CUET-UG Chemistry Sample Paper-21

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. The Van't Hoff factor (i) for a 100% dissociated aqueous solution of $BaCl_2$ is:

(A) 1

(B) 2

(C) 3

(D) 4

Q2. Which of the following is a characteristic of an ideal solution?

(A) $\Delta H_{mixing} \neq 0$

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

(C) It forms an azeotrope

(D) It deviates from Raoult's Law

Q3. The relative lowering of vapour pressure 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 2g of $NaOH$ is dissolved in 250 mL of solution, the molarity is:

(A) 0.1 M

(B) 0.2 M

(C) 0.5 M

(D) 0.05 M

Q5. An isotonic solution has the same:

(A) Boiling point

(B) Osmotic pressure

(C) Freezing point

(D) Vapor pressure

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

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

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

(C) $S\,cm^2\,mol$

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

Q7. The electrode potential of a Standard Hydrogen Electrode (SHE) is:

(A) 1.0 V

(B) 0.0 V

(C) 0.5 V

(D) 1.1 V

Q8. How many Faradays of electricity are required to reduce 1 mole of Al^{3+} to Al?

(A) 1 F

(B) 2 F

(C) 3 F

(D) 0.3 F

Q9. The Nernst equation for the electrode M^{n+}/M at $298K$ is:

(A) $E = E^0 - \frac{0.059}{n} \log \frac{1}{[M^{n+}]}$

(B) $E = E^0 + \frac{0.059}{n} \log \frac{1}{[M^{n+}]}$

(C) $E = E^0 - 0.059 \log[M^{n+}]$

(D) $E = E^0 - \frac{n}{0.059} \log[M^{n+}]$

Q10. In a fuel cell, the reactant used is:

(A) Nitrogen

(B) Hydrogen

(C) Argon

(D) Helium

Q11. Kohlrausch's law is applicable to:

(A) Strong electrolytes only

(B) Weak electrolytes only

(C) Both strong and weak electrolytes

(D) Non-electrolytes only

Q12. The unit of rate constant (k) for a zero-order reaction is:

(A) s^{-1}

(B) $mol\, L^{-1}\, s^{-1}$

(C) $L\, mol^{-1}\, s^{-1}$

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

Q13. For a first-order reaction, the time required for 50% completion $(t_{1/2})$ is:

(A) $0.693/k$

(B) $k/0.693$

(C) $2.303/k$

(D) $0.10/k$

Q14. The molecularity of a complex reaction:

(A) Is always a whole number

(B) Has no meaning

(C) Can be fractional

(D) Is determined from the overall balanced equation

Q15. On increasing temperature, the rate of reaction increases mainly due to:

(A) Increase in collision frequency

(B) Decrease in activation energy

(C) Increase in the number of effective collisions

(D) Decrease in threshold energy

Q16. The slope of the plot of $\ln k$ vs $1/T$ is:

(A) $-E_a/R$

(B) E_a/R

(C) $-R/E_a$

(D) $E_a/2.303R$

Q17. The highest oxidation state shown by Manganese (Mn) is:

(A) +4

(B) +6

(C) +7

(D) +2

Q18. Which of the following ions is expected to be coloured in aqueous solution?

(A) Sc^{3+}

(B) Ti^{4+}

(C) Cu^{2+}

(D) Zn^{2+}

Q19. Lanthanoid contraction is due to:

(A) Shielding of 4f electrons

(B) Poor shielding of 4f electrons

(C) Strong shielding of 5d electrons

(D) Increase in atomic radius

Q20. What is the spin-only magnetic moment of Fe^{2+} $(Z = 26)$?

(A) 1.73 BM

(B) 3.87 BM

(C) 4.90 BM

(D) 5.92 BM

Q21. The IUPAC name of $[Pt(NH_3)_2Cl_2]$ is:

(A) Diamminedichloridoplatinum (II)

(B) Dichloridodiammineplatinum (II)

(C) Diamminedichloridoplatinum (IV)

(D) Platinumdiammine dichloride

Q22. The coordination number and oxidation state of Cr in $K_3[Cr(C_2O_4)_3]$ are:

(A) 3 and +3

(B) 6 and +3

(C) 6 and +6

(D) 3 and 0

Q23. Which of the following ligands is a chelating agent?

(A) Cl^-

(B) NH_3

(C) en (ethylenediamine)

(D) CN^-

Q24. According to Crystal Field Theory, for a d^4 ion in an octahedral field, if $\Delta_o < P$, the configuration is:

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

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

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

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

Q25. Facial and meridional (fac-mer) isomerism is associated with which type of complex?

(A) $[MA_4B_2]$

(B) $[MA_3B_3]$

(C) $[MA_2B_4]$

(D) $[MABCD]$

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

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

(B) $[Fe(CN)_6]^{3-}$

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

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

Q27. Which of the following reacts fastest by S_N2 mechanism?

(A) CH_3Cl

(B) CH_3CH_2Cl

(C) $(CH_3)_2CHCl$

(D) $(CH_3)_3CCl$

Q28. The reaction: $R - X + NaI \xrightarrow{\text{acetone}} R - I + NaX$ is known as:

(A) Swarts reaction

(B) Finkelstein reaction

(C) Wurtz reaction

(D) Sandmeyer reaction

Q29. S_N1 reactions are favored in:

(A) Non-polar solvents

(B) Polar protic solvents

(C) Polar aprotic solvents

(D) Gas phase

Q30. Chlorobenzene is prepared commercially by:

(A) Raschig process

(B) Deacon's process

(C) Contact process

(D) Etard's process

Q31. Which alcohol reacts fastest with Lucas reagent?

(A) Ethanol

(B) Propan-2-ol

(C) 2-Methylpropan-2-ol

(D) Methanol

Q32. Phenol is more acidic than ethanol because:

(A) Ethoxide ion is more stable than phenoxide ion

(B) Phenoxide ion is resonance stabilized

(C) Phenol has higher molecular weight

(D) Ethanol is a liquid

Q33. The reaction of Phenol with $CHCl_3$ and aqueous $NaOH$ to give Salicylaldehyde is:

(A) Kolbe's reaction

(B) Reimer-Tiemann reaction

(C) Friedel-Crafts reaction

(D) Wurtz reaction

Q34. In Williamson synthesis of ethers, the reagents are:

(A) Alcohol + Acid

(B) Alkyl halide + Sodium alkoxide

(C) Alkyl halide + Alcohol

(D) Aldehyde + Grignard reagent

Q35. Propan-2-ol on oxidation with CrO_3 gives:

(A) Propanal

(B) Propanone

(C) Propanoic acid

(D) Ethanoic acid

Q36. Which of the following will not give Aldol condensation?

(A) CH_3CHO

(B) CH_3COCH_3

(C) $HCHO$

(D) CH_3CH_2CHO

Q37. The reagent used in Clemmensen reduction is:

(A) $Zn - Hg/\text{conc. } HCl$

(B) NH_2NH_2/KOH

(C) $LiAlH_4$

(D) $NaBH_4$

Q38. Which of the following gives a Silver Mirror test?

(A) Acetone

(B) Benzophenone

(C) Benzaldehyde

(D) Acetic acid

Q39. Cannizzaro reaction is given by:

(A) Aldehydes with α-hydrogen

(B) Aldehydes without α-hydrogen

(C) All Ketones

(D) All Carboxylic acids

Q40. The correct order of acid strength is:

(A) $ClCH_2COOH > CH_3COOH$

(B) $CH_3COOH > ClCH_2COOH$

(C) $CH_3COOH > HCOOH$

(D) $CH_3CH_2COOH > CH_3COOH$

Q41. Formaldehyde reacts with CH_3MgBr followed by hydrolysis to give:

(A) Methanol

(B) Ethanol

(C) Propan-2-ol

(D) Acetone

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

(A) $2^\circ > 1^\circ > 3^\circ > NH_3$

(B) $3^\circ > 2^\circ > 1^\circ > NH_3$

(C) $NH_3 > 1^\circ > 2^\circ > 3^\circ$

(D) $2^\circ > 3^\circ > 1^\circ > NH_3$

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

(A) Primary aromatic amines

(B) Primary aliphatic amines

(C) Secondary amines

(D) Tertiary amines

Q44. Which of the following tests is used to identify primary amines?

(A) Tollens' test

(B) Carbylamine test

(C) Lucas test

(D) Fehling's test

Q45. Hinsberg's reagent is:

(A) Benzene sulphonyl chloride

(B) Benzene sulphonic acid

(C) Phenyl isocyanide

(D) Benzene chloride

Q46. Glucose on prolonged heating with HI gives:

(A) n-Hexane

(B) Gluconic acid

(C) Saccharic acid

(D) Hexanoic acid

Q47. Which of the following is a non-reducing sugar?

(A) Glucose

(B) Maltose

(C) Lactose

(D) Sucrose

Q48. The linkage present in proteins is:

(A) Glycosidic linkage

(B) Peptide linkage

(C) Phosphodieaster linkage

(D) Hydrogen linkage

Q49. Deficiency of Vitamin B1 causes:

(A) Scurvy

(B) Beri-beri

(C) Rickets

(D) Cheilosis

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

(A) Adenine

(B) Guanine

(C) Cytosine

(D) Uracil

Detailed Solutions

Q1.

Solution

Concept: The Van't Hoff factor (i) is used to account for the extent of dissociation or association of a solute in a solution. For a strong electrolyte like $BaCl_2$ that undergoes complete dissociation, i is equal to the total number of ions produced per formula unit.

Solution: 1. Barium Chloride ($BaCl_2$) dissociates in an aqueous medium according to the following chemical equation:

$$BaCl_2(s) \xrightarrow{H_2O} Ba^{2+}(aq) + 2Cl^-(aq)$$

2. From this equation, we can see that one mole of $BaCl_2$ yields one mole of Barium ions (Ba^{2+}) and two moles of Chloride ions (Cl^-). 3. The total number of particles (n) produced is $1 + 2 = 3$. 4. The general formula for the Van't Hoff factor is $i = 1 + (n - 1)\alpha$, where α is the degree of dissociation. 5. Given the solution is 100% dissociated, $\alpha = 1$. Therefore:

$$i = 1 + (3 - 1)(1) = 3$$

The effective number of particles in the solution is 3 times the number of moles of the salt added.

Answer: (C)

Q2.

Solution

Concept: An ideal solution is defined as a solution that obeys Raoult's Law over the entire range of concentrations. This happens when the intermolecular forces between the solute and solvent (A-B) are of the same magnitude as the forces between the pure components (A-A and B-B).

Solution: For a solution to be considered ideal, it must satisfy several thermodynamic conditions:

1. Enthalpy of Mixing (ΔH_{mix}): There should be no heat exchange during mixing. Thus, $\Delta H_{mix} = 0$.

2. Volume of Mixing (ΔV_{mix}): The total volume of the solution must be exactly equal to the sum of the volumes of the two components before mixing. Thus, $\Delta V_{mix} = 0$.

3. Vapour Pressure: The observed vapour pressure matches the calculated value from Raoult's Law. Looking at the options: (A) states $\Delta H \neq 0$, which describes a non-ideal solution. (B) states $\Delta V_{mix} = 0$, which is the correct characteristic of an ideal solution. (C) and (D) describe non-ideal solutions (azeotropes and deviations).

Answer: (B)

Q3.

Solution

Concept: The Relative Lowering of Vapour Pressure is a colligative property. Colligative properties depend solely on the number of solute particles present in the solution, regardless of their identity.

Solution: 1. According to Raoult's Law, the vapour pressure of a solvent in a solution (P_s) is equal to the vapour pressure of the pure solvent (P^0) multiplied by its mole fraction ($\chi_{solvent}$):

$$P_s = P^0 \cdot \chi_{solvent}$$

2. The "Lowering of Vapour Pressure" is the difference between the pure solvent and the solution: $\Delta P = P^0 - P_s$. 3. The "Relative Lowering" is defined as the ratio of this lowering to the vapour pressure of the pure solvent:

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

4. Since $\chi_{solvent} + \chi_{solute} = 1$, we can substitute $P_s = P^0(1 - \chi_{solute})$ into the formula:

$$\frac{P^0 - P^0(1 - \chi_{solute})}{P^0} = \frac{P^0 \cdot \chi_{solute}}{P^0} = \chi_{solute}$$

Therefore, the relative lowering of vapour pressure is equal to the mole fraction of the solute.

Answer: (B)

Q4.

Solution

Concept: Molarity (M) is a measure of the concentration of a solute in a solution, defined as the number of moles of solute per litre of solution.

Solution: 1. Identify the Molar Mass of $NaOH$:

$$\text{Na (23) + O (16) + H (1) = 40 g/mol}$$

2. Calculate the number of moles (n):

$$n = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{2\text{ g}}{40\text{ g/mol}} = 0.05\text{ moles}$$

3. Convert Volume to Litres: The volume is given as 250 mL. To convert this to Litres:

$$V = \frac{250}{1000} = 0.25\text{ L}$$

4. Calculate Molarity (M):

$$M = \frac{\text{moles of solute}}{\text{Volume of solution in L}} = \frac{0.05}{0.25}$$

$$M = \frac{5}{25} = 0.2\text{ M}$$

The concentration of the solution is 0.2 mol/L.

Answer: (B)

Q5.

Solution

Concept: Isotonic solutions are two solutions that have the same osmotic pressure at the same temperature. Osmosis occurs when solvent molecules move from a region of lower solute concentration to higher solute concentration through a semi-permeable membrane.

Solution: 1. Osmotic Pressure (π): According to the van't Hoff equation, the osmotic pressure is given by $\pi = iCRT$, where C is molarity, R is the gas constant, and T is temperature.

2. Definition of Isotonicity: For two solutions to be isotonic, their osmotic pressures must be equal:

$$\pi_1 = \pi_2$$

3. Physical Significance: When two isotonic solutions are separated by a semi-permeable membrane, there is no net flow of solvent because the pressure on both sides of the membrane is equal.

4. Although other properties like boiling point or freezing point are also colligative, they do not define the term "isotonic." The term "isotonic" refers specifically and fundamentally to equal osmotic pressure.

Answer: (B)

Q6.

Solution

Concept: Molar conductivity (Λ_m) represents the conducting power of all the ions produced by dissolving exactly one mole of an electrolyte in a solution of a given volume. It provides a way to compare the efficiency of different electrolytes in conducting electricity.

Solution: 1. The fundamental relationship between molar conductivity (Λ_m), specific conductivity (κ), and molar concentration (C) is given by:

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

2. Units of Specific Conductivity (κ): Conductivity is the reciprocal of resistivity. Its SI unit is $S\,m^{-1}$, but in laboratory practice, it is commonly expressed as $S\,cm^{-1}$ (where S = Siemens = Ω^{-1}).

3. Units of Concentration (C): In chemistry, concentration is typically measured in Molarity ($mol\,L^{-1}$). Since we use cm in conductivity, we must convert Litres to cubic centimeters ($1\,L = 1000\,cm^3$).

4. Deriving the Unit: - κ has units of $S \cdot cm^{-1}$. - C has units of $mol \cdot cm^{-3}$ (after the conversion factor of 1000). - Therefore, the unit of $\Lambda_m = \frac{S \cdot cm^{-1}}{mol \cdot cm^{-3}} = S \cdot cm^{-1} \cdot cm^3 \cdot mol^{-1} = S \cdot cm^2 \cdot mol^{-1}$.

5. Thus, the standard unit used for molar conductivity in the CGS system is $S\,cm^2\,mol^{-1}$.

Answer: (A)

Q7.

Solution

Concept: In electrochemistry, it is impossible to measure the absolute potential of an individual half-cell. We can only measure the difference between two electrodes. Therefore, a reference electrode is required to build a scale for electrode potentials.

Solution: 1. The Standard Hydrogen Electrode (SHE) is the universal reference electrode used for this purpose.

2. It consists of a platinum electrode coated with finely divided platinum (platinum black). The electrode is immersed in an acidic solution where the concentration of hydrogen ions (H^+) is exactly $1.00\,M$.

3. Pure hydrogen gas is bubbled through the solution at a constant pressure of 1 bar (or 1 atm) at a temperature of $298\,K$.

4. The Convention: By international agreement (IUPAC), the standard reduction potential of the SHE is defined as exactly 0.000... Volts at all temperatures.

5. This arbitrary zero point allows scientists to determine the "Standard Reduction Potential" (E^0) of all other chemical species by connecting them to the SHE in a galvanic cell.

Answer: (B)

Q8.

Solution

Concept: Faraday's laws of electrolysis relate the mass of a substance altered at an electrode to the quantity of electricity passed through the electrolyte. The fundamental unit of charge used here is the Faraday (F), which is the total charge carried by one mole (6.022×10^{23}) of electrons.

Solution: 1. To determine the electricity required, we must first look at the reduction half-reaction occurring at the cathode:

$$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$$

2. The stoichiometry of this balanced equation tells us that: - To reduce 1 ion of Al^{3+}, 3 electrons are required. - Therefore, to reduce 1 mole of Al^{3+} ions to 1 mole of Aluminum atoms, 3 moles of electrons are required.

3. Since the charge of 1 mole of electrons is defined as $1\,Faraday$ ($1\,F \approx 96500\,C$): - Charge for 3 moles of electrons = $3 \times 1\,F = 3\,F$.

4. Thus, 3 Faradays of electricity are necessary to deposit one mole of Aluminum from a solution containing Al^{3+} ions.

Answer: (C)

Q9.

Solution

Concept: The Nernst Equation is used to calculate the electrode potential (E) under non-standard conditions (i.e., when concentrations are not 1 M). It shows the dependence of potential on the temperature and the concentration of the species involved.

Solution: 1. For a general reduction electrode reaction: $M^{n+}(aq) + ne^- \longrightarrow M(s)$.

2. The complete Nernst equation is:

$$E = E^0 - \frac{RT}{nF} \ln \frac{[\text{Products}]}{[\text{Reactants}]}$$

3. In this case, the product is the pure solid metal M. By thermodynamic convention, the activity (concentration) of a pure solid is always taken as unity (1).

4. The reactant is the ion M^{n+} in the aqueous phase.

5. At the standard temperature of $298\,K$: - $R = 8.314\,J\,K^{-1}\,mol^{-1}$ - $T = 298\,K$ - $F = 96485\,C\,mol^{-1}$ - Conversion from natural log (ln) to common log ($\log_{10}$) involves a factor of 2.303.

6. Substituting these constants: $\frac{2.303 \times R \times T}{F} \approx 0.0591$. 7. The equation simplifies to:

$$E = E^0 - \frac{0.059}{n} \log \frac{1}{[M^{n+}]}$$

Answer: (A)

Q10.

Solution

Concept: A fuel cell is a unique type of electrochemical cell that converts the chemical energy of a redox reaction directly into electrical energy. Unlike standard batteries, fuel cells do not "run down" or require recharging; they produce electricity as long as fuel is supplied to them.

Solution: 1. The most common fuels used in these cells are simple, high-energy-density gases like Hydrogen (H_2), Methanol (CH_3OH), or Methane (CH_4).

2. The most famous example is the Hydrogen-Oxygen fuel cell, which was famously used in the Apollo space program.

3. In this cell, Hydrogen gas (H_2) is bubbled through the anode and Oxygen gas (O_2) through the cathode. The electrolyte is typically a concentrated aqueous solution of KOH.

4. The overall cell reaction is the formation of water: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$.

5. Nitrogen, Argon, and Helium are chemically inert or non-combustible under these conditions and cannot serve as "fuel" for a redox-based electrical cell. Therefore, Hydrogen is the correct reactant.

Answer: (B)

Q11.

Solution

Concept: Kohlrausch's Law of Independent Migration of Ions addresses the behavior of electrolytes at infinite dilution (where ions are so far apart that they do not interact with each other).

Solution: 1. The law states that the limiting molar conductivity of an electrolyte (Λ_m^o) is the sum of the individual molar conductivities of its constituent ions.

2. Strong Electrolytes: For salts like $NaCl$ or KCl, Λ_m increases slowly with dilution and can be found by extrapolating the Λ_m vs. $\sqrt{C}$ plot. Kohlrausch's law holds true here as the sum of ionic conductivities.

3. Weak Electrolytes: For substances like Acetic Acid (CH_3COOH), dissociation is incomplete at moderate concentrations. The Λ_m vs. $\sqrt{C}$ curve becomes very steep at low concentrations, making extrapolation impossible.

4. Kohlrausch's law is the only way to calculate Λ_m^o for weak electrolytes by using values from strong electrolytes (e.g., Λ_m^o of $CH_3COOH = \Lambda_m^o$ of $CH_3COONa + \Lambda_m^o$ of $HCl - \Lambda_m^o$ of $NaCl$).

5. Since the law describes a fundamental property of ions, it is applicable to both strong and weak electrolytes.

Answer: (C)

Q12.

Solution

Concept: The "Order of a Reaction" defines how the rate of reaction is affected by the concentration of the reactants. The units of the rate constant (k) change depending on this order because the overall "Rate" always has the same units ($mol\, L^{-1}\, s^{-1}$).

Solution: 1. For any reaction, the rate is defined as the change in concentration over time:

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

2. For a zero-order reaction, the rate law is:

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

3. Since any value raised to the power of zero is 1, the equation becomes:

$$\text{Rate} = k \times 1 \implies k = \text{Rate}$$

4. Therefore, for a zero-order reaction, the rate constant (k) must have the exact same units as the rate of the reaction.

5. Final Units: $mol \cdot L^{-1} \cdot s^{-1}$.

6. (Note: For a first-order reaction, the unit would be s^{-1}, and for a second-order reaction, it would be $L \cdot mol^{-1} \cdot s^{-1}$).

Answer: (B)

Q13.

Solution

Concept: The half-life ($t_{1/2}$) of a reaction is the time required for the concentration of a reactant to decrease to exactly half of its initial value. For a first-order reaction, the half-life is unique because it is independent of the initial concentration of the reactant.

Solution: 1. The integrated rate equation for a first-order reaction is:

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

2. At the half-life ($t = t_{1/2}$), the concentration $[R]$ becomes half of the initial concentration $[R]_0$:

$$[R] = \frac{[R]_0}{2}$$

3. Substituting these values into the equation:

$$k = \frac{2.303}{t_{1/2}} \log \frac{[R]_0}{[R]_0/2} = \frac{2.303}{t_{1/2}} \log 2$$

4. Since $\log 2 \approx 0.3010$, the equation becomes:

$$k = \frac{2.303 \times 0.3010}{t_{1/2}} = \frac{0.693}{t_{1/2}}$$

5. Rearranging for $t_{1/2}$:

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

This formula shows that if you know the rate constant (k), you can directly calculate the time taken for 50% completion regardless of how much material you started with.

Answer: (A)

Q14.

Solution

Concept: Molecularity is defined as the number of reacting species (atoms, ions, or molecules) that must collide simultaneously to bring about a chemical reaction. It is a theoretical property applicable only to elementary (single-step) reactions.

Solution: 1. Elementary Reactions: For reactions that occur in a single step, molecularity is equal to the sum of the stoichiometric coefficients of the reactants. It is always a positive integer (1, 2, or 3).

2. Complex Reactions: Most chemical reactions occur through a sequence of elementary steps, known as the "mechanism."

3. For a complex reaction, there is no such thing as "overall molecularity" because the molecules from different steps do not collide all at once.

4. Therefore, while "Order" can be determined for a complex reaction from the slowest step, molecularity has no meaning for the overall complex reaction. It is only defined for the individual elementary steps within the mechanism.

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

Q15.

Solution

Concept: According to the Collision Theory of chemical kinetics, for a reaction to occur, reactant molecules must collide with each other. However, not all collisions result in a chemical change.

Solution: 1. Collision Frequency: Increasing the temperature increases the kinetic energy of molecules, leading to more frequent collisions. However, the increase in rate (often doubling for every 10°C rise) is too large to be explained by frequency alone.

2. Effective Collisions: For a collision to be successful (effective), the colliding molecules must possess a minimum energy called "Activation Energy" (E_a).

3. Maxwell-Boltzmann Distribution: When temperature increases, the distribution curve shifts. The fraction of molecules having energy equal to or greater than the activation energy increases significantly.

4. Therefore, the rate increases primarily because a much larger number of molecules now have enough energy to cross the energy barrier, leading to an increase in the number of effective collisions.

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

Q16.

Solution

Concept: The Arrhenius equation describes the quantitative relationship between the rate constant (k), activation energy (E_a), and absolute temperature (T): $k = A \cdot e^{-E_a/RT}$.

Solution: 1. To find the slope of the plot, we take the natural logarithm (ln) on both sides of the Arrhenius equation:

$$\ln k = \ln(A \cdot e^{-E_a/RT})$$

$$\ln k = \ln A + \ln(e^{-E_a/RT})$$

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

2. Rearranging this into the form of a straight-line equation ($y = mx + c$):

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

3. In this equation: - $y = \ln k$ - $x = 1/T$ - m(slope) $= -E_a/R$ - c(intercept) $= \ln A$

4. Therefore, the slope of the plot of $\ln k$ versus $1/T$ is exactly $-E_a/R$.

Answer: (A)

Q17.

Solution

Concept: The oxidation state of a transition metal depends on the number of electrons it can lose or share from its outermost s and inner d orbitals.

Solution: 1. Manganese (Mn) has the atomic number $Z = 25$.

2. Its ground-state electronic configuration is: $[Ar]3d^5 4s^2$.

3. Transition elements show variable oxidation states by using both ns and $(n-1)d$ electrons.

4. For Manganese, the total number of valence electrons available is $5(\text{from } 3d) + 2(\text{from } 4s) = 7$.

5. When all these 7 electrons are involved in bonding (as in the permanganate ion, MnO_4^-), Manganese exhibits its maximum oxidation state of +7.

6. This is the highest oxidation state among the elements of the $3d$ series.

Answer: (C)

Q18.

Solution

Concept: The color of transition metal ions is typically due to $d-d$ transitions. For an ion to be colored, it must have a partially filled d-orbital (between d^1 and d^9).

Solution: 1. Sc^{3+} $(Z = 21)$: Configuration is $[Ar]3d^0$. Since there are no d-electrons, $d-d$ transition is impossible. It is colorless.

2. Ti^{4+} $(Z = 22)$: Configuration is $[Ar]3d^0$. Like Sc^{3+}, it has no d-electrons and is colorless.

3. Zn^{2+} $(Z = 30)$: Configuration is $[Ar]3d^{10}$. The d-orbital is completely filled; there is no vacant space for an electron to jump. It is colorless.

4. Cu^{2+} $(Z = 29)$: Configuration is $[Ar]3d^9$. It has one unpaired electron (one vacancy in the d-orbital). This allows for $d-d$ transitions, which absorb light in the visible region, making the ion colored (typically blue).

Answer: (C)

Q19.

Solution

Concept: Lanthanoid contraction refers to the steady decrease in the atomic and ionic radii of the lanthanoid elements with the increase in atomic number.

Solution: 1. In the lanthanoid series $(Z = 58$ to $71)$, electrons are added to the $4f$ subshell.

2. The f-orbitals have a very diffused shape, which results in very poor shielding of the outer electrons from the nuclear charge.

3. Because the $4f$ electrons do not shield the nucleus effectively, the "Effective Nuclear Charge" (Z_{eff}) acting on the outer electrons increases significantly as we move across the period.

4. This increased nuclear pull causes the entire electron cloud to shrink, leading to a reduction in atomic size. This effect is known as Lanthanoid Contraction.

Answer: (B)

Q20.

Solution

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

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

where n is the number of unpaired electrons.

Solution: 1. Iron (Fe) has atomic number $Z = 26$. Configuration: $[Ar]3d^6 4s^2$.

2. For Fe^{2+}, two electrons are removed from the $4s$ orbital. Configuration: $[Ar]3d^6$.

3. According to Hund's Rule, the 6 electrons in the d-orbital are distributed as: $(\uparrow\downarrow)(\uparrow)(\uparrow)(\uparrow)(\uparrow)$.

4. This gives us 4 unpaired electrons ($n = 4$).

5. Calculate μ:

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

6. Since $\sqrt{25} = 5$, $\sqrt{24}$ is slightly less than 5, which is approximately 4.90 BM.

Answer: (C)

Q21.

Solution

Concept: IUPAC nomenclature for coordination compounds follows specific rules: ligands are named first in alphabetical order, followed by the metal with its oxidation state in Roman numerals.

Solution: 1. Identify Ligands: There are two NH_3 (ammine) and two Cl^- (chlorido) ligands.

2. Alphabetical Order: "Ammine" comes before "Chlorido." So, we use "diamminedichlorido."

3. Calculate Oxidation State of Pt: - Let $Pt = x$. Ammine is neutral (0), Chlorido is -1. - $x + 2(0) + 2(-1) = 0 \implies x - 2 = 0 \implies x = +2$.

4. Metal Name: Since the complex is neutral, the metal is named as "platinum."

5. Combine: Diamminedichloridoplatinum(II).

6. Note: There is no space between ligand names and the metal name.

Answer: (A)

Q22.

Solution

Concept: The Coordination Number (CN) is the total number of coordinate bonds formed between the central metal ion and the ligands. The Oxidation State (OS) is the charge the metal would carry if all ligands were removed.

Solution: 1. Coordination Number: The ligand is Oxalate ($C_2O_4^{2-}$). Oxalate is a bidentate ligand, meaning each molecule forms 2 bonds with the metal. - Since there are 3 oxalate ligands, CN = $3 \times 2 = 6$.

2. Oxidation State: - Potassium (K) has a charge of $+1$. There are 3 K atoms, total = $+3$. - The complex ion $[Cr(C_2O_4)_3]$ must have a charge of -3 to balance the K_3. - Let the OS of Cr be x. Oxalate has a charge of -2. - $x + 3(-2) = -3 \implies x - 6 = -3 \implies x = +3$.

3. Result: Coordination Number is 6 and Oxidation State is +3.

Answer: (B)

Q23.

Solution

Concept: Ligands are classified by their "denticity," which is the number of donor atoms they use to bind to a central metal. A chelating agent is a multidentate ligand that attaches to the metal ion using two or more of its donor atoms simultaneously, creating a stable cyclic (ring) structure.

Solution: 1. Monodentate Ligands: Ligands like Chloride (Cl^-), Ammonia (NH_3), and Cyanide (CN^-) possess only one lone pair-bearing atom that can coordinate with the metal at any given time. They are incapable of forming ring structures.

2. Ethylenediamine (en): This is a bidentate ligand with the structure $NH_2 - CH_2 - CH_2 - NH_2$. It contains two nitrogen atoms, each having a lone pair of electrons.

3. When ethylenediamine reacts with a metal ion (M^{n+}), both nitrogen atoms donate their lone pairs to the same metal center. This results in the formation of a five-membered heterocyclic ring consisting of the metal, two nitrogens, and two carbons.

4. The Chelate Effect: Complexes involving chelating ligands are significantly more stable than those formed by similar monodentate ligands. This enhanced stability is known as the "chelate effect," driven primarily by an increase in entropy during the displacement of monodentate ligands.

Answer: (C)

Q24.

Solution

Concept: In an octahedral coordination environment, the five degenerate d-orbitals split into two sets: the lower-energy t_{2g} set (d_{xy}, d_{yz}, d_{zx}) and the higher-energy e_g set ($d_{x^2-y^2}, d_{z^2}$). The gap between these sets is the Crystal Field Splitting Energy (Δ_o).

Solution: 1. For a d^4 metal ion, the first three electrons occupy the three t_{2g} orbitals individually with parallel spins, following Hund's Rule.

2. For the fourth electron, there is a competition between two energy factors: - Splitting Energy (Δ_o): The energy required to jump to the e_g level. - Pairing Energy (P): The energy required to force two electrons into the same t_{2g} orbital.

3. The question specifies $\Delta_o < P$. This implies that the "cost" of jumping to the higher energy level is lower than the "cost" of pairing up with another electron in the lower level.

4. Consequently, the fourth electron remains unpaired and moves into the e_g orbital. This creates a "High Spin" complex.

5. The final electron distribution is three electrons in t_{2g} and one electron in e_g, written as $t_{2g}^3 e_g^1$.

Answer: (B)

Q25.

Solution

Concept: Geometrical isomerism in octahedral complexes arises due to different spatial arrangements of ligands. Facial (fac) and Meridional (mer) isomerism is a specific subtype that occurs only in octahedral complexes with the stoichiometry $[MA_3B_3]$.

Solution: 1. In an octahedron, there are eight faces, each being an equilateral triangle formed by three coordination sites.

2. Facial (fac) Isomer: This isomer occurs when three identical ligands (A) occupy the three corners of the same octahedral face. In this arrangement, any two A ligands are "cis" to each other (adjacent).

3. Meridional (mer) Isomer: This isomer occurs when the three identical ligands (A) occupy a plane that passes through the metal center (a "meridian"). In this case, two of the A ligands are "trans" to each other (180 degrees apart), while the third is "cis" to the others.

4. Other types like $[MA_4B_2]$ or $[MA_2B_4]$ show cis-trans isomerism, but they cannot form the specific "triangle-face" or "meridian-arc" patterns required for $fac - mer$ terminology. Thus, $[MA_3B_3]$ is the unique requirement.

Answer: (B)

Q26.

Solution

Concept: According to Valence Bond Theory (VBT), octahedral complexes are classified based on the d-orbitals used for hybridization. If the inner $(n-1)d$ orbitals are used, it is an "inner orbital" complex (d^2sp^3). If the outer nd orbitals are used, it is an "outer orbital" complex (sp^3d^2).

Solution: 1. The Metal Ion: In $[CoF_6]^{3-}$, Cobalt is in the +3 oxidation state. The electronic configuration of Co^{3+} is $[Ar]3d^6$.

2. The Ligand Effect: Fluoride (F^-) is a "weak field ligand" according to the spectrochemical series. It does not provide enough energy to force the pairing of the $3d$ electrons.

3. The Arrangement: In the $3d^6$ configuration of Co^{3+}, there are 4 unpaired electrons. Since F^- cannot cause pairing, the $3d$ orbitals remain occupied and are not available for hybridization.

4. Hybridization: To accommodate 6 fluoride ligands, the cobalt ion must use its available outer orbitals: one $4s$, three $4p$, and two $4d$ orbitals. This results in sp^3d^2 hybridization.

5. Because the $4d$ (outer) orbitals are utilized, $[CoF_6]^{3-}$ is categorized as an outer orbital or "high spin" complex. In contrast, ligands like CN^- or NH_3 would cause pairing and form inner orbital complexes.

Answer: (C)

Q27.

Solution

Concept: The S_N2 (Substitution Nucleophilic Bimolecular) mechanism is a single-step concerted process where the nucleophile attacks the electrophilic carbon from the side opposite to the leaving group (backside attack).

Solution: 1. Steric Hindrance: In the transition state of an S_N2 reaction, the carbon atom is coordinated to five groups simultaneously. Therefore, the rate of reaction is extremely sensitive to the size of the groups attached to the reaction center.

2. As the number of bulky alkyl groups on the carbon increases, they physically block the incoming nucleophile from reaching the carbon, significantly increasing the activation energy.

3. Reactivity Order: The standard order of reactivity for S_N2 is:

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

4. Analyzing Options: - (A) CH_3Cl is a methyl halide. It has only three small hydrogen atoms, offering minimal steric resistance. - (B) CH_3CH_2Cl is 1°. - (C) $(CH_3)_2CHCl$ is 2°. - (D) $(CH_3)_3CCl$ is 3° (highly hindered; virtually no S_N2 occurs).

5. Because CH_3Cl has the lowest steric hindrance, it allows the nucleophile to attack most easily and thus reacts the fastest.

Answer: (A)

Q28.

Solution

Concept: Halogen exchange reactions are vital synthetic tools in organic chemistry used to synthesize alkyl halides that are difficult to prepare through direct halogenation of hydrocarbons.

Solution: 1. Finkelstein Reaction: This specific reaction involves the treatment of an alkyl chloride ($R - Cl$) or alkyl bromide ($R - Br$) with Sodium Iodide (NaI) in the presence of dry acetone to produce an alkyl iodide ($R - I$).

2. Role of Acetone: The reaction is driven to completion by Le Chatelier's Principle. Sodium Iodide is soluble in acetone, but the resulting $NaCl$ or $NaBr$ are poorly soluble in acetone and precipitate as solids. This precipitation "pulls" the equilibrium toward the formation of the alkyl iodide.

3. Contrast with other reactions: - Swarts Reaction: Used for fluorination (e.g., $R - Cl + AgF \rightarrow R - F$). - Wurtz Reaction: Involves Na metal in dry ether to couple two alkyl groups ($2R - X + 2Na \rightarrow R - R$). - Sandmeyer Reaction: Uses cuprous salts to replace a diazonium group in aromatic rings.

The equation $R - X + NaI \rightarrow R - I$ is the classic definition of the Finkelstein reaction.

Answer: (B)

Q29.

Solution

Concept: The S_N1 (Substitution Nucleophilic Unimolecular) mechanism proceeds through two distinct steps: (1) the slow ionization of the substrate to form a carbocation intermediate and (2) the rapid attack of the nucleophile on that carbocation.

Solution: 1. The rate-determining step is the formation of the carbocation (R^+) and the leaving group anion (X^-). This process involves the breaking of a covalent bond into two charged species.

2. Polar Protic Solvents: These are solvents like water (H_2O), alcohols (ROH), or organic acids that have a high dielectric constant and contain hydrogen atoms bonded to highly electronegative elements (like Oxygen).

3. Solvation: These solvents are excellent at stabilizing the transition state and the intermediates. - The oxygen's lone pairs solvate the positive carbocation. - The acidic hydrogen atoms form strong hydrogen bonds with the leaving group anion (X^-).

4. This stabilization significantly lowers the activation energy for the ionization step. Consequently, S_N1 reactions are vastly accelerated in polar protic solvents compared to non-polar or aprotic ones.

Answer: (B)

Q30.

Solution

Concept: Industrial organic chemistry utilizes specific named processes for the large-scale manufacture of chemical intermediates. Chlorobenzene is a key precursor for dyes and insecticides.

Solution: 1. The Raschig Process: This is the primary industrial method for producing chlorobenzene. It involves the catalytic vapor-phase chlorination of benzene.

2. Benzene vapors, air (oxygen), and Hydrogen Chloride (HCl) gas are passed over a catalyst containing Copper(II) chloride ($CuCl_2$) and Iron(III) chloride ($FeCl_3$) at temperatures around 230°C to 250°C.

3. The overall reaction is:

$$C_6H_6 + HCl + \frac{1}{2}O_2 \rightarrow C_6H_5Cl + H_2O$$

4. Other Processes: - Deacon's Process: An industrial method for making Cl_2 gas from HCl and O_2. - Contact Process: The standard industrial method for producing high-concentration Sulfuric Acid (H_2SO_4). - Etard's Process: A laboratory method for oxidizing toluene to benzaldehyde using chromyl chloride (CrO_2Cl_2).

Therefore, the Raschig process is the correct industrial match for chlorobenzene.

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

Q31.

Solution

Concept: The Lucas Test is used to categorize alcohols based on their reactivity with the Lucas Reagent (a solution of anhydrous $ZnCl_2$ in concentrated HCl). The reaction follows an S_N1 pathway involving a carbocation intermediate.

Solution: 1. The reagent converts alcohols ($R-OH$) into alkyl chlorides ($R-Cl$). Since alkyl chlorides are insoluble in the reagent, the solution becomes cloudy or turbid.

2. The rate of the reaction depends entirely on the stability of the carbocation intermediate (R^+) formed after the loss of water.

3. Carbocation Stability Order: Tertiary (3°) > Secondary (2°) > Primary (1°).

4. Behavior of Alcohols: - 2-Methylpropan-2-ol (Tertiary): Forms a highly stable 3° carbocation. It reacts instantly at room temperature, showing immediate turbidity. - Propan-2-ol (Secondary): Forms a 2° carbocation. Turbidity appears within 5 to 10 minutes. - Ethanol/Methanol (Primary): Form very unstable 1° carbocations. The solution remains clear at room temperature; turbidity only appears upon heating.

5. Among the choices, the tertiary alcohol (2-Methylpropan-2-ol) is the fastest to react.

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

Q32.

Solution

Concept: Acidity is fundamentally determined by the stability of the conjugate base formed after the loss of a proton (H^+). The more stable the anion, the more the equilibrium shifts toward the acidic side.

Solution: 1. Ethanol vs. Ethoxide: When ethanol (CH_3CH_2OH) loses a proton, it forms the ethoxide ion ($CH_3CH_2O^-$). The negative charge is strictly localized on the oxygen atom. Furthermore, the ethyl group exerts a $+I$ (inductive) effect, pushing electron density toward the oxygen and further destabilizing the negative charge.

2. Phenol vs. Phenoxide: When phenol (C_6H_5OH) loses a proton, it forms the phenoxide ion ($C_6H_5O^-$).

3. Resonance Stabilization: The phenoxide ion is exceptionally stable because the lone pair of electrons on the oxygen atom is in conjugation with the π-system of the benzene ring. The negative charge is delocalized over the ortho and para positions of the ring through multiple resonance structures.

4. Because the phenoxide ion is so much more stable than the ethoxide ion, phenol has a much greater tendency to donate its proton. This makes phenol significantly more acidic than ethanol (with a pK_a of ≈ 10 vs. ≈ 16).

Answer: (B)

Q33.

Solution

Concept: The Reimer-Tiemann reaction is a significant electrophilic aromatic substitution used to introduce a formyl group (—CHO) onto a phenol ring. It is the standard laboratory method for synthesizing phenolic aldehydes.

Solution: 1. The Mechanism: When phenol is treated with chloroform ($CHCl_3$) and aqueous sodium hydroxide ($NaOH$), the base first reacts with chloroform to generate a highly reactive, neutral intermediate called dichlorocarbene ($: CCl_2$) via α-elimination of HCl.

2. Electrophilic Attack: The dichlorocarbene acts as an electrophile. Since the reaction medium is basic, phenol exists as the phenoxide ion, which is highly activated toward electrophilic attack. The carbene attacks the ortho position of the phenoxide ion.

3. Intermediate Formation: An intermediate substituted with a $—CHCl_2$ group is formed. Under the basic conditions of the reaction, this dichloromethyl group undergoes alkaline hydrolysis.

4. Final Product: The hydrolysis replaces the two chlorine atoms with a carbonyl oxygen, resulting in the formation of salicylaldehyde (2-hydroxybenzaldehyde).

5. Comparison: If CCl_4 were used instead of $CHCl_3$, the product would be salicylic acid (a carboxylic acid). The Friedel-Crafts reaction involves alkyl/acyl halides with $AlCl_3$, and the Wurtz reaction involves coupling of alkyl halides with sodium.

Answer: (B)

Q34.

Solution

Concept: Williamson ether synthesis is an organic reaction used to form ethers from an organohalide and a deprotonated alcohol (alkoxide). It follows a bimolecular nucleophilic substitution (S_N2) mechanism.

Solution: 1. Reagents involved: The reaction requires a nucleophile and an electrophile. The nucleophile is a sodium alkoxide ($R - O^- Na^+$), which is typically prepared by reacting an alcohol with sodium metal. The electrophile is an alkyl halide ($R' - X$).

2. The S_N2 Step: The alkoxide ion attacks the alkyl halide from the backside, displacing the halide ion in a single concerted step.

$$R - O^- + R' - X \rightarrow R - O - R' + X^-$$

3. Reactivity and Constraints: Because it is an S_N2 reaction, steric hindrance is the most critical factor. The alkyl halide ($R' - X$) must ideally be primary (1°) or methyl.

4. Side Reactions: If a tertiary (3°) alkyl halide is used, the alkoxide ion (which is also a strong base) will favor an E2 elimination reaction over substitution. This leads to the formation of an alkene instead of an ether.

5. Versatility: This method is excellent because it can produce both symmetrical (e.g., diethyl ether) and unsymmetrical (e.g., ethyl methyl ether) ethers.

Answer: (B)

Q35.

Solution

Concept: The oxidation of alcohols involves the removal of hydrogen from the —OH group and the α-carbon atom (the carbon bearing the —OH group), resulting in the formation of a carbon-oxygen double bond ($C = O$).

Solution: 1. Structure of Propan-2-ol: It is a secondary alcohol (2°) with the formula $CH_3 - CH(OH) - CH_3$. The hydroxyl group is attached to a carbon that is bonded to two other carbon atoms.

2. The Role of CrO_3: Chromic anhydride (CrO_3) is a powerful oxidizing agent. In acidic media, it forms chromic acid, which facilitates the removal of the two hydrogen atoms (dehydrogenation).

3. The Chemical Change: - A primary alcohol would oxidize to an aldehyde ($R - CHO$) and potentially further to a carboxylic acid. - A secondary alcohol is oxidized to a ketone ($R - CO - R$).

4. Product Analysis: Propan-2-ol contains three carbons. When oxidized, the middle carbon (the α-carbon) becomes part of a carbonyl group. The resulting molecule is $CH_3 - CO - CH_3$, which is propanone (commonly known as acetone).

5. Further Oxidation: Ketones do not undergo further oxidation easily because they lack a hydrogen atom on the carbonyl carbon; breaking the molecule further would require the cleavage of strong carbon-carbon bonds.

Answer: (B)

Q36.

Solution

Concept: Aldol condensation is a fundamental C-C bond-forming reaction that requires the formation of an enolate ion. This is only possible if the aldehyde or ketone possesses at least one α-hydrogen atom (a hydrogen atom on the carbon directly adjacent to the carbonyl group).

Solution: 1. The Role of α-Hydrogen: The α-hydrogen is acidic due to the electron-withdrawing nature of the carbonyl group and the resonance stabilization of the resulting anion (enolate). Without this hydrogen, a base cannot create the nucleophile required to attack another carbonyl molecule.

2. Option-by-Option Analysis: - Acetaldehyde (CH_3CHO): The carbon adjacent to —CHO is a CH_3 group. It has 3 α-hydrogens. (Gives Aldol) - Acetone (CH_3COCH_3): Has two methyl groups adjacent to the carbonyl. It has 6 α-hydrogens. (Gives Aldol) - Propanal (CH_3CH_2CHO): The carbon adjacent to —CHO is a CH_2 group. It has 2 α-hydrogens. (Gives Aldol) - Formaldehyde ($HCHO$): The structure is $H - C(= O) - H$. There is no carbon atom attached to the carbonyl carbon. Therefore, there is no α-carbon and consequently no α-hydrogen.

3. Conclusion: Since Formaldehyde lacks the necessary α-hydrogen, it cannot undergo Aldol condensation. Instead, when treated with a concentrated base, it undergoes the Cannizzaro reaction.

Answer: (C)

Q37.

Solution

Concept: Carbonyl compounds (aldehydes and ketones) can be reduced to alkanes by completely removing the oxygen atom and adding two hydrogen atoms to the carbon. The Clemmensen reduction is the standard method used when the reaction must be performed under acidic conditions.

Solution: 1. The Reagent System: The Clemmensen reduction utilizes Zinc amalgam ($Zn - Hg$) and concentrated hydrochloric acid (HCl).

2. The Process: The amalgam (zinc dissolved in mercury) provides a clean surface for the transfer of electrons to the carbonyl group. The concentrated acid provides the protons (H^+) required to form water as the oxygen is removed.

3. The Result: The $C = O$ group is converted directly into a $-CH_2-$ (methylene) group.

$$\text{Ketone/Aldehyde} \xrightarrow{Zn(Hg)/HCl} \text{Alkane}$$

4. Selective Application: This method is particularly useful for ketones that are sensitive to basic conditions. If the molecule were sensitive to acid (e.g., if it contained an —OH group that could dehydrate), the Wolff-Kishner reduction (NH_2NH_2/KOH) would be used instead, as it operates under basic conditions.

Answer: (A)

Q38.

Solution

Concept: The Tollens' Test (Silver Mirror test) is a qualitative laboratory test used to distinguish between aldehydes and ketones. It relies on the fact that aldehydes are mild reducing agents, whereas ketones cannot be oxidized without breaking carbon-carbon bonds.

Solution: 1. The Reagent: Tollens' reagent is an aqueous solution of silver nitrate and ammonia, containing the complex ion diamminesilver(I), $[Ag(NH_3)_2]^+$.

2. The Redox Reaction: When an aldehyde is added to the reagent and heated gently, the aldehyde is oxidized to a carboxylate ion, and the silver ions (Ag^+) are reduced to metallic silver (Ag^0).

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

3. Observations: The metallic silver deposits on the clean inner surface of the test tube, creating a mirror-like finish.

4. Analysis of Compounds: - Acetone and Benzophenone: Both are ketones; they do not react with Tollens' reagent. - Acetic acid: A carboxylic acid; it is already in an oxidized state and does not react. - Benzaldehyde: An aromatic aldehyde. Like aliphatic aldehydes, it reduces Tollens' reagent to metallic silver.

5. Benzaldehyde is therefore the only compound listed that will produce a silver mirror.

Answer: (C)

Q39.

Solution

Concept: The Cannizzaro reaction is a chemical reaction that involves the base-induced disproportionation of an aldehyde. "Disproportionation" means that one molecule of the reactant is oxidized while another identical molecule is reduced.

Solution: 1. Structural Requirement: This reaction is specifically given by aldehydes that do not have an α-hydrogen atom (e.g., formaldehyde, benzaldehyde, pivalaldehyde). If an α-hydrogen were present, the base would prefer to remove it to start an Aldol reaction.

2. Reaction Conditions: The reaction requires a very concentrated strong base (usually 50% $NaOH$ or KOH) and heating.

3. The Mechanism: A hydroxide ion attacks one carbonyl carbon, and eventually, a hydride ion (H^-) is transferred from this molecule to a second aldehyde molecule.

4. The Products: - The molecule that loses the hydride is oxidized to a carboxylic acid (which immediately becomes a salt in the basic medium, e.g., sodium formate). - The molecule that receives the hydride is reduced to a primary alcohol (e.g., methanol). 5. Thus, the reaction is a characteristic test for aldehydes without α-hydrogens.

Answer: (B)

Q40.

Solution

Concept: The acidity of a carboxylic acid is determined by the stability of the resulting carboxylate anion ($RCOO^-$). Any factor that withdraws electron density from the negatively charged oxygens will stabilize the anion and increase the acidity of the parent acid.

Solution: 1. The Inductive Effect (I): This is the transmission of charge through a chain of atoms in a molecule. - Electron-Withdrawing Groups ($-I$): Halogens like Chlorine are highly electronegative. They pull electron density toward themselves through the sigma bonds. - Electron-Donating Groups ($+I$): Alkyl groups like the methyl group (CH_3-) push electron density toward the rest of the molecule.

2. Comparing Chloroacetic acid ($Cl - CH_2COOH$) and Acetic acid ($CH_3 - COOH$): - In chloroacetic acid, the Chlorine atom exerts a strong $-I$ effect. This "pulls" the negative charge of the carboxylate ion away from the oxygens, spreading the charge over a larger volume (delocalization). A stabilized anion is easier to form, making the acid stronger. - In acetic acid, the methyl group exerts a $+I$ effect, which "pushes" more negative charge toward the already negative carboxylate group, destabilizing it.

3. Result: Chloroacetic acid ($pK_a \approx 2.8$) is much more acidic than acetic acid ($pK_a \approx 4.7$). Therefore, $ClCH_2COOH > CH_3COOH$ is the correct order.

Answer: (A)

Q41.

Solution

Concept: The Grignard reaction is one of the most powerful tools for carbon-carbon bond formation. Grignard reagents ($R - MgX$) act as strong nucleophiles because the carbon-magnesium bond is highly polarized, giving the carbon a partial negative charge.

Solution: 1. The Starting Material: Formaldehyde ($H - CHO$) is a planar molecule with a highly electrophilic carbonyl carbon.

2. Step 1: Nucleophilic Attack: The methyl group from CH_3MgBr attacks the carbonyl carbon. Simultaneously, the pi-electrons of the $C = O$ bond move to the oxygen atom.

$$H_2C = O + CH_3^- \rightarrow CH_3 - CH_2 - O^-$$

3. The Intermediate: An adduct is formed where the oxygen is coordinated to the magnesium (CH_3CH_2OMgBr). Note that the chain length has increased from one carbon (in formaldehyde) to two carbons.

4. Step 2: Hydrolysis: The addition of water or dilute acid breaks the $O - Mg$ bond, protonating the oxygen to form a hydroxyl group.

$$CH_3 - CH_2 - OMgBr + H_2O \rightarrow CH_3 - CH_2 - OH + Mg(OH)Br$$

5. The Final Product: The resulting molecule is CH_3CH_2OH, which is Ethanol.

6. General Trend: Reaction with formaldehyde always yields a primary alcohol. Reaction with any other aldehyde yields a secondary alcohol, and reaction with a ketone yields a tertiary alcohol.

Answer: (B)

Q42.

Solution

Concept: Basic strength of amines in aqueous solution does not follow a simple linear trend because it is determined by the equilibrium: $R - NH_2 + H_2O \rightleftharpoons R - NH_3^+ + OH^-$. The stability of the substituted ammonium ion ($R - NH_3^+$) is the key.

Solution: In an aqueous medium, three competing factors determine basicity: 1. Inductive Effect ($+I$): Alkyl groups donate electrons to Nitrogen, making the lone pair more available. This predicts $3° > 2° > 1°$.

2. Solvation (Hydration) Effect: The protonated amine (cation) is stabilized by hydrogen bonding with water molecules. The more hydrogens the cation has, the better it is solvated. This predicts $1° > 2° > 3°$.

3. Steric Hindrance: Bulky alkyl groups make it difficult for a proton to approach the Nitrogen atom and for water molecules to solvate the resulting cation. This also favors smaller amines.

4. The Combination for Methyl Groups: When the alkyl group is small (Methyl), the steric hindrance is low, but solvation is very important. The interplay of these three factors results in a specific order: - Secondary ($2°$) is the strongest (benefits from both $+I$ and decent solvation). - Primary ($1°$) is next (excellent solvation). - Tertiary ($3°$) is weaker (poor solvation due to three methyl groups). - Ammonia (NH_3) is the weakest (no $+I$ effect).

5. The resulting "213" order is: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$.

Answer: (A)

Q43.

Solution

Concept: Gabriel Phthalimide Synthesis is a highly selective laboratory method used for the preparation of pure primary aliphatic amines. It is preferred over the ammonolysis of alkyl halides because it prevents the formation of a mixture of secondary and tertiary amines, ensuring a high yield of the primary product.

Solution: The reaction proceeds through three distinct chemical stages: 1. **Formation of Nucleophile:** Phthalimide is treated with ethanolic potassium hydroxide (KOH). The acidic hydrogen attached to the nitrogen is removed, forming the potassium salt of phthalimide, which acts as a strong nucleophile.

2. **Nucleophilic Substitution:** This salt is then reacted with a primary alkyl halide ($R - X$). The phthalimide anion attacks the alkyl group via an S_N2 **mechanism**, displacing the halide ion to form N-alkylphthalimide.

3. **Hydrolysis/Hydrazinolysis:** The N-alkylphthalimide is then cleaved, typically by alkaline hydrolysis using $NaOH$ or by treatment with hydrazine (NH_2NH_2). This releases the **primary aliphatic amine** ($R - NH_2$) and the byproduct (sodium phthalate or phthalhydrazide).

4. **Why not Aromatic Amines?** This method cannot produce primary aromatic amines (like Aniline) because aryl halides (like chlorobenzene) do not undergo S_N2 reactions. The $C - Cl$ bond in aryl halides has a partial double-bond character due to resonance, making it extremely difficult to break.

Answer: (B)

Q44.

Solution

Concept: The Carbylamine reaction, also known as the Hofmann Isocyanide Test, is a sensitive diagnostic test used exclusively to detect the presence of primary amines. It is widely used in organic analysis to distinguish primary amines from secondary and tertiary ones.

Solution: 1. **The Chemical Process:** When any **primary amine** (whether it is aliphatic like methylamine or aromatic like aniline) is heated with a mixture of chloroform ($CHCl_3$) and an ethanolic solution of potassium hydroxide (KOH), a chemical transformation occurs.

2. **Formation of Product:** The reaction produces an alkyl/aryl isocyanide, also called a "carbylamine" ($R - NC$).

$$R - NH_2 + CHCl_3 + 3KOH \xrightarrow{\text{heat}} R - NC + 3KCl + 3H_2O$$

3. **Physical Observation:** Isocyanides are characterized by an **extremely foul, repulsive, and pungent odor**. The appearance of this characteristic "bad smell" confirms that the starting material was a primary amine.

4. **Selectivity:** Secondary (2°) and Tertiary (3°) amines do not give this test because they do not have the two hydrogen atoms on the nitrogen required for the elimination steps that lead to the formation of the triple bond in the $-NC$ group.

Answer: (B)

Q45.

Solution

Concept: The Hinsberg Test is a classic chemical method used to distinguish and separate primary, secondary, and tertiary amines. The test is based on the different ways these amines react with a specific sulfonyl chloride and the solubility of the resulting products in an alkaline medium.

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

2. **Reaction with Primary Amines** ($1°$)**:** They react to form N-alkylbenzenesulphonamide. This product contains an acidic hydrogen atom attached to the nitrogen (due to the strong electron-withdrawing effect of the sulphonyl group). Consequently, this derivative is **soluble in alkali** ($NaOH$).

3. **Reaction with Secondary Amines** ($2°$)**:** They react to form N,N-dialkylbenzenesulphonamide. This product has **no acidic hydrogen** on the nitrogen; therefore, it is **insoluble in alkali** and remains as a solid or oil.

4. **Reaction with Tertiary Amines** ($3°$)**:** They do not react with benzene sulphonyl chloride under these conditions because they lack a replaceable hydrogen on the nitrogen. The amine simply remains unreacted and can be recovered by acidification.

Answer: (A)

Q46.

Solution

Concept: Determining the structure of glucose involved various chemical degradations. Reducing agents like Hydroiodic acid (HI) are used to convert oxygen-containing organic molecules into their corresponding hydrocarbons by removing all oxygen atoms.

Solution: 1. **The Reaction:** Glucose is a hexose sugar (6 carbons) containing one aldehyde group and five hydroxyl groups. When it is heated for a long time with concentrated **Hydroiodic acid** **(**HI**)** in the presence of red phosphorus (P), a complete reduction takes place.

2. **The Result:** All the functional groups (^-CHO and ^-OH) are stripped of their oxygen and fully hydrogenated. The six-carbon skeleton is converted into a saturated hydrocarbon.

3. **The Product:** The resulting molecule is **n-Hexane** ($CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$).

4. **Structural Significance:** This reaction is a cornerstone of carbohydrate chemistry because the formation of n-hexane (a straight-chain alkane) provides definitive proof that in a glucose molecule, **all six carbon atoms are linked in a continuous, straight chain** without any branching. If the chain were branched, a different alkane (like isohexane) would have formed.

Answer: (A)

Q47.

Solution

Concept: Reducing sugars are carbohydrates that can act as reducing agents because they possess a free aldehyde or ketone group (or a hemiacetal/hemiketal group that can easily open). Non-reducing sugars are those in which these functional groups are "locked" in a bond and cannot react with reagents like Fehling's or Tollens'.

Solution: 1. **Reducing Examples:** Glucose (monosaccharide), Lactose, and Maltose (disaccharides) all have an "anomeric carbon" that is not fully bonded to another sugar. This allows the ring to open in water, exposing a reducing group.

2. **The Case of Sucrose:** Sucrose is a disaccharide made of α-D-glucose and β-D-fructose.

3. **The Glycosidic Linkage:** In sucrose, the bond is formed between the **C1 of glucose** and the **C2 of fructose**. These specific carbons are the "anomeric carbons" of their respective monosaccharides.

4. **Why it is Non-Reducing:** Because both the aldehydic group (of glucose) and the ketonic group (of fructose) are utilized in forming the glycosidic bond, **neither is free**. The molecule cannot open its rings to expose a carbonyl group, making it unable to reduce Cu^{2+} (Fehling's) or Ag^{+} (Tollens'). Thus, sucrose is a **non-reducing sugar**.

Answer: (D)

Q48.

Solution

Concept: Proteins are linear polymers of α-amino acids. For these small units to form a large macromolecule, they must be linked by a strong covalent bond. This bond is formed via a condensation reaction, which is the hallmark of protein structure.

Solution: 1. **Chemical Foundation:** Every amino acid has an amino group ($—NH_2$) and a carboxyl group ($—COOH$).

2. **Bond Formation:** When two amino acids come together, the carboxyl group of one reacts with the amino group of the other. In this process, a molecule of water (H_2O) is eliminated.

3. **The Linkage:** The resulting chemical bond is an amide linkage with the structure —CO—NH—.

4. **Terminology:** While "amide bond" is the general chemical term, in the specific context of amino acids and proteins, it is strictly referred to as a **peptide linkage** or peptide bond.

5. **Distinction:** - *Glycosidic linkages* connect sugar units in carbohydrates. - *Phosphodiester linkages* connect nucleotides in DNA/RNA. - *Peptide linkages* are the backbone of proteins.

Answer: (B)

Q49.

Solution

Concept: Vitamins are organic compounds required in minute quantities for the normal growth and maintenance of the body. Since the body cannot synthesize most vitamins, their absence in the diet leads to specific deficiency syndromes.

Solution: 1. **Vitamin B1 (Thiamine):** It is a water-soluble vitamin that plays a vital role as a coenzyme in the metabolism of carbohydrates.

2. **Deficiency Disease:** The clinical condition resulting from Vitamin B1 deficiency is Beri-beri. It primarily affects the nervous system and the cardiovascular system. Symptoms include extreme weakness, swelling of limbs (edema), and loss of appetite.

3. **Other Vitamin Deficiencies:** - **Scurvy** is caused by a lack of **Vitamin C**, leading to weakened collagen and bleeding gums. - **Rickets** is caused by a lack of **Vitamin D**, leading to bone deformities in children. - **Cheilosis** (inflammation of the lips/mouth) is typically caused by a lack of **Vitamin B2** (Riboflavin).

4. Therefore, Beri-beri is the correct match for Vitamin B1.

Answer: (B)

Q50.

Solution

Concept: The primary structural difference between the two types of nucleic acids, DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid), lies in the sugar component and one of the four nitrogenous bases.

Solution: 1. **Nitrogenous Bases:** There are five main bases used in genetics, divided into Purines (Adenine, Guanine) and Pyrimidines (Cytosine, Thymine, Uracil).

2. **DNA Composition:** DNA uses the four bases: **Adenine (A), Guanine (G), Cytosine (C), and Thymine (T)**. Here, A pairs with T, and G pairs with C.

3. **RNA Composition:** RNA uses the four bases: **Adenine (A), Guanine (G), Cytosine (C), and Uracil (U)**. In RNA, A pairs with U, and G pairs with C.

4. **The Critical Difference:** As seen in the comparison, **Uracil (U)** is the unique base found in RNA that is entirely absent in DNA. Conversely, Thymine (T) is found in DNA but is replaced by Uracil in RNA.

5. This chemical substitution (Uracil lacks the methyl group found in Thymine) is a fundamental distinction between these two biological molecules.

Answer: (D)

Answer Key

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