CUET UG Chemistry Sample Paper - 5

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. An unknown solute is dissolved in water. If the Van't Hoff factor (i) is found to be 2.5, the solute is most likely:

(A) $NaCl$
(B) $CaCl_2$
(C) $AlCl_3$
(D) Glucose

Q2. Which of the following aqueous solutions will exhibit the highest boiling point?

(A) 0.1 M KNO_3
(B) 0.1 M Na_3PO_4
(C) 0.1 M $BaCl_2$
(D) 0.1 M Urea

Q3. According to Raoult's Law, the relative lowering of vapor pressure for a solution containing a non-volatile solute is equal to:

(A) Mole fraction of the solvent
(B) Mole fraction of the solute
(C) Molality of the solution

(D) Molarity of the solution

Q4. If the molality of a dilute solution is doubled, the value of the molal depression constant (K_f) will be:

(A) Doubled
(B) Halved
(C) Tripled
(D) Unchanged

Q5. The osmotic pressure of a solution can be increased by:

(A) Increasing the volume
(B) Increasing the temperature
(C) Decreasing the number of solute particles
(D) Removing the semi-permeable membrane

Q6. What is the cell potential (E_{cell}) of the following cell at 298 K? $Zn|Zn^{2+}(0.1M)||Cu^{2+}(0.01$
(Given $E^0_{cell} = 1.10V$)

(A) 1.10 V
(B) 1.07 V
(C) 1.13 V
(D) 1.20 V

Q7. The unit of molar conductivity (Λ_m) is:

(A) $S\,cm^2\,mol^{-1}$
(B) $S\,cm^{-1}\,mol^{-1}$
(C) $S^2\,cm^2\,mol$
(D) $\Omega\,cm^2\,mol^{-1}$

Q8. According to Kohlrausch Law, the limiting molar conductivity of an electrolyte A_xB_y is:

(A) $x\lambda_A^0 + y\lambda_B^0$

(B) $y\lambda_A^0 + x\lambda_B^0$

(C) $\lambda_A^0 + \lambda_B^0$

(D) $x\lambda_A^0 - y\lambda_B^0$

Q9. How much charge (in Faradays) is required to reduce 1 mole of MnO_4^- to Mn^{2+}?

(A) 1 F

(B) 3 F

(C) 5 F

(D) 2 F

Q10. In a hydrogen-oxygen fuel cell, the reaction occurring at the cathode is:

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

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

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

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

Q11. Which battery is used in hearing aids and watches?

(A) Leclanche cell

(B) Mercury cell

(C) Lead storage battery

(D) Ni-Cd cell

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

(A) Become 3 times

(B) Become 1/3 times

(C) Remain the same

(D) Become $\sqrt{3}$ times

Q13. The rate constant of a reaction is $k = 2.3 \times 10^{-5} L\, mol^{-1}\, s^{-1}$. 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) Total number of collisions

(B) Fraction of molecules with energy $\geq E_a$

(C) Frequency factor

(D) Steric factor

Q15. If the rate of reaction increases 2 times for every 10°C rise in temperature, how many times will the rate increase if temperature rises from 20°C to 50°C?

(A) 4

(B) 6

(C) 8

(D) 10

Q16. A catalyst increases the rate of reaction by:

(A) Increasing Activation Energy

(B) Decreasing Activation Energy
(C) Increasing Enthalpy
(D) Decreasing Enthalpy

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) Fe^{2+}

Q19. The magnetic moment of an ion with 3 unpaired electrons is approximately:

(A) 1.73 BM
(B) 2.84 BM
(C) 3.87 BM
(D) 4.90 BM

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

(A) +7 to +4
(B) +7 to +2
(C) +7 to +6

(D) +6 to +2

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

(A) Pentaaminechloridocobalt(III) chloride

(B) Chloridopentaaminecobalt(III) chloride

(C) Pentaaminechlorocobalt(II) chloride

(D) Pentaaminechloridocobalt(IV) chloride

Q22. Which of the following complexes shows linkage isomerism?

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

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

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

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

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

(A) sp^3

(B) dsp^2

(C) sp^3d^2

(D) d^2sp^3

Q24. Crystal Field Splitting Energy (CFSE) for an octahedral complex is maximum for:

(A) F^-

(B) Cl^-

(C) CN^-

(D) H_2O

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

(A) 2

(B) 3

(C) 4

(D) 0

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

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

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

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

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

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

(A) CH_3CH_2Cl

(B) $(CH_3)_2CHCl$

(C) $(CH_3)_3CCl$

(D) CH_3Cl

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

(A) Nucleophilic substitution

(B) Electrophilic substitution

(C) Addition reaction

(D) Elimination reaction

Q29. Finkelstein reaction is used for the preparation of:

(A) Alkyl fluorides

(B) Alkyl iodides

(C) Alkyl chlorides

(D) Alkyl bromides

Q30. Chirality is observed in:

(A) 2-chlorobutane

(B) 1-chlorobutane

(C) 2-chloropropane

(D) Chloromethane

Q31. Which of the following reagents is used in Lucas Test?

(A) $HCl + anhyd.ZnCl_2$

(B) $H_2SO_4 + KMnO_4$

(C) $Pd/BaSO_4$

(D) $Na/Liq.NH_3$

Q32. Phenol is more acidic than Ethanol because:

(A) Phenoxide ion is resonance stabilized

(B) Ethoxide ion is resonance stabilized

(C) Phenol has higher molecular weight

(D) Phenol is a liquid

Q33. Reimer-Tiemann reaction of phenol with $CHCl_3$ and $NaOH$ gives:

(A) Salicylic acid

(B) Salicylaldehyde

(C) Benzene

(D) Benzoic acid

Q34. Propan-1-ol and Propan-2-ol can be distinguished by:

(A) Oxidation with $KMnO_4$ followed by Iodoform test

(B) Fehling's test

(C) Tollen's test

(D) Bromine water

Q35. Williamson synthesis is used to prepare:

(A) Alcohols

(B) Ketones

(C) Ethers

(D) Aldehydes

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 most reactive towards nucleophilic addition among the following is:

(A) $HCHO$

(B) CH_3CHO

(C) CH_3COCH_3

(D) $PhCOCH_3$

Q39. The reduction of an aldehyde to a hydrocarbon using $Zn-Hg/HCl$ is known as:

(A) Wolff-Kishner reduction

(B) Clemmensen reduction

(C) Rosenmund reduction

(D) Stephen reduction

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

(A) CH_3COOH

(B) $ClCH_2COOH$

(C) $Cl_2CHCOOH$

(D) FCH_2COOH

Q41. Tollen's reagent is:

(A) Ammoniacal silver nitrate

(B) Alkaline $CuSO_4$

(C) $SnCl_2/HCl$

(D) $NaOCl$

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

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

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

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

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

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's reagent is:

(A) Benzene sulphonyl chloride

(B) Benzene sulphonic acid

(C) Phenyl isocyanide

(D) Nitrous acid

Q45. Aniline reacts with $NaNO_2 + HCl$ at 0-5°C to give:

(A) Chlorobenzene

(B) Benzene diazonium chloride

(C) Nitrobenzene

(D) Phenol

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

(A) Glucose

(B) Fructose

(C) Lactose

(D) Sucrose

Q47. The linkage present in proteins is:

(A) Glycosidic linkage
(B) Peptide linkage
(C) Phosphodiester linkage
(D) Ester linkage

Q48. Deficiency of Vitamin C causes:

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

Q49. Denaturation of proteins leads to the loss of:

(A) Primary structure
(B) Secondary and Tertiary structure
(C) Sequence of amino acids
(D) Peptide bonds

Q50. In DNA, the base Guanine pairs with:

(A) Adenine
(B) Cytosine
(C) Thymine
(D) Uracil

Detailed Solutions

Q1.

Solution

Concept: The Van't Hoff factor (i) represents the number of particles into which a solute dissociates in solution. For electrolytes, actual i may be less than the ideal value due to incomplete dissociation or ion pairing.

Solution: Given $i = 2.5$, we compare it with the expected dissociation of each option:

- $NaCl$: Dissociates into Na^+ and Cl^- $\implies i = 2$
- $CaCl_2$: Dissociates into Ca^{2+} and $2Cl^-$ $\implies i = 3$ (Actual i can be less than 3 due to incomplete dissociation, typically around 2.5)
- $AlCl_3$: Dissociates into Al^{3+} and $3Cl^-$ $\implies i = 4$
- **Glucose:** Does not dissociate (non-electrolyte) $\implies i = 1$

Since the observed Van't Hoff factor is $i = 2.5$, it is closest to $CaCl_2$, which ideally gives $i = 3$ but practically shows a lower value due to ion pairing.

Answer: (B)

Q2.

Solution

Concept: Boiling point elevation (ΔT_b) is a colligative property, meaning it depends on the total number of solute particles (ions or molecules) in the solution. The higher the number of particles, the higher the boiling point.

Solution: The elevation in boiling point is given by the formula:

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

Since the molality (m) is the same (0.1 M) for all solutions, the boiling point depends on the Van't Hoff factor (i):

- KNO_3: Dissociates into K^+ and NO_3^- $\implies i = 2$
- Na_3PO_4: Dissociates into $3Na^+$ and PO_4^{3-} $\implies i = 3 + 1 = 4$
- $BaCl_2$: Dissociates into Ba^{2+} and $2Cl^-$ $\implies i = 1 + 2 = 3$
- **Urea:** Does not dissociate (non-electrolyte) $\implies i = 1$

Na_3PO_4 has the highest Van't Hoff factor ($i = 4$), meaning it produces the maximum number of particles in solution. Therefore, it will exhibit the highest elevation in boiling point and the highest boiling point.

Answer: (B)

Q3.

Solution

Concept: Raoult's Law for non-volatile solutes states that the relative lowering of vapor pressure of a dilute solution is equal to the mole fraction of the solute present in the solution.

Solution: The mathematical expression for Raoult's Law is:

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

Where:

- P^0 is the vapor pressure of the pure solvent.
- P_s is the vapor pressure of the solution.
- $(P^0 - P_s)$ is the lowering of vapor pressure.
- $\frac{P^0-P_s}{P^0}$ is the **relative lowering of vapor pressure**.
- χ_{solute} is the **mole fraction of the solute**.

As seen from the formula, the relative lowering of vapor pressure is directly equal to the mole fraction of the solute.

Answer: (B)

Q4.

Solution

Concept: The molal depression constant (K_f), also known as the cryoscopic constant, is a characteristic property of the **solvent** only. It does not depend on the concentration (molality or molarity) of the solute in the solution.

Solution: The value of K_f is defined by the properties of the solvent through the relation:

$$K_f = \frac{R \cdot M \cdot T_f^2}{1000 \cdot \Delta H_{fus}}$$

Where:

- R is the gas constant.
- M is the molar mass of the solvent.
- T_f is the freezing point of the pure solvent.
- ΔH_{fus} is the enthalpy of fusion of the solvent.

Since K_f is a constant for a specific solvent, changing the molality of the solution (doubling, tripling, etc.) will have **no effect** on its value. While the total depression (ΔT_f) will double if molality doubles, the constant K_f remains unchanged.

Answer: (D)

Q5.

Solution

Concept: Osmotic pressure (π) is the hydrostatic pressure required to stop the flow of solvent through a semi-permeable membrane. It is a colligative property defined by the van't Hoff equation.
Solution: According to the van't Hoff equation for osmotic pressure:

$$\pi = iCRT$$

Where:

- i is the Van't Hoff factor.
- C is the molar concentration (Molarity, n/V).
- R is the gas constant.
- T is the absolute temperature (in Kelvin).

Analyzing the options:

- **Increasing Temperature (T):** Since $\pi \propto T$, increasing the temperature directly increases the osmotic pressure.
- **Increasing Volume (V):** Since $C = n/V$, increasing volume decreases concentration, which decreases π.
- **Decreasing Solute Particles:** This decreases C, which decreases π.
- **Removing the membrane:** This stops the process of osmosis entirely; osmotic pressure is no longer defined.

Therefore, increasing the temperature is the correct method to increase osmotic pressure.

Answer: (B)

Q6.

Solution

Concept: The cell potential (E_{cell}) under non-standard conditions is calculated using the **Nernst Equation**. For the given cell reaction:

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

The Nernst Equation at 298 K is:

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

Solution: 1. **Identify variables:**

- $E^0_{cell} = 1.10$ V
- $n = 2$ (number of electrons exchanged: $Zn \longrightarrow Zn^{2+} + 2e^-$)
- $Q = \frac{[Zn^{2+}]}{[Cu^{2+}]} = \frac{0.1}{0.01} = 10^1$

2. **Substitute into the equation:**

$$E_{cell} = 1.10 - \frac{0.0591}{2} \log(10)$$

Since $\log(10) = 1$:

$$E_{cell} = 1.10 - 0.02955$$

$$E_{cell} \approx 1.07045 \text{ V}$$

The cell potential is approximately 1.07 V.

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

Q7.

Solution

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

Solution: The mathematical formula for molar conductivity is:

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

Where:

- κ (Conductivity) has the unit $S\,cm^{-1}$ (where S is Siemens, or Ω^{-1}).
- M (Molarity) has the unit $mol\,L^{-1}$. In the context of cm^3, it represents $mol\,cm^{-3}$.

To find the unit of Λ_m:

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

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

Commonly, S (Siemens) is used, but it can also be expressed as $\Omega^{-1}\,cm^2\,mol^{-1}$.

Answer: (A)

Q8.

Solution

Concept: Kohlrausch's Law of independent migration of ions states that the limiting molar conductivity (Λ_m^0) of an electrolyte can be represented as the sum of the individual contributions of the anions and cations of the electrolyte.

Solution: For an electrolyte of the general formula A_xB_y, it dissociates in solution as follows:

$$A_xB_y \longrightarrow xA^{y+} + yB^{x-}$$

According to Kohlrausch Law, each ion makes a definite contribution to the total molar conductivity of an electrolyte at infinite dilution, irrespective of the nature of the other ion with which it is associated.

The mathematical expression is:

$$\Lambda_m^0(A_xB_y) = x\lambda_A^0 + y\lambda_B^0$$

Where:

- Λ_m^0 is the limiting molar conductivity of the electrolyte.
- x and y are the number of cations and anions respectively, per formula unit.
- λ_A^0 and λ_B^0 are the limiting molar conductivities of the individual ions.

Thus, the total conductivity is the sum of the products of the number of ions and their respective limiting molar conductivities.

Answer: (A)

Q9.

Solution

Concept: According to Faraday's First Law of Electrolysis, the charge (Q) required for the oxidation or reduction of 1 mole of a substance is given by $Q = nF$, where n is the number of electrons exchanged in the balanced half-reaction and F is the Faraday constant (1 F ≈ 96500 C).

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

1. **Calculate Oxidation States:**

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

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

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

2. **Write the Half-Reaction:** The reduction of Permanganate to Manganese(II) ion in acidic medium is represented as:

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

3. **Determine the Charge:** The reaction shows that **5 moles of electrons** ($5e^-$) are required to reduce 1 mole of MnO_4^-. Since the charge of 1 mole of electrons is equal to 1 Faraday (1 F):

$$\text{Charge required} = 5 \text{ Faradays (F)}$$

Answer: (C)

Q10.

Solution

Concept: A hydrogen-oxygen fuel cell generates electricity through the redox reaction between hydrogen and oxygen gases. In such cells (typically using a concentrated aqueous KOH electrolyte), oxidation occurs at the anode and reduction occurs at the cathode.

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

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

2. **At the Cathode (Reduction):** Oxygen gas is reduced in the presence of water to form hydroxide ions. This is where electrons from the external circuit are consumed.

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

3. **Overall Cell Reaction:**

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

Comparing the options, option (B) correctly represents the reduction half-reaction occurring at the cathode.

Answer: (B)

Q11.

Solution

Concept: Different types of commercial cells are designed for specific applications based on their size, voltage stability, and shelf life. Small electronic devices like hearing aids and watches require a constant voltage in a very compact form factor.

Solution: 1. **Mercury Cell:** This is a miniature primary cell that provides a constant voltage of approximately 1.35 V throughout its life. Because the overall reaction does not involve any ionic species in solution whose concentration can change, the voltage remains steady. This makes it ideal for **hearing aids, watches, and cameras**. 2. **Leclanché Cell (Dry Cell):** Used in low-drain devices like transistors and clocks. 3. **Lead Storage Battery:** A secondary (rechargeable) battery used in automobiles and inverters. 4. **Ni-Cd Cell:** A rechargeable cell used in cordless appliances, but it is larger and more expensive than mercury cells.

Therefore, the Mercury cell is the correct choice for small, precision electronic devices.

Answer: (B)

Q12.

Solution

Concept: The half-life ($t_{1/2}$) of a chemical reaction is the time required for the concentration of a reactant to reduce to one-half of its initial value. The dependency of half-life on initial concentration varies according to the order of the reaction.

Solution: For a **first-order reaction**, the rate equation is integrated to give the following expression for the half-life:

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

Where:

- k is the rate constant of the reaction.
- $t_{1/2}$ is the half-life.

From this formula, it is evident that:

- The half-life is inversely proportional to the rate constant (k).
- The expression **does not contain** the initial concentration term ($[A]_0$).

Therefore, for a first-order reaction, the half-life is **independent** of the initial concentration of the reactants. Whether the initial concentration is doubled, tripled, or reduced, the time taken for half of the reactant to be consumed remains the same.

Answer: (C)

Q13.

Solution

Concept: The order of a chemical reaction (n) can be determined by inspecting the units of its rate constant (k). The general expression for the units of a rate constant is:

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

Where n is the overall order of the reaction.

Solution: The given rate constant is $k = 2.3 \times 10^{-5} L\, mol^{-1}\, s^{-1}$. 1. **Identify the units:** The units are $L\, mol^{-1}\, s^{-1}$, which can be rewritten as $(mol\, L^{-1})^{-1} \cdot s^{-1}$. 2. **Compare with the general formula:**

$$(mol\, L^{-1})^{1-n} \cdot s^{-1} = (mol\, L^{-1})^{-1} \cdot s^{-1}$$

3. **Equate the exponents:**

$$1 - n = -1$$

$$n = 1 + 1 = 2$$

Since $n = 2$, the reaction is of the **second order**.

Answer: (C)

Q14.

Solution

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

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

Where:

- A is the **Arrhenius factor** or **frequency factor**.
- E_a is the **activation energy**.
- R is the gas constant.
- T is the absolute temperature.

Solution: According to collision theory, for a reaction to occur, molecules must collide with energy greater than or equal to the activation energy (E_a).
The term $e^{-E_a/RT}$ is the Boltzmann factor. It represents the **fraction of molecules** that possess kinetic energy equal to or greater than the activation energy at a given temperature T.

- A (the frequency factor) represents the total frequency of collisions per unit volume.
- The product $A \cdot e^{-E_a/RT}$ gives the number of effective collisions that result in a reaction.

As temperature (T) increases, the magnitude of the negative exponent decreases, causing the fraction $e^{-E_a/RT}$ to increase, which explains why reaction rates typically increase with temperature.

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

Q15.

Solution

Concept: The effect of temperature on the rate of a reaction is often expressed using the **temperature coefficient** (μ), which is the ratio of rate constants at temperatures differing by 10°C. The relationship between the change in rate and temperature rise is given by:

$$\text{Rate Ratio} = \frac{r_2}{r_1} = (\mu)^{\frac{\Delta T}{10}}$$

Solution: 1. **Identify given values:**

- Temperature coefficient (μ) = 2 (rate doubles for every 10°C rise).
- Initial temperature (T_1) = 20°C.
- Final temperature (T_2) = 50°C.

2. **Calculate the change in temperature (ΔT):**

$$\Delta T = T_2 - T_1 = 50^\circ\text{C} - 20^\circ\text{C} = 30^\circ\text{C}$$

3. **Determine the number of 10°C intervals (n):**

$$n = \frac{\Delta T}{10} = \frac{30}{10} = 3$$

4. **Calculate the increase in rate:**

$$\text{Increase Factor} = 2^n = 2^3 = 2 \times 2 \times 2 = 8$$

The rate of reaction will increase 8 times.

Answer: (C)

Q16.

Solution

Concept: A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the process. It functions by providing an **alternative reaction pathway** with a lower energy barrier.

Solution: 1. **Activation Energy (E_a):** For a reaction to occur, reactant molecules must collide with enough energy to overcome the activation energy barrier. 2. **Mechanism of Catalyst:** A catalyst lowers this threshold (E_a). By reducing the energy required to reach the transition state, a larger fraction of reactant molecules possess sufficient kinetic energy to react at a given temperature. 3. **Enthalpy (ΔH):** A catalyst does **not** affect the enthalpy of the reaction (the difference in energy between reactants and products) or the equilibrium constant. It only speeds up the rate at which equilibrium is reached.

Therefore, the primary function of a catalyst in increasing reaction speed is the reduction of the activation energy.

Answer: (B)

Q17.

Solution

Concept: Lanthanoid contraction refers to the steady decrease in the atomic and ionic radii of the lanthanoids ($Z = 58$ to 71) with the increase in atomic number. This phenomenon is a result of the unique properties of the $4f$ subshell.

Solution: The contraction is attributed to two primary factors:

- **Poor Shielding Effect:** The $4f$ electrons have a diffused shape and are far from the nucleus. Consequently, they provide very poor shielding (screening) to the outer electrons from the pull of the nucleus compared to s, p, or d electrons.
- **Increase in Nuclear Charge:** As we move across the lanthanoid series, the atomic number (number of protons) increases by one at each step. Because the $4f$ electrons fail to effectively shield this increasing positive charge, the effective nuclear charge (Z_{eff}) experienced by the outermost electrons increases.

As a result of this increased Z_{eff}, the entire electron cloud is pulled closer to the nucleus, leading to a decrease in size. Thus, both the poor shielding of $4f$ electrons and the increasing nuclear charge are responsible.

Answer: (D)

Q18.

Solution

Concept: The color of transition metal ions in aqueous solution is generally due to **d-d transitions**. For an ion to exhibit color, it must have a partially filled d-subshell (i.e., d^1 to d^9 configuration). If the d-subshell is empty (d^0) or completely filled (d^{10}), no d-d transition is possible, and the ion is colorless.

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

- **Ti^{3+}:** Neutral Ti is $[Ar]3d^2 4s^2$. Ti^{3+} is $[Ar]3d^1$. (1 unpaired electron $\implies$ **Colored**)
- **V^{3+}:** Neutral V is $[Ar]3d^3 4s^2$. V^{3+} is $[Ar]3d^2$. (2 unpaired electrons $\implies$ **Colored**)
- **Sc^{3+}:** Neutral Sc is $[Ar]3d^1 4s^2$. Sc^{3+} is $[Ar]3d^0$. (Empty d-orbital $\implies$ **Colorless**)
- **Fe^{2+}:** Neutral Fe is $[Ar]3d^6 4s^2$. Fe^{2+} is $[Ar]3d^6$. (4 unpaired electrons $\implies$ **Colored**)

Since Sc^{3+} has a d^0 configuration, there are no electrons available in the d-orbital to undergo excitation (d-d transition) upon absorption of visible light. Therefore, Sc^{3+} is colorless.

Answer: (C)

Q19.

Solution

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

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

Where:

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

Solution: Given that the ion has $n = 3$ unpaired electrons: 1. **Substitute the value into the formula:**

$$\mu = \sqrt{3(3+2)}$$

$$\mu = \sqrt{3 \times 5}$$

$$\mu = \sqrt{15}$$

2. **Calculate the numerical value:** Since $\sqrt{9} = 3$ and $\sqrt{16} = 4$, the value must be close to 4.

$$\sqrt{15} \approx 3.87 \text{ BM}$$

Comparison with other common values:

- $n = 1 \implies \mu = \sqrt{3} \approx 1.73$ BM
- $n = 2 \implies \mu = \sqrt{8} \approx 2.83$ BM
- $n = 3 \implies \mu = \sqrt{15} \approx 3.87$ BM
- $n = 4 \implies \mu = \sqrt{24} \approx 4.90$ BM

Answer: (C)

Q20.

Solution

Concept: Potassium permanganate ($KMnO_4$) acts as a powerful oxidizing agent in acidic medium. During its reaction with reducing agents like oxalic acid ($H_2C_2O_4$), the Manganese (Mn) atom undergoes reduction, while the carbon in oxalic acid is oxidized to carbon dioxide (CO_2).

Solution: 1. **Determine the initial oxidation state of Mn in $KMnO_4$:** In $KMnO_4$, let the oxidation state of Mn be x. Potassium (K) is +1 and Oxygen (O) is −2.

$$(+1) + x + 4(-2) = 0 \implies 1 + x - 8 = 0 \implies x = +7$$

2. **Determine the final oxidation state of Mn in acidic medium:** In an acidic medium (usually using H_2SO_4), the permanganate ion (MnO_4^-) is reduced to the Manganese(II) ion (Mn^{2+}). The balanced reduction half-reaction is:

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

The oxidation state of Mn in Mn^{2+} is **+2**.

3. **Conclusion:** The oxidation state of Manganese changes from **+7** (in MnO_4^-) to **+2** (in Mn^{2+}). This represents a gain of 5 electrons per Mn atom.

Answer: (B)

Q21.

Solution

Concept: To name a coordination compound according to IUPAC nomenclature, follow these steps: 1. Name the ligands in alphabetical order before the central metal atom. 2. Use prefixes (di, tri, tetra, penta, etc.) to indicate the number of ligands. 3. For anionic ligands, change the ending (e.g., chloride becomes chlorido). Neutral ligands use specific names (e.g., NH_3 is ammine). 4. Write the oxidation state of the central metal in Roman numerals in parentheses. 5. Name the counter ion outside the coordination sphere last.

Solution: 1. **Identify Ligands and Metal:**

- Central metal: Cobalt (Co)
- Ligands: 5 Ammine (NH_3) and 1 Chlorido (Cl^-)

2. **Calculate the Oxidation State of Cobalt (x):**

- NH_3 is a neutral ligand (charge = 0).
- Cl inside and outside the sphere has a charge of -1.

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

$$x - 3 = 0 \implies x = +3$$

So, it is Cobalt(III).

3. **Construct the Name:**

- Alphabetical order: Ammine comes before Chlorido.
- Coordination sphere: **Pentaaminechloridocobalt(III)**
- Counter ion: **chloride**

Cl2]

Putting it all together, the name is **Pentaaminechloridocobalt(III) chloride**. Note that according to the latest IUPAC guidelines, "chlorido" is preferred over "chloro".

Answer: (A)

Q22.

Solution

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

Common ambidentate ligands include:

- NO_2^- (Nitrito-N, bonded via N; or Nitrito-O, bonded via O)
- SCN^- (Thiocyanato-S, bonded via S; or Isothiocyanato-N, bonded via N)
- CN^- (Cyanido, bonded via C; or Isocyanido, bonded via N)

Solution: Let's analyze the options:

- **(A)** $[Co(NH_3)_5Cl]SO_4$**:** This complex shows **ionization isomerism** (exchange of Cl^- and SO_4^{2-} between the coordination and ionization spheres).
- **(B)** $[Co(NH_3)_5(NO_2)]Cl_2$**:** This contains the **nitro ligand** (NO_2^-), which is ambidentate. It can exist as the "nitro" form (Co–NO_2) or the "nitrito" form (Co–ONO). Therefore, it exhibits linkage isomerism.
- **(C)** $[Co(en)_3]Cl_3$**:** This complex shows **optical isomerism** because it is a tris-chelate complex with no plane of symmetry.
- **(D)** $[Pt(NH_3)_2Cl_2]$**:** This complex shows **geometrical isomerism** (cis and trans forms).

Since option (B) contains an ambidentate ligand, it is the correct answer.

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

Q23.

Solution

Concept: To determine the hybridization of a coordination complex, we apply the **Valence Bond Theory (VBT)**. This involves identifying the oxidation state of the metal, its electronic configuration, and the nature of the ligands (strong field vs. weak field).

Solution: 1. **Oxidation State of Nickel (Ni):** Let x be the oxidation state of Ni. Since CN^- is a unidentate ligand with a -1 charge:

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

The metal ion is Ni^{2+}.

2. **Electronic Configuration:**

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

In the $3d$ subshell, there are 8 electrons. In a free ion, these occupy five orbitals, leaving two unpaired electrons.

3. **Nature of Ligand and Pairing:** Cyanide (CN^-) is a **strong field ligand** (according to the Spectrochemical Series). It provides enough energy to force the unpaired electrons in the $3d$ orbitals to pair up.

$$3d^8 \text{ (unpaired)} \xrightarrow{CN^-} 3d^8 \text{ (paired)}$$

This pairing clears one $3d$ orbital.

2-]

4. **Hybridization:** Nickel needs 4 empty orbitals to accommodate 4 pairs of electrons from the 4 CN^- ligands. The available orbitals are:

- One $3d$ orbital (vacated by pairing)
- One $4s$ orbital
- Two $4p$ orbitals

These four orbitals undergo hybridization to form dsp^2 hybrid orbitals. This resulting geometry is **square planar**. Since all electrons are paired, the complex is diamagnetic.

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

Q24.

Solution

Concept: The Crystal Field Splitting Energy (Δ_o) represents 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 nature of the ligand, as described by the **Spectrochemical Series**.

[Image of crystal field splitting in octahedral complex]

Solution: The Spectrochemical Series is an experimentally determined series that arranges ligands in increasing order of their field strength (ability to cause d-orbital splitting):

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

1. **Analyze the given ligands:**

    - **F^- and Cl^-:** These are halide ions and are considered **weak field ligands**. They cause small splitting.
    - **H_2O:** This is a neutral ligand and falls in the middle of the series (often a boundary between weak and strong).
    - **CN^-:** The cyanide ion is a **strong field ligand** located towards the end of the series.

2. **Conclusion:** Because CN^- is the strongest field ligand among the choices, it produces the greatest repulsion with the metal d-orbitals, resulting in the **maximum Crystal Field Splitting Energy** (Δ_o). Strong field ligands like CN^- typically result in low-spin complexes.

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

Q25.

Solution

Concept: Geometrical isomerism (also known as cis-trans isomerism) occurs in coordination compounds due to different possible spatial arrangements of ligands around the central metal atom. For a square planar complex of the type $[MA_2B_2]$, two distinct geometrical arrangements exist.

Solution: 1. **Identify Coordination Geometry:** The complex $[Pt(NH_3)_2Cl_2]$ (known as Cisplatin or Transplatin depending on the isomer) has a coordination number of 4. Since Pt^{2+} is a d^8 metal ion with strong-field-like behavior in the presence of most ligands, it forms a **square planar** geometry.

2. **Determine Isomers:** In a square planar arrangement for the formula $[MA_2B_2]$:

- **Cis-isomer:** The two identical ligands (NH_3 or Cl) are adjacent to each other (at an angle of 90°).
- **Trans-isomer:** The two identical ligands are opposite to each other (at an angle of 180°).

3. **Note on Biological Significance:** The *cis* form, known as **Cisplatin**, is a widely used anti-cancer drug, whereas the *trans* form is physiologically inactive. This highlights how crucial geometrical arrangement is to the properties of a molecule.

Since there are exactly two arrangements (cis and trans), the number of geometrical isomers is 2.

Answer: (A)

Q26.

Solution

Concept: According to **Valence Bond Theory (VBT)**, octahedral complexes are classified into two types based on the d-orbitals used for hybridization (sp^3d^2 or d^2sp^3):

- **Inner Orbital Complex (d^2sp^3):** Uses $(n-1)d$ orbitals. Usually formed with **strong field ligands** that cause electron pairing.
- **Outer Orbital Complex (sp^3d^2):** Uses nd orbitals. Usually formed with **weak field ligands** that cannot force electron pairing.

Solution: Let's analyze the electronic configuration and ligand strength for each option:
1. **(A)** $[Co(NH_3)_6]^{3+}$**:** Cobalt is in +3 state ($3d^6$). NH_3 acts as a **strong field ligand** with Co^{3+}, forcing electrons to pair up, leaving two $3d$ orbitals vacant. Hybridization: d^2sp^3 (Inner orbital). 2. **(B)** $[Fe(CN)_6]^{4-}$**:** Iron is in +2 state ($3d^6$). CN^- is a **very strong field ligand**, causing pairing. Hybridization: d^2sp^3 (Inner orbital). 3. **(C)** $[CoF_6]^{3-}$**:** Cobalt is in +3 state ($3d^6$). F^- is a **weak field ligand**. It cannot force the $3d$ electrons to pair up. To accommodate 6 ligand pairs, the metal uses the outer $4d$ orbitals.
3- showing sp3d2 hybridization]
Hybridization: $s + p_x + p_y + p_z + d_{x^2-y^2} + d_{z^2}$ of the **4th shell** $\implies$ sp^3d^2 **(Outer orbital)**.
4. **(D)** $[Mn(CN)_6]^{3-}$**:** Manganese is in +3 state ($3d^4$). CN^- is a **strong field ligand**, causing pairing to vacate $3d$ orbitals. Hybridization: d^2sp^3 (Inner orbital).
Therefore, $[CoF_6]^{3-}$ is the outer orbital complex.

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

Q27.

Solution

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

Solution: 1. **Identify the carbocations formed:**

- **(A)** $CH_3CH_2Cl \rightarrow CH_3CH_2^+$ (Ethyl carbocation, **Primary -** 1°)
- **(B)** $(CH_3)_2CHCl \rightarrow (CH_3)_2CH^+$ (Isopropyl carbocation, **Secondary -** 2°)
- **(C)** $(CH_3)_3CCl \rightarrow (CH_3)_3C^+$ (tert-Butyl carbocation, **Tertiary -** 3°)
- **(D)** $CH_3Cl \rightarrow CH_3^+$ (Methyl carbocation, **Least stable**)

2. **Stability Order:** Carbocations are stabilized by the inductive effect $(+I)$ and hyperconjugation from adjacent alkyl groups. The stability order is:

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

3. **Conclusion:** Since the **tert-butyl chloride** (3°) forms the most stable carbocation, it lowers the activation energy for the first step, making it the **fastest** to react via the S_N1 mechanism. Conversely, CH_3Cl and CH_3CH_2Cl prefer the S_N2 mechanism.

Answer: (C)

Q28.

Solution

Concept: The reaction of an alkyl halide ($R - X$) with aqueous potassium hydroxide (KOH) involves the replacement of a halide ion (X^-) by a hydroxyl group (OH^-). To understand the nature of this reaction, we must identify the attacking species.

Solution: 1. **Identify the Reagent:** Aqueous KOH dissociates into K^+ and OH^- ions. The OH^- ion is a **nucleophile** (a nucleus-loving species) because it possesses a lone pair of electrons and a negative charge, seeking a positively charged center. 2. **The Reaction Center:** In an alkyl halide ($R - X$), the carbon atom bonded to the halogen is **electrophilic** due to the higher electronegativity of the halogen, which creates a partial positive charge (δ^+) on the carbon. 3. **The Process:** The nucleophile (OH^-) attacks the electrophilic carbon, and the halide ion (leaving group) departs. 4. **Classification:** Since one nucleophile (X^-) is being replaced by another nucleophile (OH^-), the reaction is classified as **Nucleophilic Substitution**. Depending on the structure of the alkyl halide, this can follow either an S_N1 or S_N2 pathway.

Note on aqueous vs. alcoholic KOH:

- **Aqueous KOH:** Favors **Substitution** to form alcohols.
- **Alcoholic KOH:** Favors **Elimination** (Dehydrohalogenation) to form alkenes, as the $C_2H_5O^-$ ion acts as a strong base.

Answer: (A)

Q29.

Solution

Concept: The **Finkelstein reaction** is a classic organic reaction used for the synthesis of alkyl iodides. It is a specific type of **halogen exchange reaction** that typically follows an S_N2 mechanism.

Solution: 1. **The Reaction:** In this process, an alkyl chloride ($R - Cl$) or alkyl bromide ($R - Br$) is treated with **sodium iodide** (NaI) in the presence of **dry acetone**.

$$R - X + NaI \xrightarrow{\text{Acetone}} R - I + NaX$$

(where $X = Cl, Br$)

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

Comparison with Swarts Reaction:

- **Finkelstein Reaction:** Used to prepare **alkyl iodides**.
- **Swarts Reaction:** Used to prepare **alkyl fluorides** using metallic fluorides like AgF, Hg_2F_2, CoF_2, or SbF_3.

Answer: (B)

Q30.

Solution

Concept: A molecule is considered **chiral** if it possesses a **chiral center** (or stereocenter). A chiral center is typically a carbon atom that is bonded to **four different groups** or atoms. Such molecules are non-superimposable on their mirror images.

Solution: To identify chirality, we must examine the substituents on the carbon atoms for each molecule:

- **(A) 2-chlorobutane:** The structure is $CH_3 - \overset{*}{C}H(Cl) - CH_2 - CH_3$. The second carbon $(C2)$ is bonded to: 1. A Hydrogen atom $(-H)$ 2. A Chlorine atom $(-Cl)$ 3. A Methyl group $(-CH_3)$ 4. An Ethyl group $(-CH_2CH_3)$ Since all four groups are different, $C2$ is a **chiral center**.
- **(B) 1-chlorobutane:** $Cl - CH_2 - CH_2 - CH_2 - CH_3$. Each carbon is bonded to at least two identical hydrogen atoms. No chiral center.
- **(C) 2-chloropropane:** $CH_3 - CH(Cl) - CH_3$. The central carbon is bonded to **two identical methyl groups**. No chiral center.
- **(D) Chloromethane:** CH_3Cl. The carbon is bonded to **three identical hydrogen atoms**. No chiral center.

Therefore, chirality is only observed in 2-chlorobutane.

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

Q31.

Solution

Concept: The **Lucas Test** is used to distinguish between primary (1°), secondary (2°), and tertiary (3°) alcohols. The test is based on the difference in the rate of reaction of these alcohols with the Lucas reagent to form alkyl chlorides.

Solution: 1. **The Reagent:** The Lucas reagent consists of a mixture of **concentrated Hydrochloric acid** (HCl) and **anhydrous Zinc chloride** ($ZnCl_2$).

2. **The Reaction:** The alcohol reacts with HCl in the presence of $ZnCl_2$ (which acts as a Lewis acid catalyst) to form an insoluble alkyl chloride, which appears as **turbidity** (cloudiness) in the solution.

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

3. **Observations:**

- **Tertiary** (3°) **alcohols:** React immediately, producing turbidity instantly at room temperature.
- **Secondary** (2°) **alcohols:** React within 5 to 10 minutes to produce turbidity.
- **Primary** (1°) **alcohols:** Do not produce turbidity at room temperature; they only react upon heating.

4. **Analysis of other options:**

- **(B)** $H_2SO_4 + KMnO_4$**:** A strong oxidizing agent.
- **(C)** $Pd/BaSO_4$**:** Known as Lindlar's catalyst (used for partial hydrogenation).
- **(D)** $Na/Liq.NH_3$**:** Used in Birch reduction.

Answer: (A)

Q32.

Solution

Concept: The acidity of a compound is determined by the stability of its conjugate base formed after the loss of a proton (H^+). A more stable conjugate base corresponds to a stronger acid.

Solution: 1. **Comparison of Conjugate Bases:**

- **Phenol (C_6H_5OH):** Loses a proton to form the **Phenoxide ion** ($C_6H_5O^-$).
- **Ethanol (C_2H_5OH):** Loses a proton to form the **Ethoxide ion** ($C_2H_5O^-$).

2. **Stability Analysis:**

- **Phenoxide Ion:** The negative charge on the oxygen atom is delocalized into the benzene ring through **resonance**. This resonance stabilization spreads the negative charge over the ortho and para positions of the ring, making the ion more stable and less likely to re-bind with a proton.
- **Ethoxide Ion:** The negative charge is localized strictly on the oxygen atom. Furthermore, the ethyl group exerts an **inductive effect** ($+I$), which pushes electron density toward the already negatively charged oxygen, destabilizing the ion.

3. **Conclusion:** Because the phenoxide ion is significantly more stable due to resonance than the ethoxide ion, Phenol ($pK_a \approx 10$) is much more acidic than Ethanol ($pK_a \approx 16$).

Note: Physical properties like molecular weight or state of matter do not determine chemical acidity.

Answer: (A)

Q33.

Solution

Concept: The **Reimer-Tiemann reaction** is a classic organic chemical reaction used for the ortho-formylation of phenols. It involves the treatment of phenol with chloroform ($CHCl_3$) in the presence of an aqueous alkali (like $NaOH$ or KOH).

Solution: 1. **The Reaction:** When phenol is heated with chloroform and aqueous sodium hydroxide, an aldehyde group ($-CHO$) is introduced onto the benzene ring, primarily at the **ortho** position.

$$\text{Phenol} + CHCl_3 + 3NaOH \xrightarrow{\text{343 K}} \text{Salicylaldehyde} + 3NaCl + 2H_2O$$

2. **Mechanism Highlights:**

- The reaction proceeds via the formation of a highly reactive intermediate called **dichlorocarbene** ($:CCl_2$), which acts as an electrophile.
- The electrophile attacks the phenoxide ion (formed by the reaction of phenol with $NaOH$).
- Hydrolysis of the intermediate substituted benzal chloride yields the final product.

3. **The Product:** The IUPAC name of the product is 2-hydroxybenzaldehyde, commonly known as **Salicylaldehyde**.

[Image of chemical structure of salicylaldehyde]

Note: If carbon tetrachloride (CCl_4) is used instead of chloroform ($CHCl_3$), the product formed is **Salicylic acid**. Since the question specifies $CHCl_3$, the correct product is Salicylaldehyde.

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

Q34.

Solution

Concept: To distinguish between primary and secondary alcohols, we can utilize their oxidation products. Primary alcohols (1°) oxidize to aldehydes and then to carboxylic acids, while secondary alcohols (2°) oxidize to ketones. Ketones containing a **methyl keto group** ($-COCH_3$) respond to the **Iodoform test**.

Solution: 1. **Oxidation with $KMnO_4$:**

- **Propan-1-ol ($CH_3CH_2CH_2OH$):** Being a primary alcohol, it is oxidized to **Propanoic acid** (CH_3CH_2COOH).
- **Propan-2-ol ($CH_3CH(OH)CH_3$):** Being a secondary alcohol, it is oxidized to **Propanone** (Acetone, CH_3COCH_3).

2. **Iodoform Test:** The Iodoform test requires the presence of a $CH_3CH(OH)-$ group in alcohols or a CH_3CO- group in carbonyl compounds.

- **From Propan-1-ol:** The oxidation product is Propanoic acid. It does **not** have a methyl keto group and will give a **negative** Iodoform test (no yellow precipitate).
- **From Propan-2-ol:** The oxidation product is Propanone (CH_3COCH_3). Since it contains the methyl keto group, it reacts with $I_2/NaOH$ to form a **yellow precipitate** of Triiodomethane (CHI_3).

3. **Analysis of other options:**

- **(B) (C):** Fehling's and Tollen's tests are used to distinguish aldehydes from ketones; they do not directly distinguish these two alcohols.
- **(D) Bromine water:** This is used to test for unsaturation (alkenes/alkynes) or phenol/aniline; both alcohols are saturated and will not react.

Answer: (A)

Q35.

Solution

Concept: The **Williamson synthesis** is a vital organic reaction used for the synthesis of symmetrical and unsymmetrical **ethers**. It is an S_N2 reaction involving a nucleophilic attack by an alkoxide ion on a primary alkyl halide.

Solution: 1. **The Reagents:** The reaction requires an **alkyl halide** $(R-X)$ and a **sodium alkoxide** $(R'-ONa)$.

$$R'-O^{-}Na^{+}+R-X\rightarrow R'-O-R+NaX$$

2. **Mechanism:**

- The alkoxide ion $(R'-O^{-})$ acts as a strong nucleophile.
- It attacks the electrophilic carbon of the alkyl halide from the backside, displacing the halide ion in a single concerted step.

3. **Limitations:**

- For the best yield of ethers, the alkyl halide should be **primary** (1°).
- If a secondary (2°) or tertiary (3°) alkyl halide is used, **elimination** becomes the major pathway due to the basic nature of the alkoxide, leading to the formation of **alkenes** instead of ethers.

4. **Conclusion:** Since the primary product of this reaction is an organic compound with an $R-O-R'$ linkage, the process is used to prepare **ethers**.

Answer: (C)

Q36.

Solution

Concept: Aldol condensation is a reaction exhibited by aldehydes and ketones that possess at least one **α-hydrogen** atom. An α-hydrogen is a hydrogen atom attached to the carbon atom immediately adjacent to the carbonyl group ($C = O$).

In the presence of a dilute alkali (like $NaOH$ or KOH), the α-hydrogen is acidic enough to be removed, forming a nucleophilic enolate ion that attacks another carbonyl molecule to form a β-hydroxy aldehyde (aldol) or β-hydroxy ketone (ketol).

Solution: To determine which compound does **not** undergo this reaction, we must check for the presence of α-hydrogens:

- **(A)** CH_3CHO **(Acetaldehyde):** The carbonyl carbon is attached to a methyl group (CH_3). This carbon has **three α-hydrogens**. It undergoes Aldol condensation.
- **(B)** CH_3COCH_3 **(Acetone):** The carbonyl carbon is flanked by two methyl groups. It has **six α-hydrogens**. It undergoes Aldol condensation.
- **(C)** $HCHO$ **(Formaldehyde):** The carbonyl carbon is bonded only to two hydrogen atoms ($H - CO - H$). There is **no carbon atom** adjacent to the carbonyl group; therefore, there are **zero α-hydrogens**.
- **(D)** CH_3CH_2CHO **(Propionaldehyde):** The carbon adjacent to the carbonyl group is a $-CH_2-$ group. It has **two α-hydrogens**. It undergoes Aldol condensation.

Conclusion: Since Formaldehyde ($HCHO$) lacks α-hydrogens, it cannot form an enolate ion and therefore **does not undergo Aldol condensation**. Instead, it undergoes the **Cannizzaro reaction** when treated with concentrated alkali.

Answer: (C)

Q37.

Solution

Concept: The **Cannizzaro reaction** is a redox (disproportionation) reaction exhibited by aldehydes that **do not have an α-hydrogen atom**. In the presence of a concentrated alkali (like 50% NaOH or KOH), one molecule of the aldehyde is reduced to an alcohol, while another molecule is oxidized to a carboxylic acid salt.

Solution: To identify which compound gives the Cannizzaro reaction, we must check for the **absence** of α-hydrogens:

- **(A) Formaldehyde ($HCHO$):** The carbonyl carbon is bonded only to hydrogen atoms. There is no carbon atom adjacent to the carbonyl group (α-carbon); hence, it has **no α-hydrogens**. It undergoes the Cannizzaro reaction.
- **(B) Acetaldehyde (CH_3CHO):** It has three α-hydrogens. It undergoes **Aldol condensation** instead.
- **(C) Acetone (CH_3COCH_3):** It has six α-hydrogens. It undergoes **Aldol condensation**.
- **(D) Propionaldehyde (CH_3CH_2CHO):** It has two α-hydrogens. It undergoes **Aldol condensation**.

Reaction for Formaldehyde:

$$2HCHO + \text{conc. } NaOH \rightarrow \underset{\text{Methanol}}{CH_3OH} + \underset{\text{Sodium formate}}{HCOONa}$$

Other common examples of compounds giving the Cannizzaro reaction include **Benzaldehyde** (C_6H_5CHO) and **Trimethylacetaldehyde** ($(CH_3)_3CCHO$), as they also lack α-hydrogens.

Answer: (A)

Q38.

Solution

Concept: Nucleophilic addition is the characteristic reaction of carbonyl compounds (aldehydes and ketones). The reactivity of a carbonyl group ($C = O$) toward a nucleophile depends on two main factors:

(a) **Electronic Effect (+I effect):** Alkyl groups are electron-donating. They reduce the partial positive charge (δ^+) on the carbonyl carbon, making it less attractive to a nucleophile.

(b) **Steric Effect:** Larger groups around the carbonyl carbon create "crowding," hindering the approach of the nucleophile.

Solution: Let's compare the given compounds:

- **(A)** $HCHO$ **(Formaldehyde):** The carbonyl carbon is attached to two tiny hydrogen atoms. There is **minimal steric hindrance** and **no** $+I$ **effect** from alkyl groups. The δ^+ charge is most intense here.
- **(B)** CH_3CHO **(Acetaldehyde):** One methyl group (CH_3) is present. It donates electrons ($+I$) and increases steric hindrance compared to $HCHO$.
- **(C)** CH_3COCH_3 **(Acetone):** Two methyl groups are present. These significantly reduce the electrophilicity of the carbon and increase steric crowding.
- **(D)** $PhCOCH_3$ **(Acetophenone):** It has a bulky phenyl ring and a methyl group. Furthermore, the carbonyl group is in **resonance** with the benzene ring, which significantly stabilizes the δ^+ charge, making it the least reactive.

Reactivity Order: $HCHO > CH_3CHO > CH_3COCH_3 > PhCOCH_3$
Formaldehyde is the most reactive because its carbonyl carbon is the most electrophilic and the least sterically hindered.

Answer: (A)

Q39.

Solution

Concept: The conversion of a carbonyl group ($> C = O$) of aldehydes or ketones into a methylene group ($> CH_2$) is a deoxygenation reaction. There are two primary methods used for this reduction to hydrocarbons, differing mainly in the reaction conditions (acidic vs. basic).

Solution: 1. **Analyze the Reagent:** The combination of **Zinc amalgam** ($Zn - Hg$) and **concentrated Hydrochloric acid** (HCl) defines the reagents for the **Clemmensen reduction**.

2. **The Reaction:**

$$\text{R-CHO} \xrightarrow{Zn-Hg/\text{conc. } HCl} \text{R-CH}_3 + H_2O$$

This method is particularly useful for compounds that are stable in strong acids.

3. **Distinguish from other options:**

- **(A) Wolff-Kishner reduction:** Achieves the same result (Carbonyl → Alkane) but uses **Hydrazine** (NH_2NH_2) and KOH in ethylene glycol. It is the **basic** counterpart to Clemmensen.
- **(B) Clemmensen reduction:** Uses **acidic** conditions ($Zn - Hg/HCl$).
- **(C) Rosenmund reduction:** Converts an acid chloride to an aldehyde using $H_2/Pd{-}BaSO_4$.
- **(D) Stephen reduction:** Converts a nitrile to an aldehyde using $SnCl_2/HCl$.

Since the question specifies $Zn - Hg/HCl$, the reaction is the Clemmensen reduction.

Answer: (B)

Q40.

Solution

Concept: The acidity of a carboxylic acid is determined by the stability of its conjugate base, the carboxylate ion ($RCOO^-$). Any factor that withdraws electron density away from the negatively charged carboxylate group will stabilize it, thereby increasing the acidity of the parent acid.
Factors affecting acidity:

- **Inductive Effect ($-I$ effect):** Electron-withdrawing groups (EWGs) like halogens (F, Cl, Br, I) increase acidity.
- **Number of EWGs:** More electron-withdrawing groups result in higher acidity.
- **Electronegativity:** A more electronegative atom exerts a stronger $-I$ effect ($F > Cl > Br > I$).

Solution: Let's compare the given options:

- **(A)** CH_3COOH **(Acetic acid):** The methyl group is electron-donating ($+I$ effect), which destabilizes the carboxylate ion. This is the weakest acid in the list.
- **(B)** $ClCH_2COOH$ **(Chloroacetic acid):** One chlorine atom exerts a $-I$ effect, increasing acidity.
- **(C)** $Cl_2CHCOOH$ **(Dichloroacetic acid):** Two chlorine atoms exert a combined $-I$ effect, making it significantly more acidic than chloroacetic acid.
- **(D)** FCH_2COOH **(Fluoroacetic acid):** While Fluorine is more electronegative than Chlorine, it is only a single atom.

Comparison of (C) and (D): The presence of **two** chlorine atoms in $Cl_2CHCOOH$ provides a stronger cumulative electron-withdrawing effect than a **single** fluorine atom in FCH_2COOH.
Order of Acidity: $Cl_2CHCOOH > FCH_2COOH > ClCH_2COOH > CH_3COOH$
Therefore, Dichloroacetic acid is the strongest acid among the given options.

Answer: (C)

Q41.

Solution

Concept: **Tollen's reagent** is a mild oxidizing agent used to distinguish aldehydes from ketones. Aldehydes are easily oxidized to carboxylate ions, while the silver ions in the reagent are reduced to metallic silver.

Solution: 1. **Composition:** Tollen's reagent is a solution of **Ammoniacal Silver Nitrate**. It is prepared by adding a dilute solution of ammonium hydroxide (NH_4OH) to silver nitrate ($AgNO_3$) until the initial precipitate of silver oxide (Ag_2O) just dissolves. 2. **Active Species:** The active oxidizing species in the reagent is the complex ion:

$$[Ag(NH_3)_2]^+$$

(Diamminesilver(I) complex)

3. **The Reaction:** When an aldehyde is heated with Tollen's reagent, the aldehyde is oxidized to a carboxylate ion, and Ag^+ is reduced to metallic silver (Ag), which deposits on the inner wall of the test tube, forming a **Silver Mirror**.

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

4. **Analysis of other options:**

- **(B) Alkaline $CuSO_4$:** This is the basis for **Fehling's solution** (specifically Fehling's A is $CuSO_4$ and Fehling's B is alkaline sodium potassium tartrate).
- **(C) $SnCl_2/HCl$:** This is the reagent for the **Stephen reduction** (Nitriles → Aldehydes).
- **(D) $NaOCl$:** Sodium hypochlorite, often used as a household bleach or in the **Haloform reaction**.

Answer: (A)

Q42.

Solution

Concept: The basic strength of aliphatic amines in **aqueous solution** is determined by a complex interplay of three factors:

(a) **Inductive Effect ($+I$):** Alkyl groups are electron-donating, increasing the electron density on Nitrogen and making the lone pair more available for donation. Order: $3^\circ > 2^\circ > 1^\circ > NH_3$.

(b) **Solvation Effect (Hydration):** In water, the substituted ammonium ion is stabilized by hydrogen bonding with water molecules. Smaller ions are better solvated. Order: $NH_3 > 1^\circ > 2^\circ > 3^\circ$.

(c) **Steric Hindrance:** Bulky alkyl groups hinder the approach of a proton to the Nitrogen atom.

Solution: For **Methyl-substituted amines** ($-CH_3$), the small size of the methyl group allows the inductive effect and solvation effect to find a specific balance.

- The **Secondary amine** ($(CH_3)_2NH$) is always the strongest base because it strikes the best balance between the inductive effect and hydration.
- In the case of methyl groups, the hydration effect is quite significant, which pushes the **Primary amine** (CH_3NH_2) to be stronger than the **Tertiary amine** ($(CH_3)_3N$).
- **Ammonia** (NH_3) lacks any electron-donating alkyl groups and is thus the weakest.

Correct Order (for Methyl amines in water):

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

$$(2^\circ > 1^\circ > 3^\circ > \text{Ammonia})$$

Note: If the alkyl group were **Ethyl** ($-C_2H_5$), the order would change to $2^\circ > 3^\circ > 1^\circ > NH_3$ because the larger ethyl groups make the inductive effect more dominant over solvation for the tertiary amine.

Answer: (A)

Q43.

Solution

Concept: The **Gabriel phthalimide synthesis** is a specific and highly effective method used for the preparation of **primary aliphatic amines** ($R - NH_2$). It involves a nucleophilic substitution reaction followed by hydrolysis, ensuring the production of a pure primary amine without contamination from secondary or tertiary amines.

Solution: The reaction proceeds in three main steps:

(a) **Formation of nucleophile:** Phthalimide reacts with ethanolic KOH to form potassium phthalimide.

(b) **Nucleophilic attack (S_N2):** The phthalimide anion reacts with a **primary alkyl halide** ($R - X$) to form N-alkylphthalimide.

(c) **Hydrolysis:** Basic hydrolysis (or reaction with hydrazine) of N-alkylphthalimide yields the **primary aliphatic amine** and a phthalate salt.

Key Limitation: Aryl halides (like chlorobenzene) do not undergo nucleophilic substitution (S_N2) with the phthalimide anion because the $C - X$ bond in haloarenes has partial double-bond character. Therefore, **primary aromatic amines** (like aniline) **cannot** be prepared by this method.

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

Q44.

Solution

Concept: The **Hinsberg test** is a chemical method used to distinguish between primary (1°), secondary (2°), and tertiary (3°) amines. It is based on the reaction of amines with **Hinsberg's reagent** and the subsequent solubility of the product in an alkali (like $NaOH$).

Solution: 1. **The Reagent:** Hinsberg's reagent is **Benzene sulphonyl chloride** ($C_6H_5SO_2Cl$).

2. **Observations:**

- **Primary** (1°) **Amines:** React to form an N-alkylbenzene sulphonamide. Because of the presence of an acidic hydrogen on the nitrogen, the product is **soluble in alkali**.
- **Secondary** (2°) **Amines:** React to form an N,N-dialkylbenzene sulphonamide. Since there is no acidic hydrogen on the nitrogen, the product is **insoluble in alkali**.
- **Tertiary** (3°) **Amines:** Do **not react** with benzene sulphonyl chloride under ordinary conditions.

3. **Analysis of other options:**

- **(B) Benzene sulphonic acid:** The parent acid of the reagent, but lacks the reactive chloride for substitution.
- **(C) Phenyl isocyanide:** The product of the **Carbylamine reaction**, known for its foul smell.
- **(D) Nitrous acid** (HNO_2)**:** Used in the **Diazotization reaction** to distinguish aliphatic and aromatic amines.

Answer: (A)

Q45.

Solution

Concept: The reaction of primary aromatic amines with nitrous acid (HNO_2, prepared in situ from $NaNO_2$ and HCl) at low temperatures (0 – 5°C) is known as the **Diazotization reaction**. This reaction is a fundamental step in the synthesis of various substituted benzene derivatives.

Solution: 1. **The Reactants:** Aniline ($C_6H_5NH_2$) reacts with nitrous acid, which is generated by the reaction of **sodium nitrite** ($NaNO_2$) and **hydrochloric acid** (HCl). 2. **Reaction Conditions:** It is critical to maintain the temperature between 0°**C and** 5°**C**. If the temperature rises, the product decomposes to form phenol. 3. **The Product:** Under these cold conditions, the amino group ($-NH_2$) is converted into the **diazonium salt** group ($-N_2^+Cl^-$).

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

The resulting compound is **Benzene diazonium chloride**.

4. **Analysis of other options:**

- **(A) Chlorobenzene:** Formed if benzene diazonium chloride reacts with Cu_2Cl_2/HCl (Sandmeyer reaction).
- **(C) Nitrobenzene:** Formed by the nitration of benzene with conc. HNO_3 and H_2SO_4.
- **(D) Phenol:** Formed if the diazonium salt solution is **warmed** with water.

Answer: (B)

Q46.

Solution

Concept: A **reducing sugar** is any carbohydrate that is capable of acting as a reducing agent because it has a free aldehyde group or a free ketone group. In cyclic forms, this means having a free **anomeric hydroxyl group** (hemiacetal or hemiketal group) that can open into a chain. Reducing sugars give a positive result with Tollen's reagent and Fehling's solution.
[Image of reducing vs non-reducing sugar structures]
Solution: To identify the non-reducing sugar, we examine the linkage between the monosaccharide units:

- **(A) Glucose:** A monosaccharide with a free aldehyde group at C_1. It is a **reducing sugar**.
- **(B) Fructose:** A monosaccharide with a free ketone group at C_2. It is a **reducing sugar** (it tautomerizes to an aldehyde in alkaline reagents).
- **(C) Lactose:** A disaccharide composed of β-D-galactose and β-D-glucose. The anomeric carbon (C_1) of the glucose unit is free; therefore, it is a **reducing sugar**.
- **(D) Sucrose:** A disaccharide composed of α-D-glucose and β-D-fructose. The glycosidic linkage is formed between the **anomeric carbon of glucose (C_1) and the anomeric carbon of fructose (C_2)**.

Since both reducing groups (aldehyde and ketone) are involved in the formation of the glycosidic bond, there is no free anomeric center. Consequently, sucrose does not reduce Tollen's or Fehling's reagents and is classified as a **non-reducing sugar**.

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

Q47.

Solution

Concept: Proteins are high molecular weight polymers of α-**amino acids**. These amino acids are joined together by a specific type of covalent bond formed through a condensation reaction between the carboxyl group ($-COOH$) of one amino acid and the amino group ($-NH_2$) of the next.

Solution: 1. **Peptide Linkage:** The bond formed between the $-COOH$ group and $-NH_2$ group is an amide linkage, specifically referred to as a **peptide linkage** or peptide bond ($-CO-NH-$).

2. **Reaction:** During the formation of this bond, a molecule of water is eliminated.

$$\text{H}_2\text{N-CH(R)-COOH} + \text{H}_2\text{N-CH(R')-COOH} \xrightarrow{-H_2O} \text{H}_2\text{N-CH(R)-CO-NH-CH(R')-COOH}$$

3. **Analysis of other options:**

- **(A) Glycosidic linkage:** Found in **carbohydrates** (polysaccharides like starch and cellulose) to join monosaccharide units.
- **(C) Phosphodiester linkage:** Found in **nucleic acids** (DNA and RNA) to join nucleotides.
- **(D) Ester linkage:** Found in **fats/lipids** (triglycerides) between glycerol and fatty acids.

Conclusion: Proteins are characterized by the presence of peptide linkages.

Answer: (B)

Q48.

Solution

Concept: Vitamins are organic compounds required in small amounts for the normal growth and maintenance of the body. Each vitamin has a specific biological function, and its deficiency leads to a characteristic deficiency disease.

Solution: 1. **Vitamin C (Ascorbic Acid):** It is a water-soluble vitamin essential for the synthesis of collagen, absorption of iron, and maintaining a healthy immune system. 2. **The Deficiency Disease:** A lack of Vitamin C leads to **Scurvy**. Symptoms include bleeding gums, bruising, skin rashes, and delayed wound healing because the body cannot produce adequate collagen to repair tissues.

3. **Analysis of other options:**

- **(A) Rickets:** Caused by the deficiency of **Vitamin D**. It leads to soft and weak bones in children.
- **(C) Beri-beri:** Caused by the deficiency of **Vitamin B1** (Thiamine). It affects the nervous system and cardiovascular system.
- **(D) Night blindness:** Caused by the deficiency of **Vitamin A** (Retinol). It leads to poor vision in low light.

Conclusion: Vitamin C deficiency results in Scurvy.

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

Q49.

Solution

Concept: Denaturation is a process in which a protein loses its native conformation (its specific three-dimensional shape) due to external stress or compounds, such as changes in temperature (heating), pH, or the addition of certain chemicals.

Solution: 1. **Structural Changes:** During denaturation, the relatively weak bonds responsible for the higher-order structures—such as hydrogen bonds, disulphide bridges, and hydrophobic interactions—are disrupted. This causes the protein to "unfold." 2. **Affected Structures:** The **secondary and tertiary structures** (and quaternary, if present) are destroyed. The protein loses its biological activity because its functional shape is gone. 3. **Preserved Structure:** The **primary structure** remains intact. The primary structure is the specific sequence of amino acids held together by strong, covalent **peptide bonds**. Since these covalent bonds are not broken during denaturation, the sequence of amino acids remains unchanged.

[Image of primary, secondary, tertiary and quaternary structure of proteins]

Analysis of options:

- **(A) Primary structure:** Incorrect. This is the most stable level and is not lost.
- **(B) Secondary and Tertiary structure:** Correct. These are the levels that unfold during denaturation.
- **(C) Sequence of amino acids:** Incorrect. This defines the primary structure, which is preserved.
- **(D) Peptide bonds:** Incorrect. Denaturation does not involve the hydrolysis of the protein backbone.

Conclusion: Denaturation leads to the loss of secondary and tertiary structures while the primary structure remains unaffected.

Answer: (B)

Q50.

Solution

Concept: Nucleic acids like DNA consist of nitrogenous bases that follow specific **base-pairing rules** (Chargaff's rules). These bases are held together by hydrogen bonds between the two strands of the double helix.

Base Classification:

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

Solution: In the DNA double helix structure:

- **Adenine (A)** always pairs with **Thymine (T)** via **two** hydrogen bonds ($A = T$).
- **Guanine (G)** always pairs with **Cytosine (C)** via **three** hydrogen bonds ($G \equiv C$).

Analysis of options:

- **(A) Adenine:** Pairs with Thymine in DNA.
- **(B) Cytosine:** Correct. It is the complementary base for Guanine.
- **(C) Thymine:** Pairs with Adenine in DNA.
- **(D) Uracil:** Found in RNA instead of Thymine; it pairs with Adenine.

Conclusion: Guanine forms a stable base pair specifically with Cytosine.

Answer: (B)

Answer Key

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