CUET UG Chemistry Sample Paper - 2

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

Instructions

- This paper contains a total of 50 Multiple Choice Questions.
- Each correct answer carries **+5 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Q1. Which of the following aqueous solutions will have the highest boiling point?

(A) 1.0 M KNO_3
(B) 1.0 M Na_2SO_4
(C) 1.0 M Glucose
(D) 1.0 M $AlCl_3$

Q2. The value of Henry's Law constant K_H is:

(A) Higher for gases with higher solubility
(B) Higher for gases with lower solubility
(C) Constant for all gases
(D) Not related to the solubility of gases

Q3. An ideal solution is formed when its components:

(A) Have zero heat of mixing
(B) Have zero volume change on mixing
(C) Obey Raoult's Law at all concentrations
(D) All of the above

Q4. The Van't Hoff factor (i) for a 100% dissociated aqueous solution of $K_4[Fe(CN)_6]$ is:

(A) 2

(B) 3

(C) 4

(D) 5

Q5. Which colligative property is used to determine the molar mass of biomolecules like proteins?

(A) Osmotic Pressure

(B) Depression in freezing point

(C) Elevation in boiling point

(D) Relative lowering of vapour pressure

Q6. The unit of molar conductivity is:

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

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

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

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

Q7. How many Coulombs are required to deposit 40.5 g of Al from Al^{3+} solution? (At. mass of $Al = 27$):

(A) 4.5 F

(B) 3.0 F

(C) 1.5 F

(D) 6.0 F

Q8. The Nernst equation for the electrode reaction $M^{n+} + ne^- \rightarrow M$ is:

(A) $E = E^o - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$

(B) $E = E^o + \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$

(C) $E = E^o - \frac{RT}{nF} \ln[M^{n+}]$

(D) $E = E^o + \frac{RT}{F} \ln[M^{n+}]$

Q9. Which of the following is used in a fuel cell?

(A) Cd

(B) Pb

(C) H_2

(D) Li

Q10. The limiting molar conductivity of an electrolyte is obtained by:

(A) Extrapolating Λ_m to zero concentration

(B) Extrapolating Λ_m to infinite concentration

(C) Increasing the temperature

(D) Decreasing the pressure

Q11. In a lead storage battery, during charging, $PbSO_4$ on the cathode is converted into:

(A) Pb

(B) PbO_2

(C) $PbSO_4$

(D) H_2SO_4

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

(A) 2 times

(B) 10 times

(C) 100 times

(D) 5 times

Q13. The rate constant of a reaction depends on:

(A) Concentration of reactants

(B) Pressure

(C) Temperature

(D) Extent of reaction

Q14. What is the order of a reaction whose rate constant unit is $L\,mol^{-1}\,s^{-1}$?

(A) Zero

(B) First

(C) Second

(D) Third

Q15. If the activation energy of a reaction is zero, then the rate constant (k) is equal to:

(A) A (Frequency factor)

(B) 0

(C) Infinite

(D) e

Q16. The role of a catalyst in a chemical reaction is to change:

(A) Internal energy

(B) Enthalpy

(C) Activation energy

(D) Equilibrium constant

Q17. Which of the following ions will exhibit the highest magnetic moment?

(A) Mn^{2+}

(B) Fe^{2+}

(C) Ti^{2+}

(D) Cr^{2+}

Q18. Lanthanoid contraction is due to:

(A) Shielding of 4f electrons

(B) Poor shielding of 4f electrons

(C) Increase in nuclear charge

(D) Both (B) and (C)

Q19. The most common oxidation state of Lanthanoids is:

(A) +2

(B) +3

(C) +4

(D) +5

Q20. $KMnO_4$ acts as an oxidizing agent in acidic medium and is reduced to:

(A) Mn^{2+}

(B) MnO_2

(C) Mn^{4+}

(D) MnO_4^{2-}

Q21. The IUPAC name of $K_3[Fe(CN)_6]$ is:

(A) Potassium ferricyanide

(B) Potassium hexacyanoferrate(II)

(C) Potassium hexacyanoferrate(III)

(D) Tripotassium hexacyanoiron(III)

Q22. The coordination number of Cobalt in $[Co(en)_3]^{3+}$ is:

(A) 3

(B) 4

(C) 6

(D) 2

Q23. Which of the following is a high spin complex?

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

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

(C) $[Fe(CN)_6]^{4-}$
(D) $[Ni(CN)_4]^{2-}$

Q24. The hybridization of Ni in $[Ni(CO)_4]$ is:

(A) sp^3
(B) dsp^2
(C) d^2sp^3
(D) sp^3d^2

Q25. Which type of isomerism is shown by $[Co(NH_3)_5SO_4]Br$ and $[Co(NH_3)_5Br]SO_4$?

(A) Linkage isomerism
(B) Ionization isomerism
(C) Coordination isomerism
(D) Solvate isomerism

Q26. Crystal Field Splitting Energy (CFSE) for octahedral complex is denoted as:

(A) Δ_t
(B) Δ_o
(C) Δ_s
(D) P

Q27. The S_N2 reaction proceeds with:

(A) Retention of configuration
(B) Inversion of configuration
(C) Racemization
(D) Partial racemization

Q28. Which of the following is an example of a vic-dihalide?

(A) Dichloromethane

(B) 1,2-dichloroethane

(C) Ethylidene chloride

(D) Allyl chloride

Q29. Finkelstein reaction is used for the preparation of:

(A) Alkyl Fluorides

(B) Alkyl Iodides

(C) Alkyl Chlorides

(D) Alkyl Bromides

Q30. Which of the following is most reactive towards nucleophilic substitution?

(A) Chlorobenzene

(B) Vinyl chloride

(C) Benzyl chloride

(D) Ethyl chloride

Q31. Lucas test is used to distinguish between:

(A) Alcohols and Phenols

(B) $1^\circ, 2^\circ$, and 3° Alcohols

(C) Aldehydes and Ketones

(D) Acids and Esters

Q32. Phenol reacts with $CHCl_3$ in the presence of $NaOH$ to give Salicylaldehyde. This reaction is:

(A) Kolbe's reaction

(B) Reimer-Tiemann reaction

(C) Etard reaction

(D) Cannizzaro reaction

Q33. The heating of ethyl phenyl ether with HI gives:

(A) Phenol + Ethyl Iodide

(B) Iodobenzene + Ethanol

(C) Phenol + Ethane

(D) Iodobenzene + Ethyl Iodide

Q34. Which of the following is the strongest acid?

(A) Phenol

(B) p-Nitrophenol

(C) p-Cresol

(D) p-Methoxyphenol

Q35. Methanol is industrially prepared by the catalytic hydrogenation of:

(A) CH_4

(B) CO

(C) CO_2

(D) C_2H_4

Q36. Which of the following compounds will give a positive Iodoform test?

(A) Benzophenone

(B) Acetophenone

(C) Pentan-3-one

(D) Methanol

Q37. Cannizzaro reaction is not given by:

(A) Formaldehyde

(B) Benzaldehyde

(C) Acetaldehyde

(D) Trimethylacetaldehyde

Q38. The product formed in the Aldol condensation of acetaldehyde is:

(A) 3-hydroxybutanal

(B) 2-hydroxybutanal

(C) 3-hydroxybutanoic acid

(D) But-2-enal

Q39. Which reagent is used in the Clemmensen reduction?

(A) NH_2NH_2/KOH

(B) $Zn - Hg/conc.HCl$

(C) $LiAlH_4$

(D) $NaBH_4$

Q40. The correct order of acidity is:

(A) $CH_3COOH > ClCH_2COOH > Cl_2CHCOOH$

(B) $Cl_3CCOOH > Cl_2CHCOOH > ClCH_2COOH$

(C) $CH_3COOH > HCOOH > CH_3CH_2COOH$

(D) $HCOOH > CH_3COOH > ClCH_2COOH$

Q41. Ethanal reacts with Tollen's reagent to give:

(A) Red ppt

(B) Silver mirror

(C) White ppt

(D) No reaction

Q42. The correct order of basicity of amines in gaseous phase is:

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

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

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

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

Q43. Hinsberg's reagent is:

(A) Benzene sulphonyl chloride

(B) Benzene sulphonic acid

(C) Phenyl isocyanide

(D) Benzene chloride

Q44. Which amine gives a foul-smelling carbylamine test?

(A) n-Butylamine

(B) Diethylamine

(C) Triethylamine

(D) N-Methylaniline

Q45. Which of the following cannot be prepared by Gabriel Phthalimide synthesis?

(A) Methylamine

(B) Aniline

(C) Ethylamine

(D) Isopropylamine

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

(A) Maltose

(B) Lactose

(C) Sucrose

(D) Glucose

Q47. The two functional groups present in all amino acids are:

(A) $-NH_2$ and $-OH$

(B) $-NH_2$ and $-CHO$

(C) $-NH_2$ and $-COOH$

(D) $-CHO$ and $-COOH$

Q48. Which of the following vitamins is water-soluble?

(A) Vitamin A

(B) Vitamin D

(C) Vitamin C

(D) Vitamin K

Q49. In DNA, the complementary bases are:

(A) Adenine and Thymine; Guanine and Cytosine

(B) Adenine and Guanine; Thymine and Cytosine

(C) Adenine and Uracil; Guanine and Cytosine

(D) Adenine and Cytosine; Guanine and Thymine

Q50. Denaturation of protein leads to loss of its biological activity due to:

(A) Loss of primary structure

(B) Loss of secondary and tertiary structures

(C) Formation of amino acids

(D) Increase in hydrogen bonding

Detailed Solutions

Q1.

Solution

Concept: Colligative properties depend on the number of solute particles (ions or molecules) present in the solution. The elevation in boiling point (ΔT_b) is directly proportional to the Van't Hoff factor (i) when the molality is constant.

Solution: The boiling point of a solution is calculated as $T_b = T_b^\circ + \Delta T_b$, where $\Delta T_b = i \cdot K_b \cdot m$. Since the concentration (1.0 M) is identical for all options, the boiling point depends entirely on the number of particles produced upon dissociation (i):

- **(A)** KNO_3**:** Dissociates into K^+ and NO_3^-. Total particles $= 2$, so $i = 2$.
- **(B)** Na_2SO_4**:** Dissociates into $2Na^+$ and SO_4^{2-}. Total particles $= 3$, so $i = 3$.
- **(C) Glucose:** Being a non-electrolyte (covalent compound), it does not dissociate. Total particles $= 1$, so $i = 1$.
- **(D)** $AlCl_3$**:** Dissociates into Al^{3+} and $3Cl^-$. Total particles $= 4$, so $i = 4$.

Comparing the values, $AlCl_3$ has the highest Van't Hoff factor ($i = 4$). Consequently, it produces the maximum elevation in boiling point, resulting in the highest boiling point among the given solutions.

Answer: (D)

Q2.

Solution

Concept: Henry's Law relates the solubility of a gas in a liquid to its partial pressure. The equation is expressed as $P = K_H \cdot \chi$, where P is the partial pressure, K_H is Henry's Law constant, and χ is the mole fraction of the gas in solution.

Solution: From the Henry's Law formula, we can express the solubility (mole fraction χ) as:

$$\chi = \frac{P}{K_H}$$

At a given constant pressure (P), the mole fraction χ is inversely proportional to K_H ($\chi \propto 1/K_H$). This mathematical relationship implies: 1. If K_H is high, the solubility (χ) of the gas is low. 2. If K_H is low, the solubility (χ) of the gas is high. Different gases have different K_H values at the same temperature, which is why different gases have different solubilities in the same solvent.

Answer: (B)

Q3.

Solution

Concept: An ideal solution is a theoretical model where the intermolecular forces between different components (A-B) are identical to the forces between like components (A-A and B-B).

Solution: For a solution to be classified as "Ideal," it must satisfy the following three thermodynamic and physical criteria:

- **Raoult's Law:** The partial vapor pressure of each component is directly proportional to its mole fraction at all concentrations ($P_i = P_i^\circ \chi_i$).
- **Enthalpy of Mixing ($\Delta H_{mix} = 0$):** No heat is absorbed or released when the components are mixed because the strength of new A-B interactions is the same as the original A-A and B-B interactions.
- **Volume of Mixing ($\Delta V_{mix} = 0$):** The total volume of the solution is exactly equal to the sum of the volumes of the individual components. There is no contraction or expansion upon mixing.

Since all options (A), (B), and (C) are fundamental requirements for an ideal solution, the correct answer is (D).

Answer: (D)

Q4.

Solution

Concept: The Van't Hoff factor (i) is the ratio of the actual concentration of particles produced when the substance is dissolved to the concentration of the substance as calculated from its mass.

Solution: For an electrolyte that undergoes 100% dissociation (complete ionization), i is equal to the number of ions produced per formula unit. $K_4[Fe(CN)_6]$ is a coordination compound. In water, the species inside the square brackets (the coordination sphere) remains intact as a single complex ion, while the counter ions outside the bracket dissociate:

$$K_4[Fe(CN)_6] \xrightarrow{H_2O} 4K^+(aq) + [Fe(CN)_6]^{4-}(aq)$$

Counting the ions:

- 4 Potassium ions ($4 \times K^+$)
- 1 Ferrocyanide complex ion ($1 \times [Fe(CN)_6]^{4-}$)

Total number of particles (n) $= 4 + 1 = 5$. Using the formula $i = 1 + (n-1)\alpha$, where α is the degree of dissociation: For 100% dissociation, $\alpha = 1$, therefore $i = n = 5$.

Answer: (D)

Q5.

Solution

Concept: While all colligative properties can theoretically be used to find molar mass, Osmotic Pressure (π) is uniquely suited for macromolecules and biomolecules like proteins, DNA, and polymers.

Solution: Osmotic pressure is preferred due to the following specific advantages:

(a) **Room Temperature Measurement:** Biomolecules like proteins are unstable at high temperatures and can denature. Boiling point elevation measurements would damage them, whereas osmotic pressure is measured at room temperature.

(b) **Large Magnitude:** For solutes with very high molar masses (macromolecules), the changes in freezing point or boiling point are so small that they are difficult to measure accurately. Osmotic pressure, however, provides a significantly larger and more measurable value even for very dilute solutions.

(c) **Use of Molarity:** Osmotic pressure uses molarity (M) instead of molality (m), which is easier to calculate in laboratory conditions for these specific substances.

The formula used is $\pi = CRT$, where C is molarity, R is the gas constant, and T is temperature.

Answer: (A)

Q6.

Solution

Concept: Molar conductivity (Λ_m) represents the total conducting power of all the ions produced by dissolving one mole of an electrolyte in a solution of a given volume. It is essentially the electrolytic conductivity normalized per unit of molar concentration.

Solution: The mathematical expression for molar conductivity is $\Lambda_m = \frac{\kappa}{C}$, where κ is the specific conductivity (electrolytic conductivity) and C is the molar concentration.

(a) **Unit of κ:** Conductance (G) is measured in Siemens (S or Ω^{-1}). Specific conductivity (κ) is the conductance of a $1\,cm^3$ cube of solution, hence its unit is $S\,cm^{-1}$.

(b) **Unit of C:** Concentration is typically given in moles per Liter. In electrochemical calculations using centimeters, we convert Liters to cubic centimeters ($1\,L = 1000\,cm^3$). Thus, the unit for concentration in this context is mol/cm^3.

(c) **Dimensional Analysis:**

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

In SI units, it can also be expressed as $S\,m^2\,mol^{-1}$, but $S\,cm^2\,mol^{-1}$ is the standard unit frequently used in chemistry textbooks and CUET exams.

Answer: (A)

Q7.

Solution

Concept: According to Faraday's First Law of Electrolysis, the mass of a substance deposited at an electrode is directly proportional to the quantity of electricity passed. The charge required to deposit 1 mole of an ion is equal to $n \times F$, where n is the valency (number of electrons exchanged) and F is Faraday's constant ($1\,F \approx 96500\,C$).

Solution: Step 1: Write the reduction half-reaction for Aluminum. Aluminum ions must gain three electrons to become solid metal:

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

This stoichiometry tells us that **3 moles of electrons** (which equals $3\,F$) are required to deposit **1 mole of** Al.

Step 2: Calculate the number of moles of Al in 40.5 g. Given that the atomic mass of Al is 27 g/mol:

$$\text{Moles of } Al = \frac{\text{Mass}}{\text{Atomic Mass}} = \frac{40.5\,g}{27\,g/mol} = 1.5\,\text{moles}$$

Step 3: Calculate the total charge (in Faradays). Since 1 mole of Al requires $3\,F$, then 1.5 moles will require:

$$Q = 1.5\,\text{moles} \times 3\,F/\text{mole} = 4.5\,F$$

Thus, 4.5 Faradays (or 4.5 × 96500 Coulombs) are necessary to deposit the given mass.

Answer: (A)

Q8.

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 factors in temperature (T), the number of electrons transferred (n), and the concentration of the species involved.
Solution: For the reduction reaction: $M^{n+}(aq) + ne^- \to M(s)$ The general form of the Nernst equation is:

$$E = E^\circ - \frac{RT}{nF} \ln \frac{[\text{Product}]}{[\text{Reactant}]}$$

- **Products:** The product is the pure metal M in solid state. The concentration (or activity) of any pure solid or liquid is always taken as **unity** (1) because its density remains constant.
- **Reactants:** The reactant is the aqueous ion M^{n+}.

Substituting these values into the equation:

$$E = E^\circ - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$$

If we were to use the common logarithm ($\log_{10}$) and standard temperature (298 K), the equation would simplify to $E = E^\circ - \frac{0.059}{n} \log \frac{1}{[M^{n+}]}$. However, in its natural log (ln) form as requested in the options, the correct expression is $E = E^\circ - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$.

Answer: (A)

Q9.

Solution

Concept: Fuel cells are electrochemical devices that convert chemical energy from a continuously supplied fuel and an oxidant into electricity. Unlike standard batteries, they do not "die" as long as the fuel is supplied.

Solution: In the most common and commercially significant type of fuel cell, the **Hydrogen-Oxygen Fuel Cell**:

- **Anode:** Hydrogen gas (H_2) is oxidized.
- **Cathode:** Oxygen gas (O_2) is reduced.
- **Byproduct:** Water (H_2O), making it highly environmentally friendly.

Evaluating the options:

- (A) Cd (Cadmium) is used in rechargeable Nickel-Cadmium (Ni-Cd) batteries.
- (B) Pb (Lead) is the primary component of Lead-acid storage batteries (car batteries).
- (D) Li (Lithium) is used in high-energy Lithium-ion batteries found in phones and EVs.
- (C) H_2 **(Hydrogen)** is the primary fuel used in fuel cells because of its high energy density and clean combustion.

Answer: (C)

Q10.

Solution

Concept: Molar conductivity (Λ_m) increases as the concentration of the electrolyte decreases. The limit of this value as the concentration approaches zero (infinite dilution) is called the **limiting molar conductivity** (Λ_m°).
Solution: To find Λ_m°, we observe how Λ_m changes with concentration (c):

(a) **Strong Electrolytes:** For strong electrolytes (like KCl or HCl), the relationship is linear and follows the Debye-Hückel-Onsager equation: $\Lambda_m = \Lambda_m^\circ - A\sqrt{c}$. Because this is a straight-line graph, we can **extrapolate** the line to the point where concentration is zero ($\sqrt{c} = 0$). The y-intercept of this plot gives the value of Λ_m°.

(b) **Weak Electrolytes:** For weak electrolytes (like acetic acid), the graph is not linear and curves upward sharply at low concentrations. In this case, extrapolation is impossible, and we use **Kohlrausch's Law of Independent Migration of Ions** instead.

The standard experimental method for obtaining this limit for strong electrolytes is the extrapolation to zero concentration.

Answer: (A)

Q11.

Solution

Concept: The lead storage battery is a secondary cell. When the battery is **discharged**, it produces electricity through a chemical reaction. When the battery is **charged**, an external current is applied to reverse those reactions and regenerate the original active materials.
Solution: During **Discharge**: Both the Anode (Pb) and the Cathode (PbO_2) react with H_2SO_4 to form **Lead Sulfate ($PbSO_4$)** on the electrodes.
During **Charging**: The process is reversed. The battery acts as an electrolytic cell.

- The electrode that was the cathode during discharge is connected to the negative terminal of the charger. It now acts as an **electrolytic cathode** where reduction occurs.
- The $PbSO_4$ (Lead Sulfate) deposited on this electrode is reduced back into **spongy metallic Lead (Pb)**:

$$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$$

- Simultaneously, at the anode during charging, $PbSO_4$ is oxidized back into PbO_2 (Lead Dioxide).

Thus, during the charging phase, $PbSO_4$ on the cathode is converted back into Pb.

Answer: (A)

Q12.

Solution

Concept: First-order reaction kinetics involve an integrated rate law where the rate depends on the concentration of only one reactant. The relationship between the rate constant (k), time (t), initial concentration ($[R]_0$), and final concentration ($[R]$) is given by the formula:

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

Solution: To find the relationship, we calculate the time for half-life ($t_{1/2}$) and the time for 99.9% completion ($t_{99.9\%}$) separately:

(a) **Half-life ($t_{1/2}$):** This is the time when $[R] = \frac{1}{2}[R]_0$.

$$t_{1/2} = \frac{2.303}{k} \log \frac{[R]_0}{0.5[R]_0} = \frac{2.303 \log 2}{k} = \frac{0.693}{k}$$

(b) **Time for 99.9% completion ($t_{99.9\%}$):** For 99.9% completion, the remaining concentration $[R]$ is:

$$[R] = [R]_0 - 0.999[R]_0 = 0.001[R]_0 = 10^{-3}[R]_0$$

Substituting this into the rate equation:

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

Since $\log(10^3) = 3$:

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

Comparison: By dividing $t_{99.9\%}$ by $t_{1/2}$:

$$\frac{t_{99.9\%}}{t_{1/2}} = \frac{6.909/k}{0.693/k} \approx 9.97 \approx 10$$

Therefore, for a first-order reaction, the time required for 99.9% completion is approximately 10 times the half-life.

Answer: (B)

Q13.

Solution

Concept: The rate constant (k) is a proportionality constant in the rate law equation that is specific to a particular reaction at a specific temperature. While the *rate of reaction* depends on many factors like concentration, the *rate constant* itself is independent of concentration.

Solution: The dependence of the rate constant is best explained by the **Arrhenius Equation**:

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

Where:

- k = Rate constant
- A = Arrhenius factor (frequency factor)
- E_a = Activation energy
- R = Gas constant
- T = Absolute temperature

Why Temperature? As the temperature increases, the kinetic energy of the molecules increases. According to collision theory, more molecules will have energy equal to or greater than the activation energy (E_a), leading to a higher number of effective collisions. This results in a significant increase in the value of k. Generally, for every $10°C$ rise in temperature, the rate constant nearly doubles.

Other Options:

- **Concentration/Pressure:** Changing the concentration or pressure changes the *rate* of the reaction, but the value of k remains constant for that reaction at that temperature.
- **Extent of reaction:** k remains constant throughout the progress of the reaction.

Thus, the rate constant of a reaction primarily depends on the temperature.

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

Q14.

Solution

Concept: The units of the rate constant (k) are derived from the rate law expression: Rate $= k[\text{Reactant}]^n$, where n is the order of the reaction. The general formula to determine the units of k is $(mol\,L^{-1})^{1-n}s^{-1}$.

Solution: To identify the order of the reaction, we compare the given unit $(L\,mol^{-1}s^{-1})$ with the general formula for the rate constant unit.

(a) **General Formula:** Unit $= (mol \cdot L^{-1})^{1-n} \cdot s^{-1}$

(b) **Given Unit:** $L \cdot mol^{-1} \cdot s^{-1}$, which can be rewritten as $(mol \cdot L^{-1})^{-1} \cdot s^{-1}$.

(c) **Equating the exponents:** Comparing the power of the concentration term $(mol \cdot L^{-1})$:

$$1 - n = -1$$

$$-n = -1 - 1$$

$$n = 2$$

Verification of common orders:

- **Zero Order $(n = 0)$:** $(mol\,L^{-1})^{1-0}s^{-1} = mol\,L^{-1}s^{-1}$ (Concentration/time).
- **First Order $(n = 1)$:** $(mol\,L^{-1})^{1-1}s^{-1} = (mol\,L^{-1})^{0}s^{-1} = s^{-1}$ (Time^{-1}).
- **Second Order $(n = 2)$:** $(mol\,L^{-1})^{1-2}s^{-1} = (mol\,L^{-1})^{-1}s^{-1} = L\,mol^{-1}s^{-1}$.

Since the unit matches the second-order calculation, the reaction is of the **second order**.

Answer: (C)

Q15.

Solution

Concept: The relationship between the rate constant (k), temperature (T), and activation energy (E_a) is mathematically defined by the Arrhenius equation: $k = A \cdot e^{-E_a/RT}$. Here, A represents the frequency factor (or pre-exponential factor).

Solution: Activation energy (E_a) is the minimum energy required by reactant molecules to undergo a successful collision and form products. If we consider a theoretical case where the activation energy is zero:

(a) Substitute $E_a = 0$ into the Arrhenius equation:

$$k = A \cdot e^{-(0)/RT}$$

(b) Simplify the exponent: Since 0 divided by any non-zero value (RT) is 0, the expression becomes:

$$k = A \cdot e^0$$

(c) Evaluate the constant: Mathematically, any number (except zero) raised to the power of zero is 1 ($e^0 = 1$).

$$k = A \cdot 1$$

$$k = A$$

Conclusion: In such a scenario, the rate constant k becomes equal to the frequency factor A. This implies that every collision that occurs between reactant molecules results in a reaction, as there is no energy barrier to overcome.

Answer: (A)

Q16.

Solution

Concept: A catalyst is a substance that increases the speed of a chemical reaction without undergoing any permanent chemical change itself. It works by altering the kinetics (mechanism) of the reaction rather than the thermodynamics.

Solution: The addition of a catalyst provides an alternative reaction pathway or "bridge" that has a **lower activation energy** (E_a) compared to the uncatalyzed path.

- **Why Activation Energy?** By lowering E_a, a significantly larger number of reactant molecules have sufficient kinetic energy to cross the energy barrier at a given temperature, thus increasing the rate of reaction.
- **Thermodynamic Functions:** A catalyst does *not* affect state functions like Internal Energy (U), Enthalpy (H), or Gibbs Free Energy (G). The energy difference between reactants and products remains constant.
- **Equilibrium:** A catalyst does not change the position of equilibrium or the equilibrium constant (K_{eq}); it only allows the system to reach that equilibrium state much faster by increasing both forward and backward reaction rates equally.

Therefore, the fundamental role of a catalyst is to change (specifically decrease) the activation energy.

Answer: (C)

Q17.

Solution

Concept: For transition metal ions, the magnetic moment is calculated using the "spin-only" formula: $\mu = \sqrt{n(n+2)}\,BM$, where n is the number of unpaired electrons and BM stands for Bohr Magnetons. The more unpaired electrons an ion has, the higher its magnetic moment.
Solution: We determine the number of unpaired electrons (n) for each ion by looking at their $3d$ subshell electronic configurations:

- **(A)** Mn^{2+}**:** Atomic number 25. Configuration: $[Ar]3d^5$. All five electrons are unpaired ($n = 5$).
- **(B)** Fe^{2+}**:** Atomic number 26. Configuration: $[Ar]3d^6$. One pair of electrons and four unpaired electrons ($n = 4$).
- **(C)** Ti^{2+}**:** Atomic number 22. Configuration: $[Ar]3d^2$. Two unpaired electrons ($n = 2$).
- **(D)** Cr^{2+}**:** Atomic number 24. Configuration: $[Ar]3d^4$. Four unpaired electrons ($n = 4$).

Calculation: For Mn^{2+}, $\mu = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92\,BM$. For Fe^{2+} and Cr^{2+}, $\mu = \sqrt{4(4+2)} = \sqrt{24} \approx 4.90\,BM$. Since Mn^{2+} has the maximum number of unpaired electrons ($n = 5$), it exhibits the highest magnetic moment.

Answer: (A)

Q18.

Solution

Concept: Lanthanoid contraction refers to the gradual and steady decrease in the atomic and ionic radii of the lanthanoids (Ce to Lu) as the atomic number increases. This effect has a significant impact on the chemistry of post-lanthanoid elements.
Solution: This contraction is a cumulative effect caused by two primary factors:

(a) **Poor Shielding of 4f Electrons:** As we move along the series, electrons are added to the $4f$ subshell. The $4f$ orbitals are large and diffused in shape. Because of this, they are very ineffective at "shielding" or "screening" the outer electrons from the increasing positive charge of the nucleus.

(b) **Increase in Nuclear Charge:** With each successive element, the number of protons in the nucleus increases by one.

Because the $4f$ electrons provide poor shielding, the **effective nuclear charge** experienced by the outer electrons increases significantly. This results in the nucleus pulling the entire electron cloud closer to itself, causing a reduction in size. Thus, both the poor shielding of $4f$ electrons and the increase in nuclear charge are responsible.

Answer: (D)

Q19.

Solution

Concept: Lanthanoids (the 4f series) can exhibit various oxidation states, including +2, +3, and +4. However, the stability of these states varies based on the electronic configuration and hydration energies.

Solution: The electronic configuration of Lanthanoids is generally $[Xe]4f^{1-14}5d^{0-1}6s^2$.

- When these elements react, they most easily lose the two $6s$ electrons and one $5d$ (or $4f$) electron.
- The **+3 oxidation state** is the most stable and predominant state for all elements in the series.
- Although +2 and +4 states are observed in specific elements (like Ce^{4+} which gains an f^0 configuration or Eu^{2+} which gains an f^7 configuration), these ions usually tend to revert to the +3 state in aqueous solutions through redox reactions.

Due to its high thermodynamic stability across the entire series, +3 is considered the most common oxidation state.

Answer: (B)

Q20.

Solution

Concept: Potassium permanganate ($KMnO_4$) is a versatile and strong oxidizing agent. In redox titrations, its behavior and the final product formed depend heavily on the hydrogen ion concentration (pH) of the medium.

Solution: In an **acidic medium** (usually provided by dilute H_2SO_4): The Manganese atom in MnO_4^- is in the +7 oxidation state. It acts as a powerful oxidant by accepting 5 electrons to reach a more stable state. **The half-reaction is:**

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

- The oxidation state changes from **+7 to +2**.
- The solution changes from a deep purple color to a virtually colorless state (pale pink at high concentrations).
- In **neutral/weakly alkaline** conditions, it reduces to MnO_2 (+4).
- In **strongly alkaline** conditions, it reduces to MnO_4^{2-} (+6).

Since the question specifies an acidic medium, the resulting ion is Mn^{2+}.

Answer: (A)

Q21.

Solution

Concept: According to IUPAC rules for naming coordination compounds: 1. Name the cation first, followed by the anion. 2. Inside the coordination sphere, ligands are named alphabetically. 3. If the complex ion is an anion, the metal's name must end in the suffix "-ate". 4. The oxidation state of the metal is written in Roman numerals in parentheses.
Solution: For the compound $K_3[Fe(CN)_6]$:

(a) **Cation:** The cation is Potassium (K^+).

(b) **Anion (Complex Ion):** $[Fe(CN)_6]^{3-}$.

(c) **Ligands:** There are six CN^- (cyanido/cyano) groups, so we use "hexacyano".

(d) **Metal:** Since the complex is an anion, we use the Latin name for Iron ("Ferrum") and add the suffix "-ate," resulting in **Ferrate**.

(e) **Oxidation State (x):** $3(+1) + x + 6(-1) = 0 \Rightarrow 3 + x - 6 = 0 \Rightarrow x = +3$.

Putting it all together: **Potassium hexacyanoferrate(III)**.

Answer: (C)

Q22.

Solution

Concept: The coordination number is defined as the total number of coordinate bonds formed between the central metal ion and the ligands. It is not necessarily equal to the number of ligand molecules if the ligands are polydentate.
Solution: In the complex $[Co(en)_3]^{3+}$:

- **Central Metal:** Cobalt (Co).
- **Ligand:** "en" stands for **ethylenediamine** ($NH_2 - CH_2 - CH_2 - NH_2$).
- **Denticity:** Ethylenediamine is a **bidentate** ligand. This means each single "en" molecule has two donor atoms (both Nitrogen) and can form two separate coordinate bonds with the metal ion simultaneously.

Calculation: There are 3 "en" ligands attached to the Cobalt. Each "en" ligand provides 2 donor sites. Total coordinate bonds $= 3 \times 2 = 6$. Therefore, the coordination number of Cobalt in this specific complex is 6, resulting in an octahedral geometry.

Answer: (C)

Q23.

Solution

Concept: Crystal Field Theory (CFT) explains that the nature of the ligand determines whether a complex is high spin or low spin. Strong field ligands cause large splitting ($\Delta_o > P$), leading to electron pairing (low spin), while weak field ligands cause small splitting ($\Delta_o < P$), allowing electrons to remain unpaired (high spin).

Solution: We analyze each complex based on the metal ion and the Spectrochemical series:

- **(A)** $[Co(NH_3)_6]^{3+}$**:** Co^{3+} has a d^6 configuration. NH_3 acts as a strong field ligand for Co^{3+}, causing electrons to pair up in the t_{2g} orbitals. This is a **low spin** complex.
- **(B)** $[CoF_6]^{3-}$**:** Co^{3+} has a d^6 configuration. F^- is a **weak field ligand**. The crystal field splitting (Δ_o) is less than the pairing energy (P). Electrons occupy the e_g orbitals before pairing, resulting in four unpaired electrons. This is a **high spin** complex.
- **(C)** $[Fe(CN)_6]^{4-}$**:** Fe^{2+} has a d^6 configuration. CN^- is a very strong field ligand, causing maximum pairing. This is a **low spin** complex.
- **(D)** $[Ni(CN)_4]^{2-}$**:** Ni^{2+} has a d^8 configuration. With a strong field ligand like CN^-, it forms a square planar, **low spin** (diamagnetic) complex.

Thus, $[CoF_6]^{3-}$ is the only high spin complex among the choices.

Answer: (B)

Q24.

Solution

Concept: Valence Bond Theory (VBT) determines the hybridization of a central metal atom based on its oxidation state, electronic configuration, and the nature of the surrounding ligands.

Solution: 1. Oxidation State: In Tetracarbonylnickel(0), $[Ni(CO)_4]$, the oxidation state of Nickel is **0** because CO is a neutral ligand. **2. Electronic Configuration:** The ground state configuration of $Ni(Z = 28)$ is $[Ar]3d^8 4s^2$. **3. Effect of Ligand:** CO is a very **strong field ligand**. According to VBT, it forces the two electrons from the $4s$ orbital to move into the $3d$ orbitals to pair up with the existing d-electrons.

- Ground state Ni: $3d^8$ (with two unpaired electrons) and $4s^2$.
- Excited/Pairing state: The $4s$ electrons shift to $3d$, resulting in a fully filled $3d^{10}$ configuration.

4. Hybridization: Now, the $3d$ subshell is full. To accommodate the 4 pairs of electrons from the four CO ligands, the atom uses one $4s$ and three $4p$ orbitals. These four orbitals hybridize to form sp^3 hybrid orbitals, leading to a **tetrahedral** geometry.

Answer: (A)

Q25.

Solution

Concept: Ionization isomerism occurs when the composition of the coordination sphere (ligands attached to the metal) and the counter ions (ions outside the bracket) are interchanged. These isomers produce different ions when dissolved in water.

Solution: Let's examine the two compounds provided:

(a) $[Co(NH_3)_5SO_4]Br$**:** In this compound, the SO_4^{2-} ion is inside the coordination sphere acting as a ligand, and the Br^- ion is the counter ion. When dissolved, it releases **Bromide** (Br^-) ions.

(b) $[Co(NH_3)_5Br]SO_4$**:** In this compound, the Br^- ion is inside the coordination sphere, and the SO_4^{2-} ion is the counter ion. When dissolved, it releases **Sulfate** (SO_4^{2-}) ions.

Conclusion: Since these compounds have the same molecular formula but give different ions in solution due to the exchange of ions between the coordination sphere and the outer ionizable sphere, they are **Ionization isomers**.

Answer: (B)

Q26.

Solution

Concept: Crystal Field Theory describes the splitting of degenerate d-orbitals into sets of different energies (t_{2g} and e_g) when surrounded by ligands. The energy gap between these levels is the Crystal Field Splitting Energy (CFSE).

Solution: The notation used for the splitting energy depends entirely on the geometry of the coordination environment:

- **Δ_o:** The subscript **'o'** stands for **Octahedral**. It represents the energy difference in a 6-coordinate complex where the d-orbitals split into a lower t_{2g} set and a higher e_g set.
- **Δ_t:** The subscript **'t'** stands for **Tetrahedral**. In this geometry, the splitting is reversed, and the energy gap is denoted as Δ_t (where $\Delta_t \approx \frac{4}{9}\Delta_o$).
- **Δ_s:** Sometimes used for square planar complexes.
- **P:** Represents the **Pairing Energy**, which is the energy required to pair two electrons in the same orbital.

Since the question asks for an octahedral complex, the correct notation is Δ_o.

Answer: (B)

Q27.

Solution

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

Solution: In an S_N2 reaction, the bond formation between the nucleophile and the carbon atom occurs simultaneously with the bond breaking between the carbon and the leaving group.

(a) **Backside Attack:** Because the leaving group is bulky and negatively charged, the nucleophile must approach from the exact opposite direction (180°).

(b) **Transition State:** As the reaction progresses through a pentacoordinate transition state, the configuration of the carbon atom "flips" like an umbrella being blown inside out in a strong wind.

(c) **Result:** This process leads to the **Walden Inversion** or **Inversion of configuration**. If the starting material is (R), the product will be (S), provided the priority of the nucleophile is the same as the leaving group.

In contrast, S_N1 reactions typically lead to *racemization* due to the formation of a planar carbocation intermediate.

Answer: (B)

Q28.

Solution

Concept: Dihalides are classified based on the relative positions of the two halogen atoms.

- **Vicinal (vic) dihalides:** Halogen atoms are present on adjacent carbon atoms.
- **Geminal (gem) dihalides:** Both halogen atoms are present on the same carbon atom.

Solution: Let's analyze the structures of the given options:

- **(A) Dichloromethane (CH_2Cl_2):** Both chlorine atoms are on the same carbon. This is a gem-dihalide.
- **(B) 1,2-dichloroethane ($Cl-CH_2-CH_2-Cl$):** The two chlorine atoms are attached to two adjacent carbon atoms. This is a **vic-dihalide**.
- **(C) Ethylidene chloride (CH_3-CHCl_2):** Both chlorine atoms are on the first carbon. This is a gem-dihalide.
- **(D) Allyl chloride ($CH_2=CH-CH_2Cl$):** This contains only one halogen atom; it is a monohalide.

Since 1,2-dichloroethane has halogens on neighboring carbons, it is a vicinal dihalide.

Answer: (B)

Q29.

Solution

Concept: The Finkelstein reaction is a specific type of organic reaction known as a halogen exchange reaction. It follows an S_N2 mechanism.
Solution: In this reaction, an alkyl chloride or alkyl bromide is treated with sodium iodide (NaI) in the presence of dry acetone to produce an **alkyl iodide**.

$$R-X+NaI \xrightarrow{\text{dry acetone}} R-I+NaX \quad (\text{where } X=Cl, Br)$$

Why dry acetone?

- NaI is soluble in acetone, but the products $NaCl$ or $NaBr$ are not.
- As $NaCl$ or $NaBr$ precipitates out of the solution, the equilibrium is shifted in the forward direction according to Le Chatelier's Principle.

Therefore, the Finkelstein reaction is the primary method for the synthesis of alkyl iodides. For alkyl fluorides, the Swarts reaction is used.

Answer: (B)

Q30.

Solution

Concept: Reactivity toward nucleophilic substitution depends on the ease with which the leaving group can be displaced. This is influenced by resonance, steric hindrance, and the stability of the intermediate.

Solution: Let's compare the reactivity of the given halides:

- **Chlorobenzene and Vinyl chloride:** These are extremely unreactive. The lone pair on the chlorine atom is in resonance with the double bond/aromatic ring, giving the $C-Cl$ bond a partial double bond character, making it very strong and hard to break.
- **Ethyl chloride (CH_3CH_2Cl):** A standard 1° alkyl halide that undergoes substitution via S_N2, but it is not as fast as activated systems.
- **Benzyl chloride ($C_6H_5CH_2Cl$):** This is highly reactive.
  (a) In S_N1, the benzyl carbocation ($C_6H_5CH_2^+$) is highly stabilized by resonance with the benzene ring.
  (b) In S_N2, the transition state is stabilized by the π electron system of the aromatic ring.

Due to these stabilizing factors, benzyl chloride is the most reactive towards nucleophilic substitution.

Answer: (C)

Q31.

Solution

Concept: The Lucas test is a chemical test used to differentiate between primary (1°), secondary (2°), and tertiary (3°) alcohols based on their reactivity with the Lucas reagent (a mixture of concentrated HCl and anhydrous $ZnCl_2$).

Solution: The test works by converting alcohols into alkyl chlorides, which are insoluble in the reagent and cause the solution to become cloudy (turbid). The rate of the reaction follows the stability of the carbocation ($3° > 2° > 1°$):

- **Tertiary (3°) Alcohols:** React immediately to produce turbidity.
- **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.

Thus, the Lucas test is specifically used to distinguish between different classes of alcohols.

Answer: (B)

Q32.

Solution

Concept: The treatment of phenol with chloroform ($CHCl_3$) in the presence of an alkali ($NaOH$) introduces an aldehyde group ($-CHO$) at the ortho position of the benzene ring.

Solution: The reaction described is the **Reimer-Tiemann reaction**.

- **Reaction:** Phenol $+$ $CHCl_3$ $+$ $NaOH$ $\rightarrow$ Salicylaldehyde (o-hydroxybenzaldehyde).
- **Mechanism:** The reaction involves an electrophilic attack by **dichlorocarbene** ($:CCl_2$), which is generated in situ from the reaction of chloroform with the base.

Comparison with other options:

- **Kolbe's reaction:** Phenol reacts with CO_2 and $NaOH$ to give Salicylic acid ($-COOH$ group).
- **Etard reaction:** Chromyl chloride converts toluene to benzaldehyde.
- **Cannizzaro reaction:** Aldehydes without α-hydrogen atoms undergo self-oxidation and reduction.

Answer: (B)

Q33.

Solution

Concept: Ether cleavage by hydrogen halides (like HI) involves a nucleophilic attack. The position of the bond cleavage depends on the nature of the alkyl or aryl groups attached to the oxygen.

Solution: Ethyl phenyl ether (Phenetole) has the structure $C_6H_5 - O - C_2H_5$. When it reacts with HI, the cleavage can potentially occur at two sites:

(a) **Phenyl-Oxygen Bond:** This bond is very strong because the lone pair on the oxygen is in resonance with the benzene ring, giving the bond partial double bond character. Furthermore, the sp^2 hybridized carbon of the ring forms a stronger bond than sp^3.

(b) **Ethyl-Oxygen Bond:** This is a standard sp^3 $C - O$ single bond and is much easier to break.

The nucleophile (I^-) attacks the smaller alkyl group (ethyl) via an S_N2 mechanism, while the proton (H^+) attaches to the phenoxide part.

$$C_6H_5 - O - C_2H_5 + HI \rightarrow C_6H_5 - OH + C_2H_5I$$

The products are **Phenol** and **Ethyl Iodide**.

Answer: (A)

Q34.

Solution

Concept: The acidity of phenols is determined by the stability of the resulting phenoxide ion. Substituents on the ring significantly affect this stability.

- **Electron Withdrawing Groups (EWG):** Stabilize the negative charge on the phenoxide ion, increasing acidity.
- **Electron Donating Groups (EDG):** Destabilize the negative charge, decreasing acidity.

Solution: Let's analyze the effects of the substituents in the given options:

- **(A) Phenol:** The baseline for comparison.
- **(B) p-Nitrophenol:** The nitro group ($-NO_2$) is a powerful **EWG** through both inductive ($-I$) and resonance ($-R$) effects. It strongly stabilizes the phenoxide ion, making it much more acidic than phenol.
- **(C) p-Cresol:** The methyl group ($-CH_3$) is an **EDG** due to hyperconjugation and inductive effect ($+I$). This decreases acidity.
- **(D) p-Methoxyphenol:** The methoxy group ($-OCH_3$) is a strong **EDG** due to resonance ($+R$), which significantly decreases acidity.

Since the nitro group is the strongest electron-withdrawing group among the options, p-Nitrophenol is the strongest acid.

Answer: (B)

Q35.

Solution

Concept: Industrial methanol (CH_3OH), also known as "wood spirit," was originally produced by the destructive distillation of wood but is now synthesized from "syngas" (synthesis gas).

Solution: Methanol is prepared on a large industrial scale by the catalytic hydrogenation of **Carbon Monoxide** (CO).

- **Reaction:** $CO + 2H_2 \xrightarrow{\text{catalyst}} CH_3OH$
- **Conditions:** The reaction requires high pressure (200–300 atm) and a temperature of about 573–673 K.
- **Catalyst:** A mixture of Zinc Oxide (ZnO) and Chromium Oxide (Cr_2O_3) is used as the catalyst to speed up the process.

This direct hydrogenation of CO is the most efficient and standard industrial route.

Answer: (B)

Q36.

Solution

Concept: The Iodoform test is a chemical test used to identify the presence of a methyl ketone group (CH_3-CO-) or a methyl carbinol group ($CH_3-CH(OH)-$). When such a compound is treated with Iodine (I_2) and Sodium Hydroxide ($NaOH$), it forms a yellow precipitate of Iodoform (CHI_3).

Solution: Let us examine the structures of the given compounds:

- **(A) Benzophenone ($C_6H_5-CO-C_6H_5$):** It is a ketone, but it lacks a methyl group directly attached to the carbonyl carbon. Hence, it gives a negative test.
- **(B) Acetophenone ($C_6H_5-CO-CH_3$):** This is a phenyl methyl ketone. It contains the required CH_3-CO- group. Upon reaction with $I_2/NaOH$, the methyl group is converted into CHI_3 (yellow ppt).
- **(C) Pentan-3-one ($CH_3CH_2-CO-CH_2CH_3$):** Although it is a ketone, it is a symmetrical ketone with ethyl groups, not methyl groups. It gives a negative test.
- **(D) Methanol (CH_3OH):** It does not contain the methyl carbinol ($CH_3CH(OH)-$) structure. Ethanol (CH_3CH_2OH) would give a positive test, but methanol does not.

Thus, Acetophenone is the correct compound.

Answer: (B)

Q37.

Solution

Concept: The Cannizzaro reaction is a disproportionation reaction (self-oxidation and reduction) that occurs when aldehydes lacking an α-hydrogen atom are treated with a concentrated base ($NaOH$ or KOH).
Solution: We must identify which aldehyde contains an α-hydrogen, as such aldehydes will undergo Aldol condensation instead of the Cannizzaro reaction.

- **(A) Formaldehyde ($HCHO$):** No carbon atom is attached to the CHO group, so there are no α-hydrogens. It gives the Cannizzaro reaction.
- **(B) Benzaldehyde (C_6H_5CHO):** The carbon attached to the CHO group is part of the benzene ring and has no hydrogen atom attached to it. It gives the Cannizzaro reaction.
- **(C) Acetaldehyde (CH_3CHO):** The carbon atom attached to the CHO group (the α-carbon) has three hydrogen atoms. Since it has α-hydrogens, it does not give the Cannizzaro reaction; it undergoes Aldol condensation.
- **(D) Trimethylacetaldehyde ($(CH_3)_3CCHO$):** The α-carbon is attached to three methyl groups and has no hydrogen. It gives the Cannizzaro reaction.

Answer: (C)

Q38.

Solution

Concept: Aldol condensation occurs in aldehydes or ketones having at least one α-hydrogen atom in the presence of a dilute alkali. Two molecules of the carbonyl compound combine to form a β-hydroxy aldehyde (an aldol).
Solution: When two molecules of acetaldehyde (CH_3CHO) react in the presence of dilute $NaOH$:

(a) One molecule loses an α-proton to form a nucleophilic enolate ion ($[CH_2CHO]^-$).

(b) This ion attacks the carbonyl carbon of the second acetaldehyde molecule.

(c) The resulting intermediate is protonated to form 3-hydroxybutanal.

Reaction: $CH_3CHO + CH_3CHO \xrightarrow{\text{dil. } NaOH} CH_3 - CH(OH) - CH_2 - CHO$. Note: If the solution is heated, 3-hydroxybutanal undergoes dehydration to form But-2-enal (Crotonaldehyde), but the primary "Aldol" product itself is 3-hydroxybutanal.

Answer: (A)

Q39.

Solution

Concept: Clemmensen reduction is a chemical reaction used to reduce the carbonyl group ($C = O$) of aldehydes or ketones to a methylene group ($-CH_2-$).

Solution: The specific reagent used for Clemmensen reduction is Zinc amalgam and concentrated Hydrochloric acid ($Zn - Hg/\text{conc. } HCl$).

- **Reaction:** $R - CO - R' \xrightarrow{Zn-Hg/HCl} R - CH_2 - R'$.
- **Comparison:**
  - (A) NH_2NH_2/KOH is the reagent for Wolff-Kishner reduction, which also reduces $C = O$ to CH_2 but in basic conditions.
  - (C/D) $LiAlH_4$ and $NaBH_4$ are hydride reducing agents that reduce carbonyls to alcohols, not alkanes.

Clemmensen reduction is particularly useful for compounds that are stable in strong acids.

Answer: (B)

Q40.

Solution

Concept: The acidity of carboxylic acids is influenced by the inductive effect of the substituents.

- **Electron Withdrawing Groups (EWG):** Like Chlorine ($-Cl$), these stabilize the carboxylate ion by dispersing the negative charge, thereby increasing acidity.
- **Number of Groups:** The more EWGs attached to the α-carbon, the stronger the acid.

Solution: Let's evaluate the acidity based on the chlorine substituents:

(a) **Trichloroacetic acid (Cl_3CCOOH):** Has three $-Cl$ atoms exerting a strong $-I$ effect. It is the strongest.

(b) **Dichloroacetic acid ($Cl_2CHCOOH$):** Has two $-Cl$ atoms. It is weaker than the trichloro version but stronger than the mono-chloro version.

(c) **Chloroacetic acid ($ClCH_2COOH$):** Has only one $-Cl$ atom.

(d) **Acetic acid (CH_3COOH):** Has no EWG; in fact, the methyl group has a $+I$ effect, which decreases acidity.

Therefore, the correct order is $Cl_3CCOOH > Cl_2CHCOOH > ClCH_2COOH$.

Answer: (B)

Q41.

Solution

Concept: Tollen's reagent is an ammoniacal solution of silver nitrate, represented as $[Ag(NH_3)_2]^+$. It is a mild oxidizing agent used to distinguish aldehydes from ketones.
Solution: Ethanal (Acetaldehyde) is an aldehyde. When it is heated with Tollen's reagent:

(a) The aldehyde is oxidized to the corresponding carboxylate ion (CH_3COO^-).

(b) The silver ions (Ag^+) present in the reagent are reduced to metallic silver (Ag).

The metallic silver deposits on the inner wall of the test tube, forming a shining silver mirror. **Reaction:** $CH_3CHO + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow CH_3COO^- + 2Ag(s) + 4NH_3 + 2H_2O$. Ketones do not respond to this test (except α-hydroxy ketones).

Answer: (B)

Q42.

Solution

Concept: Basicity of amines depends on the availability of the lone pair of electrons on the Nitrogen atom. In the gaseous phase, there are no solvent effects (solvation) or steric hindrances from water molecules. Only the inductive effect ($+I$) of the alkyl groups matters.
Solution: Alkyl groups are electron-releasing in nature ($+I$ effect).

- **Tertiary (3°) Amines:** Have three alkyl groups releasing electrons toward Nitrogen, making the lone pair most available.
- **Secondary (2°) Amines:** Have two alkyl groups.
- **Primary (1°) Amines:** Have one alkyl group.
- **Ammonia (NH_3):** Has no alkyl groups.

Thus, in the gaseous phase, the basicity order strictly follows the inductive effect: $3° > 2° > 1° > NH_3$. (Note: In aqueous solution, this order changes due to solvation and steric factors).

Answer: (A)

Q43.

Solution

Concept: The Hinsberg test is a chemical method used to distinguish between primary, secondary, and tertiary amines. The reagent used in this test is known as the Hinsberg reagent.

Solution: The chemical name for Hinsberg's reagent is Benzene sulphonyl chloride $(C_6H_5SO_2Cl)$.

- **Primary amines:** React with it to form a sulfonamide that is soluble in alkali.
- **Secondary amines:** React to form a sulfonamide that is insoluble in alkali.
- **Tertiary amines:** Do not react with benzene sulphonyl chloride because they lack a replaceable hydrogen atom on the Nitrogen.

Because it reacts differently with each class of amine, it is an essential diagnostic tool in organic chemistry.

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

Q44.

Solution

Concept: The Carbylamine reaction (also known as the Hoffmann Isocyanide Test) is a highly sensitive chemical test used exclusively for the detection of **primary (1°) amines**. It is not given by secondary or tertiary amines.

Solution: When a primary amine is heated with Chloroform ($CHCl_3$) and an alcoholic solution of Potassium Hydroxide (KOH), it undergoes a reaction to form an Isocyanide (also called a Carbylamine). These isocyanides are characterized by an extremely offensive, foul, or "rotten fish" smell. **The General Reaction:**

$$R - NH_2 + CHCl_3 + 3KOH(alc.) \xrightarrow{\Delta} R - N \equiv C \text{ (Isocyanide)} + 3KCl + 3H_2O$$

Analysis of Options:

- **(A) n-Butylamine ($CH_3CH_2CH_2CH_2NH_2$):** This is a **primary aliphatic amine**. It possesses the necessary $-NH_2$ group to react and form n-butyl isocyanide, which produces the foul smell.
- **(B) Diethylamine ($(C_2H_5)_2NH$):** This is a **secondary amine**. It does not have two replaceable hydrogens on the nitrogen to form the triple bond required for an isocyanide.
- **(C) Triethylamine ($(C_2H_5)_3N$):** This is a **tertiary amine**. It has no hydrogens on the nitrogen atom.
- **(D) N-Methylaniline ($C_6H_5NHCH_3$):** This is a **secondary aromatic amine**. Like other secondary amines, it does not respond to this test.

Since the test is a diagnostic for primary amines, n-Butylamine is the only compound that will produce the foul-smelling product.

Answer: (A)

Q45.

Solution

Concept: Gabriel Phthalimide Synthesis is a specialized method used to prepare **pure primary aliphatic amines**. The reaction involves a nucleophilic substitution (S_N2 mechanism) where the phthalimide anion acts as a nucleophile.

Solution: The process consists of three main steps:

(a) Phthalimide reacts with ethanolic KOH to form **Potassium Phthalimide**.

(b) The potassium salt reacts with an **alkyl halide** ($R - X$) via an S_N2 mechanism to form N-alkylphthalimide.

(c) Alkaline hydrolysis or treatment with hydrazine yields the primary amine.

Why Aniline cannot be prepared: To prepare Aniline ($C_6H_5NH_2$), we would need to use an aryl halide (like Chlorobenzene). However, **Aryl halides** do not undergo nucleophilic substitution (S_N2) reactions with the phthalimide ion because:

- The lone pair of the halogen is in resonance with the benzene ring, giving the $C - X$ bond **partial double-bond character**.
- The sp^2 hybridized carbon of the benzene ring is more electronegative than an sp^3 carbon, making the bond stronger and harder to break.

Consequently, while methylamine, ethylamine, and isopropylamine (all aliphatic) can be prepared, aromatic amines like aniline cannot.

Answer: (B)

Q46.

Solution

Concept: Carbohydrates are classified as reducing or non-reducing based on the presence of a **free anomeric carbon** (a carbon atom that can exist as an aldehyde or ketone in its open-chain form). If the anomeric carbon is involved in a glycosidic bond, it cannot reduce Fehling's or Tollen's reagent.

Solution:

- **(A) Maltose:** Formed by two α-D-glucose units. The C_1 of the first unit is linked to C_4 of the second. The C_1 of the second glucose remains free (hemiacetal form). Thus, it is a **reducing sugar**.
- **(B) Lactose:** Formed by β-D-galactose and β-D-glucose. The C_1 of galactose is linked to C_4 of glucose. The C_1 of the glucose unit is free. Thus, it is a **reducing sugar**.
- **(D) Glucose:** As a monosaccharide, it exists in equilibrium with its open-chain aldehyde form. It is a **reducing sugar**.
- **(C) Sucrose:** Composed of α-D-glucose and β-D-fructose. The glycosidic linkage occurs between the C_1 **of glucose and the** C_2 **of fructose**. Since both reducing centers (the aldehyde group of glucose and the ketone group of fructose) are tied up in the bond, the sugar cannot open into a chain with a free carbonyl group.

Because it lacks a free hemiacetal or hemiketal group, sucrose is a **non-reducing sugar**.

Answer: (C)

Q47.

Solution

Concept: Amino acids are bifunctional organic compounds that serve as the building blocks of proteins. Their chemical properties are dominated by the presence of both an acidic and a basic functional group within the same molecule.

Solution: In an α-amino acid, a central carbon atom (the α-carbon) is covalently bonded to four different groups (except in glycine):

(a) **The Amino Group ($-NH_2$):** A basic functional group that can accept a proton to become $-NH_3^+$.

(b) **The Carboxyl Group ($-COOH$):** An acidic functional group that can donate a proton to become $-COO^-$.

(c) A Hydrogen atom ($-H$).

(d) A Side Chain ($-R$): This varies for each of the 20 standard amino acids.

Because they contain both $-NH_2$ and $-COOH$, amino acids undergo an internal acid-base reaction in aqueous solution to form a **Zwitterion** (a dipolar ion). This dual-functional nature is what allows amino acids to link together via peptide bonds (amide bonds) to form long protein chains.

Answer: (C)

Q48.

Solution

Concept: Vitamins are essential micronutrients classified into two broad categories based on their solubility in water versus fats/oils. This solubility determines how they are absorbed, stored, and excreted.

Solution:

- **Fat-Soluble Vitamins (A, D, E, K):** These are soluble in lipids and are stored in the liver and fatty tissues (adipose tissue). Because they are stored, excessive intake can lead to toxicity (hypervitaminosis).
- **Water-Soluble Vitamins (B-complex, C):** These are soluble in water and are not stored in the body to any significant extent (with the exception of B_{12}). They are readily excreted in urine, which is why they must be replenished daily through the diet.

Evaluating the options:

- **Vitamin A (Retinol):** Fat-soluble; vital for vision.
- **Vitamin D (Calciferol):** Fat-soluble; vital for bone health.
- **Vitamin C (Ascorbic Acid): Water-soluble**; acts as a powerful antioxidant and is essential for collagen synthesis.
- **Vitamin K (Phylloquinone):** Fat-soluble; essential for blood clotting.

Therefore, Vitamin C is the only water-soluble vitamin in the list.

Answer: (C)

Q49.

Solution

Concept: The structure of DNA is characterized by two polynucleotide chains that are held together by **hydrogen bonds** between nitrogenous bases. This base pairing is highly specific and follows "Chargaff's Rules."

Solution: In the DNA double helix, a purine always pairs with a pyrimidine to maintain a constant distance between the sugar-phosphate backbones:

- **Adenine (A)** and **Thymine (T)**: These form a complementary pair held together by **two hydrogen bonds** ($A = T$).
- **Guanine (G)** and **Cytosine (C)**: These form a complementary pair held together by **three hydrogen bonds** ($G \equiv C$).

Note on RNA: While DNA uses Thymine, RNA uses **Uracil (U)**. In RNA, Adenine pairs with Uracil. However, since the question specifies DNA, the correct pairs are Adenine-Thymine and Guanine-Cytosine. This pairing mechanism is the foundation for genetic replication and the storage of biological information.

Answer: (A)

Q50.

Solution

Concept: Protein denaturation is the process where a protein loses its native three-dimensional conformation due to external factors like heat, change in pH, or chemical agents. This structural change is usually irreversible and results in the loss of biological function.

Solution: Proteins have four levels of structure:

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

(b) **Secondary (2°):** α-helices and β-pleated sheets held by hydrogen bonds.

(c) **Tertiary (3°):** The overall 3D folding of the polypeptide chain.

During Denaturation: The weak interactions (hydrogen bonds, disulfide bridges, and van der Waals forces) that maintain the **secondary and tertiary structures** are broken. The protein "uncoils" and loses its specific shape. Importantly, the **primary structure remains intact** because peptide bonds are too strong to be broken by standard denaturing conditions. Since the biological activity of an enzyme or hormone depends on its specific 3D tertiary "active site" shape, the disruption of these higher levels of structure leads to a total loss of its biological activity.

Answer: (B)

Answer Key

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