cu^{2+}]}$

(B) $E_{cell} = E^{\circ}_{cell} - \frac{0.059}{2} \log \frac{[Cu^{2+}]}{[Mg^{2+}]}$

(C) $E_{cell} = E^{\circ}_{cell} - \frac{0.059}{1} \log \frac{[Mg^{2+}]}{[Cu^{2+}]}$

(D) $E_{cell} = E^{\circ}_{cell} + \frac{0.059}{2} \log \frac{[Mg^{2+}]}{[Cu^{2+}]}$

Q9. The limiting molar conductivity of an electrolyte A_2B is given by:

(A) $\lambda^{\circ}_{A^+} + \lambda^{\circ}_{B^{2-}}$

(B) $2\lambda^{\circ}_{A^+} + \lambda^{\circ}_{B^{2-}}$

(C) $\lambda^{\circ}_{A^+} + 2\lambda^{\circ}_{B^{2-}}$

(D) $\frac{1}{2}\lambda^{\circ}_{A^+} + \lambda^{\circ}_{B^{2-}}$

Q10. Which of the following batteries is used in Apollo Space Missions?

(A) Dry Cell

(B) Lead Storage Battery

(C) $H_2 - O_2$ Fuel Cell

(D) Mercury Cell

Q11. The rusting of iron is an electrochemical phenomenon where the anode is:

(A) Iron surface

(B) Impure surface

(C) Water film

(D) Dissolved Oxygen

Q12. For a first-order reaction, if the concentration of reactant is doubled, the half-life ($t_{1/2}$):

(A) Doubled

(B) Halved

(C) Remains constant

(D) Becomes four times

Q13. The rate constant of a reaction is 2×10^{-2} L mol^{-1} s^{-1}. The order of the reaction is:

(A) Zero

(B) First

(C) Second

(D) Third

Q14. In the Arrhenius equation $k = Ae^{-E_a/RT}$, the term $e^{-E_a/RT}$ represents:

(A) Frequency of collisions

(B) Fraction of molecules with energy equal to or greater than E_a

(C) Activation energy

(D) Steric factor

Q15. A substance decomposes following first-order kinetics. If 75% of the substance decomposes in 60 minutes, the half-life is:

(A) 30 min

(B) 45 min

(C) 20 min

(D) 60 min

Q16. Which of the following is the correct integrated rate equation for a zero-order reaction?

(A) $[R] = -kt + [R]_0$

(B) $\ln[R] = -kt + \ln[R]_0$

(C) $[R] = [R]_0 e^{-kt}$

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

Q17. Transition elements show high melting points due to:

(A) High ionization enthalpy

(B) Involvement of both $(n-1)d$ and ns electrons in metallic bonding

(C) Small atomic radii

(D) Lanthanoid contraction

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

(A) Ti^{4+}

(B) Cu^{2+}

(C) V^{3+}

(D) Fe^{3+}

Q19. Lanthanoid contraction is caused due to:

(A) Perfect shielding of $4f$ electrons

(B) Poor shielding of $4f$ electrons

(C) Increase in nuclear charge

(D) Decrease in nuclear charge

Q20. The magnetic moment of Mn^{2+} ion $(Z = 25)$ is:

(A) 5.92 BM

(B) 4.90 BM

(C) 3.87 BM

(D) 1.73 BM

Q21. The IUPAC name of $[Co(NH_3)_5(CO_3)]Cl$ is:

(A) Pentaamminecarbonatocobalt(III) chloride

(B) Carbonatopentaamminecobalt(III) chloride

(C) Pentaamminecarbonatocobaltate(III) chloride

(D) Pentaamminecarbonatocobalt(II) chloride

Q22. Which of the following ligands is an ambidentate ligand?

(A) H_2O

(B) SCN^-

(C) NH_3

(D) en

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. The Crystal Field Stabilization Energy (CFSE) for a high spin d^4 octahedral complex is:

(A) $-0.6\Delta_o$

(B) $-1.8\Delta_o$

(C) $-1.6\Delta_o + P$

(D) $-1.2\Delta_o$

Q25. Geometrical isomerism is not shown by:

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

(B) $[Co(NH_3)_4Cl_2]^+$

(C) $[Ni(NH_3)_2Cl_2]$ (Tetrahedral)

(D) $[Co(en)_2Cl_2]^+$

Q26. How many ions are produced from $[Co(NH_3)_6]Cl_3$ in solution?

(A) 6

(B) 4

(C) 3

(D) 2

Q27. The reaction of CH_3Br with AgF to form CH_3F is known as:

(A) Finkelstein reaction

(B) Swarts reaction

(C) Wurtz reaction

(D) Sandmeyer reaction

Q28. Which of the following is most reactive towards S_N1 reaction?

(A) CH_3Cl

(B) CH_3CH_2Cl

(C) $(CH_3)_2CHCl$

(D) $(CH_3)_3CCl$

Q29. Chirality of a molecule is due to:

(A) Presence of asymmetric carbon

(B) Non-superimposable mirror images

(C) Plane of symmetry

(D) Center of inversion

Q30. Chlorobenzene is less reactive than methyl chloride towards nucleophilic substitution due to:

(A) Resonance effect

(B) sp^2 hybridization of C-atom in chlorobenzene

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

(D) All of the above

Q31. Lucas reagent is a mixture of:

(A) Conc. HCl + Anhydrous $ZnCl_2$

(B) Conc. HNO_3 + Conc. H_2SO_4

(C) $Pd/BaSO_4$

(D) Na in liquid NH_3

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

(A) Salicylic acid

(B) Salicylaldehyde

(C) Benzene

(D) Benzoic acid

Q33. Propan-1-ol and Propan-2-ol can be distinguished by:

(A) Oxidation with $KMnO_4$

(B) Lucas Test

(C) Iodoform Test

(D) Both B and C

Q34. Phenol is more acidic than ethanol because:

(A) Phenoxide ion is resonance stabilized
(B) Ethanol is a gas
(C) Phenol has higher molecular weight
(D) Ethoxide ion is resonance stabilized

Q35. Which of the following will not undergo Aldol condensation?

(A) Acetaldehyde
(B) Propanaldehyde
(C) Benzaldehyde
(D) Acetone

Q36. The product of Cannizzaro reaction of Formaldehyde is:

(A) Methanol and Potassium Formate
(B) Ethanol
(C) Formic acid only
(D) Methane

Q37. Which of the following is the most acidic?

(A) CH_3COOH
(B) $ClCH_2COOH$
(C) $Cl_2CHCOOH$
(D) FCH_2COOH

Q38. Clemmensen reduction of a ketone is carried out in the presence of:

(A) $Zn - Hg$/Conc. HCl

(B) NH_2NH_2/KOH

(C) $LiAlH_4$

(D) H_2/Ni

Q39. Tollen's reagent is:

(A) Ammoniacal silver nitrate

(B) Alkaline copper sulfate

(C) Potassium permanganate

(D) Bromine water

Q40. The correct order of basic strength of 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) $NH_3 > CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N$

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

Q41. Gabriel phthalimide synthesis is used for the preparation of:

(A) Primary aliphatic amines

(B) Primary aromatic amines

(C) Secondary amines

(D) Tertiary amines

Q42. Hoffmann Bromamide Degradation reaction converts:

(A) Amide to Amine with one less carbon

(B) Amide to Amine with same carbon

(C) Nitro to Amine

(D) Amine to Amide

Q43. Benzene diazonium chloride reacts with phenol in basic medium to give:

(A) p-Hydroxyazobenzene (Orange dye)

(B) p-Aminoazobenzene (Yellow dye)

(C) Chlorobenzene

(D) Aniline

Q44. Which of the following sugar is a non-reducing sugar?

(A) Glucose

(B) Fructose

(C) Sucrose

(D) Maltose

Q45. The helical structure of proteins is stabilized by:

(A) Hydrogen bonds

(B) Peptide bonds

(C) Di-sulfide bonds

(D) Ionic bonds

Q46. Which of the following vitamins is water-soluble?

(A) Vitamin A

(B) Vitamin D

(C) Vitamin C

(D) Vitamin K

Q47. Glucose on oxidation with Bromine water gives:

(A) Gluconic acid

(B) Saccharic acid

(C) Sorbitol

(D) n-Hexane

Q48. Denaturation of protein involves:

(A) Loss of secondary and tertiary structure

(B) Loss of primary structure

(C) Breakage of peptide bonds

(D) Increase in enzymatic activity

Q49. An example of a globular protein is:

(A) Keratin

(B) Myosin

(C) Insulin

(D) Collagen

Q50. The linkage present in Proteins is:

(A) Glycosidic linkage

(B) Peptide linkage

(C) Phosphodiester linkage

(D) Ester linkage

Detailed Solutions

Q1.

Solution

Concept:

Deviation from Raoult's Law occurs when the intermolecular interactions between different components of a solution differ from the interactions in the pure components. - **Positive deviation:** occurs when A–B interactions are weaker than A–A or B–B interactions, leading to higher vapor pressure. - **Negative deviation:** occurs when A–B interactions are stronger than A–A or B–B interactions, leading to lower vapor pressure.

Solution:

Acetone–ethanol solution: - Ethanol forms strong hydrogen bonds. - Mixing with acetone breaks some of the hydrogen bonds, reducing A–B interactions compared to the original strong A–A (ethanol–ethanol) hydrogen bonds. - This results in a higher vapor pressure than predicted by Raoult's Law, i.e., a **positive deviation**.

Answer: (B)

Q2.

Solution

Concept: The Van't Hoff factor (i) is the ratio of the actual concentration of particles produced when the substance is dissolved to the concentration of a substance as calculated from its mass. For 100% dissociation, i is equal to the total number of ions produced per formula unit of the solute.

Solution: The coordination compound $K_4[Fe(CN)_6]$ (Potassium ferrocyanide) dissociates in aqueous solution as follows:

$$K_4[Fe(CN)_6] \longrightarrow 4K^+ + [Fe(CN)_6]^{4-}$$

In this dissociation:

- There are 4 Potassium ions (K^+).
- There is 1 complex coordination entity (ferrocyanide ion), $[Fe(CN)_6]^{4-}$.
- Total number of particles (n) = 4 + 1 = 5.

Since the degree of dissociation (α) is 100% or 1, the Van't Hoff factor is:

$$i = 1 + (n-1)\alpha = 1 + (5-1)1 = 5$$

Answer: (B)

Q3.

Solution

Concept: Molality (m) is defined as the number of moles of solute dissolved in 1 kg (1000 g) of the solvent. The formula is:

$$m = \frac{\text{Mass of solute}}{\text{Molar mass of solute}} \times \frac{1000}{\text{Mass of solvent (in g)}}$$

Solution: For a 10% (w/w) aqueous solution of glucose:

- Mass of solute (glucose) = 10 g
- Mass of solution = 100 g
- Mass of solvent (water) = 100 g − 10 g = 90 g
- Molar mass of glucose = 180 g/mol

Substituting these values into the molality formula:

$$m = \frac{10}{180} \times \frac{1000}{90}$$

$$m = \frac{1}{18} \times 11.11 \approx 0.617\ m$$

Answer: (A)

Q4.

Solution

Concept: Boiling point elevation (ΔT_b) is a colligative property, which means it depends on the number of solute particles. The formula is:

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

Where i is the Van't Hoff factor, K_b is the ebullioscopic constant, and m is the molality.
Solution: The problem states that the molality (m) is the same ($0.2\ mol/kg$) and the solvent (water) is the same for both X and Y.

- If $BP(X) > BP(Y)$, then $\Delta T_b(X) > \Delta T_b(Y)$.
- Since K_b and m are constant, it implies $i_X > i_Y$.
- A higher Van't Hoff factor ($i > 1$) indicates that the solute is **dissociating** into more particles.
- If i_X is greater, it suggests X is undergoing dissociation (increasing particle count) or Y is undergoing association (decreasing particle count).

Among the given options, the most valid conclusion is that X is undergoing dissociation.

Answer: (A)

Q5.

Solution

Concept: Boiling point elevation (ΔT_b) is a colligative property. The boiling point of a solution increases with the number of solute particles (ions or molecules) present. The formula is:

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

Where i is the Van't Hoff factor. For solutions with the same molarity, the one with the highest i value will have the highest boiling point.
Solution: Let's calculate the Van't Hoff factor (i) for each $0.1\ M$ solution:

- **NaCl:** Dissociates into Na^+ and $Cl^- \implies i = 2$
- $BaCl_2$**:** Dissociates into Ba^{2+} and $2Cl^- \implies i = 1 + 2 = 3$
- KNO_3**:** Dissociates into K^+ and $NO_3^- \implies i = 2$
- **Glucose:** Non-electrolyte (does not dissociate) $\implies i = 1$

Since $BaCl_2$ produces the maximum number of particles ($i = 3$), it will show the maximum elevation in boiling point and thus have the highest boiling point.

Answer: (B)

Q6.

Solution

Concept: Molar conductivity (Λ_m) is the conducting power of all the ions produced by dissolving one mole of an electrolyte in solution. It is related to electrolytic conductivity (κ) by the formula:

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

Solution: The units for the variables are:

- Conductivity (κ): $S\ cm^{-1}$ (where $S = \Omega^{-1}$)
- Concentration (M): $mol\ cm^{-3}$ (in the context of the formula derivation)

By substituting the units:

$$\text{Unit of } \Lambda_m = \frac{S\ cm^{-1}}{mol\ cm^{-3}} = S\ cm^2\ mol^{-1}$$

Therefore, the standard unit used in chemistry is $S\ cm^2\ mol^{-1}$.

Answer: (A)

Q7.

Solution

Concept: According to Faraday's First Law of Electrolysis, the amount of charge (Q) required for an oxidation or reduction reaction is related to the number of moles of electrons (n) exchanged in the balanced half-reaction: $Q = nF$.

Solution: The reduction half-reaction for MnO_4^- to Mn^{2+} in an acidic medium is:

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

- The oxidation state of Mn in MnO_4^- is +7.
- The oxidation state of Mn in Mn^{2+} is +2.
- Change in oxidation state = 7 − 2 = 5.

Since 5 moles of electrons are required to reduce 1 mole of MnO_4^-, the total charge required is 5 F.

Answer: (B)

Q8.

Solution

Concept: The Nernst equation relates the cell potential to the standard cell potential and the reaction quotient (Q):

$$E_{cell} = E^{\circ}_{cell} - \frac{0.059}{n} \log Q$$

Where n is the number of electrons transferred and $Q = \frac{[\text{Products}]}{[\text{Reactants}]}$ (excluding solids).
Solution: For the reaction $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$:

- $Mg \rightarrow Mg^{2+} + 2e^{-}$ (Oxidation)
- $Cu^{2+} + 2e^{-} \rightarrow Cu$ (Reduction)
- Total electrons transferred $(n) = 2$.
- Reaction quotient $Q = \frac{[Mg^{2+}]}{[Cu^{2+}]}$ (Since $Mg(s)$ and $Cu(s)$ have activity = 1).

Substituting into the Nernst equation:

$$E_{cell} = E^{\circ}_{cell} - \frac{0.059}{2} \log \frac{[Mg^{2+}]}{[Cu^{2+}]}$$

Answer: (A)

Q9.

Solution

Concept: Kohlrausch's Law of Independent Migration of Ions states that the limiting molar conductivity (Λ°_{m}) of an electrolyte is the sum of the individual contributions of its constituent ions.
Solution: An electrolyte of the form A_2B dissociates as follows:

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

According to Kohlrausch's Law, the total limiting molar conductivity is calculated by multiplying the limiting molar conductivity of each ion by its stoichiometric coefficient:

$$\Lambda^{\circ}_{m}(A_2B) = 2\lambda^{\circ}_{A^{+}} + \lambda^{\circ}_{B^{2-}}$$

Answer: (B)

Q10.

Solution

Concept: Fuel cells are galvanic cells that convert the chemical energy of a fuel (like hydrogen, methane, or methanol) directly into electrical energy. The $H_2 - O_2$ fuel cell is highly efficient and produces water as a byproduct.
Solution: The $H_2 - O_2$ fuel cell was famously used in the **Apollo Space Missions** for two primary reasons:

- **Electrical Power:** It provided a steady source of electricity for the spacecraft's systems.
- **Drinking Water:** The water vapor produced during the reaction was condensed and used as a source of drinking water for the astronauts.

The overall reaction is: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$.

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

Q11.

Solution

Concept: Corrosion (rusting) of iron is an electrochemical process. A particular spot on the surface of an object made of iron behaves as an anode, while another spot behaves as a cathode.
Solution: In the electrochemical mechanism of rusting:

- **Anode:** At a specific spot, iron is oxidised to ferrous ions:

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

  The **iron surface** itself acts as the anode.
- **Cathode:** Electrons released at the anode move through the metal to another spot where they reduce oxygen in the presence of H^+ ions (from H_2CO_3 or water).
- **Electrolyte:** The water film containing dissolved CO_2 or other gases acts as the electrolyte.

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

Q12.

Solution

Concept: The half-life ($t_{1/2}$) of a reaction is the time required for the concentration of a reactant to reduce to half of its initial value. For different orders, the dependence on initial concentration $[R]_0$ varies.

Solution: For a first-order reaction, the rate constant k is given by:

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

- The expression for $t_{1/2}$ for a first-order reaction **does not contain** the initial concentration term $[R]_0$.
- Therefore, the half-life of a first-order reaction is independent of the initial concentration of the reactants.
- Doubling, tripling, or changing the concentration in any way will leave the $t_{1/2}$ **constant**.

Answer: (C)

Q13.

Solution

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

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

where n is the order of the reaction.

Solution: Given the unit of k is $L\ mol^{-1}\ s^{-1}$ (which is equivalent to $mol^{-1}\ L\ s^{-1}$):

- Let $1 - n = -1$
- $n = 1 + 1 = 2$

Alternatively, checking orders:

- Zero order: $mol\ L^{-1}\ s^{-1}$
- First order: s^{-1}
- Second order: $L\ mol^{-1}\ s^{-1}$

Therefore, the reaction is of the **Second order**.

Answer: (C)

Q14.

Solution

Concept: The Arrhenius equation $k = Ae^{-E_a/RT}$ describes the temperature dependence of reaction rates.

- A is the pre-exponential factor (frequency factor).
- E_a is the activation energy.
- R is the gas constant and T is temperature in Kelvin.

Solution: In the expression, the exponential term $e^{-E_a/RT}$ is derived from the Maxwell-Boltzmann distribution. It represents the **fraction of molecules** that possess kinetic energy equal to or greater than the activation energy (E_a) at a given temperature T. As temperature increases, this fraction increases, leading to an increase in the rate constant.

Answer: (B)

Q15.

Solution

Concept: For a first-order reaction, the time required for a certain percentage of completion can be related to the half-life ($t_{1/2}$). Specifically, the amount of substance remaining after n half-lives is $(\frac{1}{2})^n$ of the initial concentration.
Solution: If 75% of the substance has decomposed, the amount remaining is 25% (or $1/4$ of the initial amount).

- Remaining amount $[R] = \frac{1}{4}[R]_0 = (\frac{1}{2})^2[R]_0$
- This indicates that exactly **two half-lives** have passed.
- Total time $t = 2 \times t_{1/2}$
- $60\ min = 2 \times t_{1/2} \implies t_{1/2} = 30\ min$

Answer: (A)

Q16.

Solution

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

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

Solution: Integrating the differential rate equation:

- $d[R] = -kdt$
- Integrating both sides: $[R] = -kt + I$
- At $t = 0$, $[R] = [R]_0$, therefore the integration constant $I = [R]_0$.
- The final equation is: $[R] = -kt + [R]_0$.

This represents a straight line graph of $[R]$ vs t with slope $-k$ and intercept $[R]_0$.

Answer: (A)

Q17.

Solution

Concept: The melting point of transition metals is determined by the strength of the metallic bond. Metallic bond strength depends on the number of electrons available for delocalisation and bonding.
Solution: In transition elements, the electrons in both the outermost ns orbital and the penultimate $(n-1)d$ orbital are close in energy.

- Both sets of electrons participate in interatomic metallic bonding.
- The presence of a large number of unpaired d-electrons leads to very strong covalent and metallic interactions between atoms.
- This results in high enthalpies of atomization and, consequently, high melting points.

Answer: (B)

Q18.

Solution

Concept: The color of transition metal ions is generally due to $d - d$ transitions. For an ion to be colored, it must have a partially filled d-orbital (i.e., d^1 to d^9). Ions with d^0 or d^{10} configurations are usually colorless.

Solution: Let's look at the electronic configurations:

- Ti^{4+}**:** Titanium is $Z = 22$ ($[Ar]3d^2 4s^2$). Ti^{4+} is $[Ar]3d^0$. Since there are no d-electrons, no $d - d$ transition occurs. **Colorless**.
- Cu^{2+}**:** $[Ar]3d^9$. Has unpaired electrons. **Blue**.
- V^{3+}**:** $[Ar]3d^2$. Has unpaired electrons. **Green**.
- Fe^{3+}**:** $[Ar]3d^5$. Has unpaired electrons. **Yellow/Brown**.

Answer: (A)

Q19.

Solution

Concept: Lanthanoid contraction refers to the steady decrease in the atomic and ionic radii of lanthanoid elements with increasing atomic number. This is a direct consequence of the shape and distribution of f-orbitals.

Solution: In the lanthanoid series, as the atomic number increases, the nuclear charge increases by one unit at each step, and one electron is added into the $4f$ subshell.

- The $4f$ orbitals are very diffused and have a **poor shielding effect** compared to s, p, or d orbitals.
- Due to this poor shielding, the outer electrons experience a greater effective nuclear charge (Z_{eff}).
- This results in a stronger inward pull of the electron cloud toward the nucleus, leading to a contraction in size.

Answer: (B)

Q20.

Solution

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

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

Where n is the number of unpaired electrons and BM stands for Bohr Magneton.
Solution: For Mn^{2+} ($Z = 25$):

- Ground state electronic configuration of Mn: $[Ar]3d^5 4s^2$
- Configuration of Mn^{2+}: $[Ar]3d^5$
- In the $3d^5$ subshell, all five electrons are unpaired ($n = 5$).

Substituting into the formula:

$$\mu = \sqrt{5(5+2)} = \sqrt{35} \approx 5.916 \text{ BM}$$

Rounding to two decimal places, we get 5.92 BM.

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

Q21.

Solution

Concept: IUPAC nomenclature for coordination compounds follows specific rules: 1. Name the cation first. 2. Name ligands in alphabetical order. 3. Use Greek prefixes for quantity. 4. Metal name followed by oxidation state in Roman numerals.
Solution: For the complex $[Co(NH_3)_5(CO_3)]Cl$:

- **Ligands:** 5 Ammine (NH_3) and 1 Carbonato (CO_3^{2-}). "Ammine" comes before "Carbonato" alphabetically.
- **Oxidation State of Co (x):** $x + 5(0) + 1(-2) = +1$ (since Cl is -1). So, $x - 2 = 1 \implies x = +3$.
- **Metal Name:** Since the complex part is a cation, the metal is named "Cobalt".
- **Anion:** Chloride.

Full name: **Pentaamminecarbonatocobalt(III) chloride**.

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

Q22.

Solution

Concept: An ambidentate ligand is a unidentate ligand that contains more than one coordinating atom and can bind to the central metal atom through either of these atoms.
Solution: Let's examine the options:

- H_2O**:** Unidentate ligand, binds only through Oxygen.
- SCN^- **(Thiocyanate):** Ambidentate ligand. It can bind through Sulfur ($M - SCN$, thiocyanato-S) or through Nitrogen ($M - NCS$, isothiocyanato-N).
- NH_3**:** Unidentate ligand, binds only through Nitrogen.
- en **(Ethylenediamine):** Didentate ligand, binds through two Nitrogen atoms simultaneously.

Common examples of ambidentate ligands include NO_2^-, SCN^-, and CN^-.

Answer: (B)

Q23.

Solution

Concept: Valence Bond Theory (VBT) helps determine the hybridization and geometry based on the nature of the ligand (strong field vs. weak field) and the coordination number.
Solution: For the complex $[Ni(CN)_4]^{2-}$:

- **Oxidation state of Ni:** $x + 4(-1) = -2 \implies x = +2$.
- **Electronic configuration of** Ni^{2+}**:** $[Ar]3d^8$.
- **Ligand nature:** CN^- is a **strong field ligand**, which causes the pairing of electrons in the $3d$ orbital.
- **Pairing:** The 8 electrons in $3d$ pair up, leaving **one empty** $3d$ **orbital**.
- **Hybridization:** One $3d$, one $4s$, and two $4p$ orbitals hybridize to give dsp^2 hybridization.
- **Geometry:** Complexes with dsp^2 hybridization possess a **Square Planar** geometry.

Answer: (B)

Q24.

Solution

Concept: In an octahedral field, the d-orbitals split into two sets: t_{2g} (lower energy) and e_g (higher energy). The energy difference is Δ_o. CFSE is calculated as:

$$\text{CFSE} = (-0.4 \times n_{t2g} + 0.6 \times n_{eg})\Delta_o$$

Solution: For a **high spin** d^4 complex:

- "High spin" means the pairing energy (P) is greater than Δ_o, so electrons prefer to occupy higher energy orbitals rather than pairing.
- The distribution will be $t_{2g}^3\, e_g^1$.
- Calculation:

$$\text{CFSE} = [3 \times (-0.4) + 1 \times (0.6)]\Delta_o$$

$$\text{CFSE} = [-1.2 + 0.6]\Delta_o = -0.6\Delta_o$$

Answer: (A)

Q25.

Solution

Concept: Geometrical isomerism (cis/trans) depends on the spatial arrangement of ligands. In coordination chemistry, it is common in square planar ($CN = 4$) and octahedral ($CN = 6$) complexes but absent in tetrahedral complexes.

Solution: Let's analyze the geometries:

- $[Pt(NH_3)_2Cl_2]$**:** Square planar (MA_2B_2 type), shows cis and trans isomers.
- $[Co(NH_3)_4Cl_2]^+$**:** Octahedral (MA_4B_2 type), shows cis and trans isomers.
- $[Ni(NH_3)_2Cl_2]$ **(Tetrahedral):** In a tetrahedral geometry, all four positions are equivalent and adjacent to each other. Therefore, no geometrical isomerism is possible regardless of the ligands.
- $[Co(en)_2Cl_2]^+$**:** Octahedral (Chelated), shows cis and trans isomers.

Answer: (C)

Q26.

Solution

Concept: When a coordination compound dissolves in water, the species inside the coordination sphere (square brackets) remain as a single unit, while the counter-ions outside the brackets ionize.

Solution: The compound $[Co(NH_3)_6]Cl_3$ (Hexaamminecobalt(III) chloride) ionizes as follows:

$$[Co(NH_3)_6]Cl_3 \xrightarrow{H_2O} [Co(NH_3)_6]^{3+} + 3Cl^-$$

- There is **1** complex cation: $[Co(NH_3)_6]^{3+}$.
- There are **3** chloride anions: Cl^-.
- Total number of ions = 1 + 3 = 4.

Answer: (B)

Q27.

Solution

Concept: Alkyl fluorides are best prepared by heating an alkyl chloride/bromide in the presence of a metallic fluoride such as AgF, Hg_2F_2, CoF_2, or SbF_3. This is a halogen exchange reaction.

Solution: The specific reaction provided:

$$CH_3Br + AgF \longrightarrow CH_3F + AgBr$$

- **Swarts Reaction:** Synthesis of alkyl fluorides using metallic fluorides.
- **Finkelstein Reaction:** Synthesis of alkyl iodides using NaI in dry acetone.
- **Wurtz Reaction:** Synthesis of higher alkanes using Na in dry ether.
- **Sandmeyer Reaction:** Synthesis of haloarenes from diazonium salts.

Answer: (B)

Q28.

Solution

Concept: The S_N1 (Substitution Nucleophilic Unimolecular) reaction mechanism proceeds via the formation of a carbocation intermediate. The rate of the reaction depends on the stability of this carbocation.

Solution: The order of stability for alkyl carbocations is:

$$3^\circ > 2^\circ > 1^\circ > \text{Methyl}$$

- CH_3Cl**:** Methyl chloride (Forms methyl carbocation, least stable).
- CH_3CH_2Cl**:** Ethyl chloride (1° carbocation).
- $(CH_3)_2CHCl$**:** Isopropyl chloride (2° carbocation).
- $(CH_3)_3CCl$**:** tert-Butyl chloride (3° carbocation).

Since the *tert*-butyl carbocation is the most stable due to inductive effect and hyperconjugation, $(CH_3)_3CCl$ is the most reactive towards S_N1.

Answer: (D)

Q29.

Solution

Concept: Chirality is a geometric property of a molecule. A molecule is considered chiral if it cannot be superimposed on its mirror image, much like our left and right hands.

Solution: While the presence of an asymmetric (chiral) carbon often leads to chirality, the **fundamental definition** and cause of chirality is the property of **non-superimposable mirror images**.

- If a molecule has a plane of symmetry or a center of inversion, it becomes achiral (superimposable on its mirror image).
- Therefore, the essential condition for a molecule to be chiral is that it must lack symmetry elements that would allow it to be superimposable on its mirror image.

Answer: (B)

Q30.

Solution

Concept: Aryl halides (like chlorobenzene) are significantly less reactive than alkyl halides (like methyl chloride) towards nucleophilic substitution reactions (S_N1 or S_N2).

Solution: Several factors contribute to this low reactivity:

- **Resonance Effect:** Electron pairs on the halogen atom are in conjugation with the π-electrons of the ring, giving the $C - Cl$ bond a **partial double bond character**, making it harder to break.
- **Hybridization:** The carbon in chlorobenzene is sp^2 hybridized (more electronegative), whereas in methyl chloride it is sp^3. This makes the $C - Cl$ bond in chlorobenzene shorter and stronger.
- **Instability of Phenyl Cation:** A phenyl cation is highly unstable, ruling out the S_N1 mechanism.

Since all these factors apply, the correct choice is "All of the above".

Answer: (D)

Q31.

Solution

Concept: The Lucas test is used to distinguish between primary, secondary, and tertiary alcohols. The reagent reacts with alcohols to form alkyl chlorides, which appear as turbidity in the solution.

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

- **Tertiary alcohols:** React immediately to produce turbidity.
- **Secondary alcohols:** React within 5–10 minutes.
- **Primary alcohols:** Do not react at room temperature (turbidity only appears on heating).

Other options: (B) is Nitrating mixture, (C) is Lindlar's catalyst, and (D) is used for Birch reduction.

Answer: (A)

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 sodium hydroxide ($NaOH$).

Solution: The reaction proceeds via an intermediate carbene ($: CCl_2$) and results in the introduction of an aldehyde group ($-CHO$) at the ortho position of the phenol ring.

- The major product is **Salicylaldehyde** (2-hydroxybenzaldehyde).
- If carbon tetrachloride (CCl_4) is used instead of chloroform, the product would be Salicylic acid.

Answer: (B)

Q33.

Solution

Concept: Distinguishing between different types of alcohols (primary vs. secondary) or specific structural features (like a methyl keto group or a methyl carbinol group) requires specific chemical tests.

Solution: Propan-1-ol is a **primary** (1°) alcohol, while Propan-2-ol is a **secondary** (2°) alcohol.

- **Lucas Test:** Secondary alcohols (Propan-2-ol) react with Lucas reagent to give turbidity within 5–10 minutes, whereas primary alcohols (Propan-1-ol) do not show turbidity at room temperature.
- **Iodoform Test:** Propan-2-ol contains the $CH_3CH(OH)-$ group (methyl carbinol), which reacts with $I_2/NaOH$ to give a yellow precipitate of iodoform (CHI_3). Propan-1-ol does not have this specific grouping and gives a negative test.

Since both tests can successfully distinguish the two, the correct choice is "Both B and C".

Answer: (D)

Q34.

Solution

Concept: The acidity of a compound depends on the stability of its conjugate base. A more stable conjugate base corresponds to a stronger acid.
Solution: When phenol and ethanol lose a proton (H^+), they form the phenoxide ion ($C_6H_5O^-$) and ethoxide ion ($C_2H_5O^-$), respectively.

- **Phenoxide ion:** The negative charge on the oxygen atom is delocalized over the benzene ring through **resonance**. This stabilization makes it easier for phenol to release a proton.
- **Ethoxide ion:** The negative charge is localized on the oxygen atom, and the ethyl group ($+I$ effect) actually destabilizes the charge.

Thus, phenol is significantly more acidic than ethanol.

Answer: (A)

Q35.

Solution

Concept: Aldol condensation occurs in aldehydes or ketones that possess at least one α-hydrogen atom. The reaction involves the formation of an enolate ion which acts as a nucleophile.
Solution: Let's check the structures for α-hydrogens:

- **Acetaldehyde** (CH_3CHO)**:** Has 3 α-hydrogens. **Undergoes Aldol**.
- **Propanaldehyde** (CH_3CH_2CHO)**:** Has 2 α-hydrogens. **Undergoes Aldol**.
- **Benzaldehyde** (C_6H_5CHO)**:** The carbonyl carbon is attached to a benzene ring carbon that has no hydrogen. It lacks α-hydrogens. **Does not undergo Aldol**.
- **Acetone** (CH_3COCH_3)**:** Has 6 α-hydrogens. **Undergoes Aldol**.

Benzaldehyde instead undergoes the Cannizzaro reaction when treated with concentrated alkali.

Answer: (C)

Q36.

Solution

Concept: Aldehydes which do not have an α-hydrogen atom (like formaldehyde and benzaldehyde) undergo self-oxidation and reduction (disproportionation) on treatment with concentrated alkali. This is known as the Cannizzaro reaction.

Solution: In the Cannizzaro reaction of formaldehyde ($HCHO$):

- One molecule of formaldehyde is reduced to an alcohol: **Methanol** (CH_3OH).
- Another molecule is oxidized to a carboxylic acid salt: **Formate ion** ($HCOO^-$).
- If KOH is used as the base, the product is **Potassium Formate** ($HCOOK$).

Reaction: $2HCHO + KOH \longrightarrow CH_3OH + HCOOK$.

Answer: (A)

Q37.

Solution

Concept: The acidity of carboxylic acids is increased by electron-withdrawing groups ($-I$ effect) which stabilize the carboxylate anion by dispersing the negative charge. The strength of the effect depends on the electronegativity and the number of halogen atoms.

Solution: Let's compare the effects:

- CH_3COOH**:** No electron-withdrawing groups; least acidic.
- FCH_2COOH**:** Fluorine is very electronegative, but there is only one atom.
- $ClCH_2COOH$**:** Chlorine has a $-I$ effect.
- $Cl_2CHCOOH$**:** Two Chlorine atoms exert a much stronger cumulative electron-withdrawing effect than a single Fluorine or Chlorine atom.

The presence of two chlorine atoms in dichloroacetic acid makes it the most acidic among the given options because the resulting anion is the most stabilized.

Answer: (C)

Q38.

Solution

Concept: The Clemmensen reduction is a chemical reaction used to reduce a carbonyl group ($C = O$) in aldehydes or ketones to a methylene group ($-CH_2-$). It is particularly useful for compounds that are stable in strong acids.

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

- Option (B) NH_2NH_2/KOH is used in the **Wolff-Kishner reduction**, which is the basic medium alternative.
- Option (C) $LiAlH_4$ reduces ketones to secondary alcohols.
- Option (D) H_2/Ni is used for catalytic hydrogenation to alcohols.

Answer: (A)

Q39.

Solution

Concept: Tollen's test (the Silver Mirror Test) is used to distinguish aldehydes from ketones. Aldehydes reduce the silver ions in the reagent to metallic silver, which deposits on the inner wall of the test tube.

Solution: **Tollen's reagent** is **Ammoniacal silver nitrate** solution, $[Ag(NH_3)_2]OH$.

- It is prepared by adding ammonium hydroxide to silver nitrate solution until the precipitate of silver oxide just dissolves.
- **Alkaline copper sulfate** (with sodium potassium tartrate) is known as Fehling's solution.

Reaction: $RCHO + 2[Ag(NH_3)_2]^+ + 3OH^- \longrightarrow RCOO^- + 2Ag + 2H_2O + 4NH_3$.

Answer: (A)

Q40.

Solution

Concept: The basic strength of amines in aqueous solution is determined by three factors: the inductive effect ($+I$), the solvation effect (hydration of the cation), and steric hindrance.
Solution: For **methyl-substituted amines** in water, the cumulative effect of these three factors results in a specific order:

- Secondary amine is the strongest base because it has a good balance of $+I$ effect and solvation.
- Primary amine follows because it is more highly solvated than the tertiary amine.
- Tertiary amine is weaker than primary due to significant steric hindrance to the solvation of its conjugate acid.

The order is: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$.

Answer: (A)

Q41.

Solution

Concept: The Gabriel phthalimide synthesis is a chemical reaction that transforms primary alkyl halides into primary amines. It involves the nucleophilic substitution of an alkyl halide by the phthalimide anion, followed by hydrolysis or treatment with hydrazine.
Solution: The steps involved are:

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

(b) Potassium phthalimide reacts with an alkyl halide (RX) to form N-alkylphthalimide.

(c) Alkaline hydrolysis of N-alkylphthalimide yields the **primary aliphatic amine**.

- **Note:** Primary *aromatic* amines cannot be prepared by this method because aryl halides do not undergo nucleophilic substitution with the phthalimide anion under ordinary conditions.

Answer: (A)

Q42.

Solution

Concept: The Hoffmann bromamide degradation reaction is a method used for the preparation of primary amines by treating an amide with bromine in an aqueous or ethanolic solution of sodium hydroxide.

Solution: In this reaction, the carbonyl group ($-CO-$) of the amide is removed.

- The general reaction is: $R-CONH_2+Br_2+4NaOH \longrightarrow R-NH_2+Na_2CO_3+2NaBr+2H_2O$.
- The resulting amine contains **one carbon atom less** than the starting amide.
- This makes it a "degradation" reaction because the carbon chain is shortened.

Answer: (A)

Q43.

Solution

Concept: Azo coupling is an electrophilic aromatic substitution reaction where a diazonium cation reacts with electron-rich aromatic compounds like phenols or amines to form brightly colored azo compounds ($Ar-N=N-Ar$).

Solution: When Benzene diazonium chloride reacts with phenol:

- The reaction is carried out in a **mildly basic medium** (pH 9–10) to convert phenol into the more reactive phenoxide ion.
- The diazonium cation attacks the para position of the phenol.
- The product formed is **p-hydroxyazobenzene**, which is an **orange dye**.

Answer: (A)

Q44.

Solution

Concept: Reducing sugars are those that have a free aldehydic or ketonic group (in the form of a hemiacetal or hemiketal) and can reduce Tollen's reagent or Fehling's solution. Non-reducing sugars have these reactive groups involved in a glycosidic bond.

Solution: Let's analyze the carbohydrates:

- **Glucose:** A monosaccharide with a free aldehyde group. **Reducing**.
- **Fructose:** A monosaccharide with a free ketone group. **Reducing**.
- **Maltose:** A disaccharide where the hemiacetal group of one glucose unit is free. **Reducing**.
- **Sucrose:** A disaccharide where the glycosidic linkage is formed between the C_1 of α-D-glucose and C_2 of β-D-fructose. Since both reducing groups are bonded, it is a **Non-reducing sugar**.

Answer: (C)

Q45.

Solution

Concept: The secondary structure of proteins refers to the shape in which a long polypeptide chain can exist. The most common secondary structures are the α-helix and β-pleated sheet.

Solution: In the α-helical structure, a polypeptide chain forms all possible hydrogen bonds by twisting into a right-handed screw (helix).

- The structure is stabilized by **Hydrogen bonds** between the $-NH-$ group of a peptide bond and the $C = O$ group of the fourth amino acid residue in the chain.
- Peptide bonds link the amino acids together (primary structure), but the *shape* of the helix is maintained by hydrogen bonding.

[Image of alpha helix structure of protein]

Answer: (A)

Q46.

Solution

Concept: Vitamins are classified into two groups based on their solubility in water or fat. This solubility determines how they are stored and excreted by the body.

Solution:

- **Fat-soluble vitamins:** These are soluble in fat and oils but insoluble in water. They are stored in the liver and adipose tissues. Examples: **Vitamin A, D, E, and K**.
- **Water-soluble vitamins:** These are soluble in water. Since they are excreted in urine, they must be supplied regularly in the diet. Examples: **Vitamin C** and the **B-complex vitamins**.

Therefore, Vitamin C is the water-soluble vitamin among the options.

Answer: (C)

Q47.

Solution

Concept: Glucose contains an aldehyde group ($-CHO$) at C_1. The choice of oxidizing agent determines whether only the aldehyde group is oxidized or both the aldehyde and the primary alcoholic group are oxidized.

Solution: Glucose reacts with a mild oxidizing agent like **Bromine water** (Br_2/H_2O).

- Bromine water is specific for the oxidation of the aldehyde group to a carboxylic acid group.
- The product formed is **Gluconic acid**.
- *Note:* If a strong oxidizing agent like conc. HNO_3 is used, both the $-CHO$ and the $-CH_2OH$ groups are oxidized to give **Saccharic acid**.

Answer: (A)

Q48.

Solution

Concept: Denaturation is a process where a protein loses its native conformation due to physical or chemical changes like heat, pH change, or addition of salts.
Solution: During denaturation:

- The hydrogen bonds are disturbed, and the globules unfold and helices uncoil.
- The protein loses its biological activity.
- **Secondary and tertiary structures** are destroyed, but the **primary structure** (sequence of amino acids) remains intact because peptide bonds are not broken.

[Image of protein denaturation process]

Answer: (A)

Q49.

Solution

Concept: Proteins are classified into two types based on their molecular shape: Fibrous and Globular.
Solution:

- **Fibrous Proteins:** Polypeptide chains run parallel and are held together by hydrogen and disulfide bonds; they are water-insoluble. Examples: **Keratin** (hair, wool), **Myosin** (muscles), **Collagen**.
- **Globular Proteins:** Chains coil around to give a spherical shape; they are usually water-soluble. Examples: **Insulin** and **Albumin**.

Answer: (C)

Q50.

Solution

Concept: Proteins are polymers of α-amino acids. These amino acids are linked to each other by a specific chemical bond formed between the carboxyl group of one molecule and the amino group of another.

Solution: The linkage formed by the elimination of a water molecule between the $-COOH$ group and the $-NH_2$ group is $-CO-NH-$.

- This is known as a **Peptide linkage** (or peptide bond).
- **Glycosidic linkage** is found in carbohydrates.
- **Phosphodiester linkage** is found in nucleic acids (DNA/RNA).

Answer: (B)

Answer Key

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