CUET UG Chemistry Sample Paper - 11

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 osmotic pressure of a solution containing 6.0 g of urea (mol. mass = 60) in 1 L of solution at 300 K is (R = 0.0821 L atm K^{-1} mol^{-1}):

(A) 2.46 atm

(B) 4.92 atm

(C) 1.23 atm

(D) 0.24 atm

Q2. Which of the following aqueous solutions will have the highest freezing point?

(A) 0.1 M $NaCl$

(B) 0.1 M $BaCl_2$

(C) 0.1 M $Al_2(SO_4)_3$

(D) 0.1 M Glucose

Q3. The amount of electricity required to deposit 1 mole of copper from a $CuSO_4$ solution is:

(A) 1 F

(B) 2 F

(C) 3 F

(D) 0.5 F

Q4. The standard reduction potentials of three metals A, B, and C are +0.5 V, −3.0 V, and −1.2 V respectively. The reducing power of these metals will be in the order:

(A) $A > B > C$

(B) $C > B > A$

(C) $A > C > B$

(D) $B > C > A$

Q5. For a reaction $A \rightarrow B$, the rate of reaction doubles when the concentration of A is increased by four times. The order of the reaction is:

(A) 2

(B) 1

(C) 0.5

(D) 0

Q6. The activation energy of a chemical reaction can be determined by:

(A) Evaluating rate constants at two different temperatures.

(B) Evaluating velocities of reaction at two different temperatures.

(C) Evaluating rate constant at standard temperature.

(D) Changing the concentration of reactants.

Q7. Which of the following transition metal ions has the lowest density?

(A) Sc

(B) Ti

(C) Cu

(D) Zn

Q8. $K_2Cr_2O_7$ on heating with aqueous KOH gives:

(A) CrO_4^{2-}

(B) $Cr(OH)_3$

(C) Cr_2O_3

(D) Cr^{3+}

Q9. The number of geometrical isomers possible for the complex $[Pt(NH_3)(NH_2OH)(Py)(NC$ is:

(A) 2

(B) 3

(C) 4

(D) 6

Q10. According to Crystal Field Theory, the stabilization energy (CFSE) for a d^4 high-spin octahedral complex is:

(A) $-0.6\Delta_o$

(B) $-1.8\Delta_o$

(C) $-1.6\Delta_o + P$

(D) $-0.4\Delta_o$

Q11. Which of the following is most reactive towards S_N2 reaction?

(A) CH_3CH_2Cl

(B) $(CH_3)_2CHCl$

(C) $(CH_3)_3CCl$

(D) CH_3Cl

Q12. The reaction of toluene with Cl_2 in the presence of $FeCl_3$ gives predominantly:

(A) Benzyl chloride

(B) m-Chlorotoluene

(C) o- and p-Chlorotoluene

(D) Benzoyl chloride

Q13. Phenol is less acidic than:

(A) Ethanol

(B) o-Nitrophenol

(C) o-Methylphenol

(D) o-Methoxyphenol

Q14. Which of the following reagents can convert an alcohol directly into an alkyl chloride?

(A) $NaCl$

(B) $SOCl_2$

(C) Cl_2/H_2O

(D) HCl gas only

Q15. In the Rosemund reduction, the catalyst used is:

(A) $Pd/BaSO_4$

(B) $Zn - Hg/HCl$

(C) $LiAlH_4$

(D) Ni/H_2

Q16. Which of the following will give a positive Iodoform test?

(A) Pentan-2-one

(B) Pentan-3-one

(C) Benzaldehyde

(D) Methanol

Q17. The product formed when Benzamide is treated with $POCl_3$ is:

(A) Aniline

(B) Benzonitrile

(C) Benzylamine

(D) Chlorobenzene

Q18. Which of the following does not react with Hinsberg reagent?

(A) CH_3NH_2

(B) $(CH_3)_2NH$

(C) $(CH_3)_3N$

(D) $C_6H_5NH_2$

Q19. Which of the following is a polysaccharide?

(A) Sucrose

(B) Maltose

(C) Glycogen

(D) Lactose

Q20. The linkage present in proteins is:

(A) Glycosidic linkage

(B) Peptide linkage

(C) Ester linkage

(D) Phosphodiester linkage

Q21. A graph of $\ln k$ vs $1/T$ is a straight line with slope equal to:

(A) $-E_a/R$

(B) E_a/R

(C) $-E_a/2.303R$

(D) R/E_a

Q22. Which of the following is an outer orbital complex?

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

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

(C) $[FeF_6]^{3-}$

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

Q23. Which of the following will undergo racemization on hydrolysis with aqueous KOH?

(A) CH_3CH_2Cl

(B) $CH_3CH(Cl)C_2H_5$

(C) CH_3OCH_2Cl

(D) $CH_2 = CHCH_2Cl$

Q24. Propanal and Propanone can be distinguished by:

(A) Tollen's reagent

(B) $Fehlings$ solution

(C) Schiff's reagent

(D) All of these

Q25. The base that is found in DNA but not in RNA is:

(A) Uracil

(B) Thymine

(C) Guanine

(D) Cytosine

Q26. Which of the following colligative properties can provide the most accurate molar mass of proteins?

(A) Elevation in boiling point

(B) Depression in freezing point

(C) Osmotic pressure

(D) Relative lowering of vapor pressure

Q27. The molar conductivity of a 0.05 M solution of an electrolyte is 100 S cm^2 mol^{-1}. The resistance of this solution in a conductivity cell with cell constant 0.5 cm^{-1} is:

(A) 100 Ω

(B) 50 Ω

(C) 10 Ω

(D) 200 Ω

Q28. Fuel cells are preferred over conventional cells because:

(A) They have 100% efficiency.

(B) They do not cause pollution.

(C) They can be recharged easily.

(D) They use solid electrolytes.

Q29. If the rate constant of a reaction is $k = 2.3 \times 10^{-2}\ L^2\ mol^{-2}\ s^{-1}$, the overall order of the reaction is:

(A) 1

(B) 2

(C) 3

(D) 0

Q30. Which of the following factors will not affect the rate constant of a reaction?

(A) Temperature

(B) Catalyst

(C) Concentration of reactants

(D) Activation energy

Q31. The "spin-only" magnetic moment of Ti^{3+} (At. No. 22) is:

(A) 1.73 BM

(B) 2.84 BM

(C) 3.87 BM

(D) 4.90 BM

Q32. The highest oxidation state shown by any transition element is:

(A) +7

(B) +8

(C) +6

(D) +5

Q33. The coordination number and oxidation state of Cr in $K_3[Cr(C_2O_4)_3]$ are respectively:

(A) 3 and +3

(B) 3 and 0

(C) 6 and +3

(D) 6 and +6

Q34. Which of the following is a low-spin complex?

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

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

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

(D) $[MnCl_6]^{3-}$

Q35. When Ethyl chloride is treated with excess of ammonia, the major product is:

(A) Ethylamine

(B) Diethylamine

(C) Triethylamine

(D) Tetraethylammonium chloride

Q36. Which alkyl halide exhibits the highest boiling point?

(A) CH_3F

(B) CH_3Cl

(C) CH_3Br

(D) CH_3I

Q37. The reaction $CH_3CH_2OH + HCl \xrightarrow{ZnCl_2} CH_3CH_2Cl + H_2O$ is an example of:

(A) Nucleophilic addition

(B) Electrophilic substitution

(C) Nucleophilic substitution

(D) Elimination

Q38. Dehydration of tertiary alcohols with concentrated H_2SO_4 follows:

(A) $E1$ mechanism

(B) $E2$ mechanism

(C) S_N1 mechanism

(D) S_N2 mechanism

Q39. The reduction of a nitrile with $LiAlH_4$ followed by hydrolysis gives:

(A) Aldehyde

(B) Ketone

(C) Primary amine

(D) Carboxylic acid

Q40. Which of the following is most acidic?

(A) CH_3COOH

(B) $ClCH_2COOH$

(C) $Cl_2CHCOOH$

(D) Cl_3CCOOH

Q41. Hinsberg's reagent is:

(A) Benzene sulphonyl chloride

(B) Benzene sulphonic acid

(C) Phenyl isocyanide

(D) Benzene diazonium chloride

Q42. Coupling reaction of benzene diazonium chloride with phenol in alkaline medium gives:

(A) Yellow dye

(B) Orange dye

(C) Red dye

(D) Blue dye

Q43. An example of a non-reducing disaccharide is:

(A) Lactose

(B) Maltose

(C) Sucrose

(D) Cellobiose

Q44. Which of the following is a fibrous protein?

(A) Insulin

(B) Albumin

(C) Keratin

(D) Hemoglobin

Q45. Two solutions A and B are separated by a semi-permeable membrane. If liquid flows from A to B, then:

(A) A is more concentrated than B.

(B) B is more concentrated than A.

(C) Both have same concentration.

(D) A is a saturated solution.

Q46. In a pseudo-first-order reaction $A + B \rightarrow Products$, where $[B] \gg [A]$, the rate depends on:

(A) Concentration of B only.

(B) Concentration of A only.

(C) Both A and B.

(D) Neither A nor B.

Q47. The electronic configuration of Gd^{3+} (At. No. 64) is:

(A) $[Xe]4f^7$

(B) $[Xe]4f^8$

(C) $[Xe]4f^7 5d^1$

(D) $[Xe]4f^6$

Q48. The IUPAC name of $[Ag(NH_3)_2][Ag(CN)_2]$ is:

(A) Diamminesilver(I) dicyanoargentate(I)

(B) Dicyanosilver(I) diammineargentate(I)

(C) Diamminesilver(II) dicyanoargentate(II)

(D) Silver ammine cyanide

Q49. Wurtz-Fittig reaction is used to prepare:

(A) Alkanes

(B) Arenes

(C) Alkyl arenes

(D) Haloarenes

Q50. DNA contains 2-deoxyribose sugar while RNA contains:

(A) Ribose

(B) Fructose

(C) Glucose

(D) Galactose

Detailed Solutions

Q1.

Solution

Concept: Osmotic pressure (π) is a colligative property defined by the equation:

$$\pi = CRT$$

Where: - C = Molarity (moles/volume in L) - R = Gas constant (0.0821 L atm K^{-1} mol^{-1}) - T = Temperature in Kelvin

Solution: 1. **Calculate moles of urea:**

$$\text{Moles} = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{6.0 \text{ g}}{60 \text{ g/mol}} = 0.1 \text{ mol}$$

2. **Calculate Molarity (C):**

$$C = \frac{\text{moles}}{\text{Volume (L)}} = \frac{0.1 \text{ mol}}{1 \text{ L}} = 0.1 \text{ M}$$

3. **Calculate Osmotic Pressure (π):**

$$\pi = 0.1 \times 0.0821 \times 300$$

$$\pi = 0.1 \times 24.63 = 2.463 \text{ atm}$$

The closest value is 2.46 atm.

Answer: (A)

Q2.

Solution

Concept: Colligative Properties and Freezing Point Depression

The freezing point of a solution is a colligative property, meaning it depends on the number of solute particles rather than their identity. The relationship is defined by the formula:

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

Where:

- ΔT_f is the depression in freezing point ($T_{f,\text{solvent}} - T_{f,\text{solution}}$).
- i is the **van't Hoff factor** (degree of dissociation/association).
- K_f is the cryoscopic constant of the solvent (water).
- m is the molality (assumed proportional to Molarity 0.1 M here).

Solution:

1. **Determine the Relationship:** The Freezing Point (T_f) is inversely related to the depression (ΔT_f).

$$\text{Higher Freezing Point} \implies \text{Lower } \Delta T_f \implies \text{Lower } i \text{ value}$$

2. **Calculate the van't Hoff factor (i) for each species:**

- **(A) 0.1 M $NaCl$:** Dissociates into Na^+ and Cl^-. Total particles = 2. $i = 2$.
- **(B) 0.1 M $BaCl_2$:** Dissociates into Ba^{2+} and $2Cl^-$. Total particles = 3. $i = 3$.
- **(C) 0.1 M $Al_2(SO_4)_3$:** Dissociates into $2Al^{3+}$ and $3SO_4^{2-}$. Total particles = 5. $i = 5$.
- **(D) 0.1 M Glucose:** It is a non-electrolyte and does not dissociate. $i = 1$.

3. **Conclusion:** Since Glucose has the **lowest** van't Hoff factor ($i = 1$), it causes the **minimum** depression in the freezing point. Consequently, the glucose solution retains the **highest freezing point** (closest to 0°C).

Answer: (D)

Q3.

Solution

Concept: Faraday's First Law of Electrolysis

The mass of a substance deposited at an electrode is proportional to the quantity of electricity passed. For 1 mole of any substance, the charge required is:

$$Q = n \cdot F$$

Where:

- n is the number of moles of electrons (valence change).
- F is Faraday's constant (≈ 96500 C mol^{-1}).

Solution:

1. **Identify the Ionic State:** In a $CuSO_4$ solution, copper exists in the **cupric state** as Cu^{2+} ions.
2. **Write the Cathodic Reduction Half-Reaction:** To deposit solid copper (Cu) from the solution, the ions must be reduced:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

3. **Stoichiometric Analysis:** From the equation, 1 mole of Cu^{2+} ions requires 2 moles of electrons to be converted into 1 mole of copper atoms.
4. **Calculate Electricity in Faradays:**
   - Charge on 1 mole of electrons = 1 Faraday(F).
   - Charge on 2 moles of electrons = 2 Faradays($2F$).
5. **Final Conclusion:** The amount of electricity required to deposit 1 mole of copper is exactly $2F$.

Answer: (B)

Q4.

Solution

Concept: Electrochemical Series and Reducing Power

The **Reducing Power** of a metal refers to its ability to lose electrons (undergo oxidation) and reduce another species. In electrochemistry, this is determined by the **Standard Reduction Potential** (E°):

- **Negative E°:** Higher tendency to lose electrons (Stronger Reducing Agent).
- **Positive E°:** Higher tendency to gain electrons (Weaker Reducing Agent).

Solution:

1. **List the Given Potentials:**
   - Metal A: $E^\circ = +0.5$ V
   - Metal B: $E^\circ = -3.0$ V
   - Metal C: $E^\circ = -1.2$ V
2. **Compare the Values:** A more negative reduction potential implies a more positive oxidation potential. Ranking from the **most negative** to the **most positive**:

$$-3.0 \text{ V (B)} < -1.2 \text{ V (C)} < +0.5 \text{ V (A)}$$

3. **Determine the Strength:**
   - **B** has the lowest E°, so it is the strongest reducing agent.
   - **C** is the next strongest.
   - **A** has a positive E°, making it the weakest reducing agent among the three.
4. **Final Order:** The order of reducing power is $B > C > A$.

Answer: (D)

Q5.

Solution

Concept: For a reaction $Rate = k[A]^n$, where n is the order of the reaction. If concentration is changed from $[A]$ to $[A']$, the new rate R' is:

$$\frac{R'}{R} = \left(\frac{[A']}{[A]}\right)^n$$

Solution: Given: - $[A'] = 4[A]$ - $R' = 2R$
Substitute into the formula:

$$2 = (4)^n$$

$$2^1 = (2^2)^n \Rightarrow 2^1 = 2^{2n}$$

Comparing powers:

$$1 = 2n \Rightarrow n = 0.5$$

The order of the reaction is 0.5.

Answer: (C)

Q6.

Solution

Concept: Arrhenius Equation and Activation Energy

The **Activation Energy** (E_a) is the minimum amount of energy required by reactant molecules to result in a chemical reaction. The dependence of the rate constant (k) on temperature (T) is expressed by the **Arrhenius Equation**:

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

Where:

- k is the rate constant.
- A is the pre-exponential factor (frequency factor).
- R is the gas constant (8.314 J mol^{-1} K^{-1}).
- T is the absolute temperature (in Kelvin).

Solution:

1. **Logarithmic Form:** To solve for E_a, we take the natural log of the Arrhenius equation:

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

2. **Comparison at Two Temperatures:** If we measure the rate constant k_1 at temperature T_1 and k_2 at temperature T_2, we can derive:

$$\log\left(\frac{k_2}{k_1}\right) = \frac{E_a}{2.303R}\left[\frac{T_2 - T_1}{T_1 T_2}\right]$$

3. **Conclusion:** By evaluating the **rate constants at two different temperatures**, we obtain all the necessary variables (k_1, k_2, T_1, T_2) to calculate E_a. Changing concentrations or evaluating standard temperature alone is insufficient to determine the energy barrier of the transition state.

Answer: (A)

Q7.

Solution

Concept: Physical Properties of 3d Transition Series

Density is a periodic property defined as the ratio of atomic mass to atomic volume ($d = M/V$). In the $3d$ transition series (Sc to Zn), the density generally **increases** across the period from left to right.

Solution:

1. **Trend Analysis:** Across a period, the atomic mass increases steadily. Although the atomic radius (volume) decreases slightly due to the increase in effective nuclear charge, the increase in **atomic mass** is much more significant.
2. **Comparison of Elements:**
   - **Scandium (Sc):** Atomic mass is approx. 45 u. It has the largest atomic radius in the series.
   - **Titanium (Ti):** Atomic mass is approx. 48 u. Smaller radius than Sc.
   - **Copper (Cu):** Atomic mass is approx. 63.5 u. Much smaller radius.
   - **Zinc (Zn):** Atomic mass is approx. 65 u.
3. **Data Reference:**
   - Density of $Sc \approx 2.99$ g/cm^3
   - Density of $Cu \approx 8.96$ g/cm^3
4. **Conclusion:** Since Scandium (Sc) is the first element of the series with the lowest atomic mass and a relatively large volume, it has the **lowest density** among all transition metals in the $3d$ series.

Answer: (A)

Q8.

Solution

Concept: Chromate-Dichromate Equilibrium

The transition between chromate (CrO_4^{2-}) and dichromate ($Cr_2O_7^{2-}$) ions is highly sensitive to the **pH of the medium**. Both ions exist in equilibrium in aqueous solution:

$$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$$

Solution:

1. **Identify the Medium:** The question specifies heating with **aqueous KOH**, which is a strong base. This means the concentration of OH^- is high and H^+ is very low.
2. **Le Chatelier's Principle:** When a base (OH^-) is added to the system, it reacts with H^+ to form water. According to Le Chatelier's Principle, the equilibrium shifts to the **left** to replace the lost H^+ ions.

$$Cr_2O_7^{2-}(\text{orange}) + 2OH^- \rightarrow 2CrO_4^{2-}(\text{yellow}) + H_2O$$

3. **Final Conclusion:** In an alkaline/basic medium (KOH), the dichromate ion is converted into the **chromate ion** (CrO_4^{2-}).

Answer: (A)

Q9.

Solution

Concept: Isomerism in Coordination Compounds

For a square planar complex of the type $[Mabcd]$, where all four ligands are different, geometrical isomerism occurs based on the relative spatial arrangement of the ligands.

Solution:

1. **Identify the Complex Type:** The complex is $[Pt(NH_3)(NH_2OH)(Py)(NO_2)]^+$. This fits the general formula $[Mabcd]$.
2. **Determining Isomers:** To find the number of geometrical isomers, we fix one ligand and arrange the remaining three ligands **trans** to it. Let's fix NH_3:

- Isomer 1: NH_2OH is trans to NH_3.
- Isomer 2: Py (pyridine) is trans to NH_3.
- Isomer 3: NO_2 is trans to NH_3.

3. **Conclusion:** Since there are 3 unique ways to pair the ligands in trans positions, there are **3 geometrical isomers** possible for this complex.

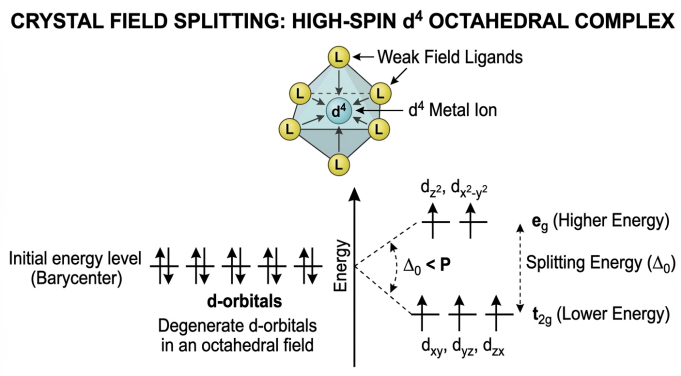
Answer: (B)

Q10.

Solution

Concept: Crystal Field Theory (CFT)

In an octahedral complex, the five 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 energy difference between these sets is Δ_o.

- Each electron in t_{2g} stabilizes the system by $-0.4\Delta_o$.
- Each electron in e_g destabilizes the system by $+0.6\Delta_o$.

Solution:

1. **Analyze the Configuration:** For a d^4 high-spin octahedral complex, the electrons fill the orbitals following Hund's rule:
   - First 3 electrons go into the t_{2g} orbitals.
   - The 4th electron goes into the e_g orbital (since it is high-spin, the pairing energy $P > \Delta_o$).
2. **Calculate CFSE:**

$$\text{CFSE} = (\text{No. of } e^- \text{ in } t_{2g} \times -0.4\Delta_o) + (\text{No. of } e^- \text{ in } e_g \times +0.6\Delta_o)$$

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

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

3. **Conclusion:** The stabilization energy is $-0.6\Delta_o$.

Answer: (A)

Q11.

Solution

Concept: Nucleophilic Substitution (S_N2) Mechanism

The S_N2 (Substitution Nucleophilic Bimolecular) reaction occurs in a single step via a transition state. The rate of this reaction is highly sensitive to **steric hindrance** around the carbon atom bearing the leaving group.

- The nucleophile attacks from the back side (180° to the leaving group).
- Bulkier groups around the carbon block the approach of the nucleophile.
- Reactivity order: Methyl > Primary(1°) > Secondary(2°) > Tertiary(3°).

Solution:

1. **Analyze the Structures:**
   - **(A)** CH_3CH_2Cl**:** Ethyl chloride (Primary halide).
   - **(B)** $(CH_3)_2CHCl$**:** Isopropyl chloride (Secondary halide).
   - **(C)** $(CH_3)_3CCl$**:** tert-Butyl chloride (Tertiary halide).
   - **(D)** CH_3Cl**:** Methyl chloride (Methyl halide).

2. **Evaluate Steric Hindrance:** Methyl chloride has only three small hydrogen atoms around the central carbon, providing the least resistance to the incoming nucleophile. As we move to 1°, 2°, and 3° halides, the bulky methyl groups hinder the attack.

3. **Conclusion:** Methyl chloride (CH_3Cl) is the **most reactive** toward S_N2 due to minimal steric hindrance.

Answer: (D)

Q12.

Solution

Concept: Electrophilic Aromatic Substitution (EAS)

The reaction of an aromatic ring with a halogen in the presence of a Lewis acid (like $FeCl_3$) is an Electrophilic Aromatic Substitution. The orientation of the incoming substituent is determined by the group already present on the ring.

Solution:

1. **Identify the Substituent Effect:** In Toluene ($C_6H_5CH_3$), the methyl group ($-CH_3$) is an **activating group**. It increases electron density in the ring through the $+I$ (Inductive) effect and hyperconjugation.
2. **Directing Influence:** Activating groups like $-CH_3$ are **ortho- and para-directing**. They stabilize the sigma-complex (carbocation intermediate) more effectively when the electrophile attacks at the ortho or para positions compared to the meta position.
3. **Reaction Outcome:** The reaction of toluene with $Cl_2/FeCl_3$ produces a mixture of **ortho-chlorotoluene** and **para-chlorotoluene**.

$$\text{Toluene} + Cl_2 \xrightarrow{FeCl_3} \text{o-Chlorotoluene} + \text{p-Chlorotoluene}$$

4. **Conclusion:** The predominant products are the ortho and para isomers.

Answer: (C)

Q13.

Solution

Concept: Acidity of Phenols and Electronic Effects

Acidity depends on the stability of the conjugate base (phenoxide ion). Any factor that stabilizes the negative charge on the oxygen increases acidity.

- **Electron Withdrawing Groups (EWG):** Stabilize the phenoxide ion (Increase acidity).
- **Electron Donating Groups (EDG):** Destabilize the phenoxide ion (Decrease acidity).

Solution:

1. **Compare Reagents:**
   - **(A) Ethanol:** Alcohols are much weaker acids than phenols because the ethoxide ion is not resonance-stabilized.
   - **(B) o-Nitrophenol:** The nitro group ($-NO_2$) is a very strong EWG ($-R$ and $-I$ effect). It significantly stabilizes the phenoxide ion, making o-Nitrophenol **more acidic** than phenol.
   - **(C) o-Methylphenol:** The $-CH_3$ group is an EDG ($+I$ and hyperconjugation), which decreases acidity.
   - **(D) o-Methoxyphenol:** The $-OCH_3$ group is an EDG ($+R$ effect), which decreases acidity.
2. **Conclusion:** Phenol is less acidic than **o-Nitrophenol**.

Answer: (B)

Q14.

Solution

Concept: Preparation of Alkyl Halides from Alcohols

Several reagents can replace the hydroxyl group ($-OH$) of an alcohol with a halogen. However, the efficiency and purity of the product depend on the reagent used.

Solution:

1. **Evaluate the Reagents:**

- **NaCl:** Does not react with alcohols as Cl^- is a poor nucleophile and $-OH$ is a poor leaving group.
- **$SOCl_2$ (Thionyl Chloride):** This is the preferred reagent (Darzen's process). It reacts with alcohols to form alkyl chlorides, $SO_2(g)$, and $HCl(g)$.

$$R - OH + SOCl_2 \rightarrow R - Cl + SO_2 \uparrow + HCl \uparrow$$

  The gaseous by-products escape, leaving behind pure alkyl chloride.

- **Cl_2/H_2O:** This forms hypochlorous acid and is used for halogenation of alkenes, not for direct conversion of alcohols.
- **HCl gas:** Generally requires a catalyst like anhydrous $ZnCl_2$ (Lucas Reagent) for primary and secondary alcohols.

2. **Conclusion: Thionyl chloride** ($SOCl_2$) is the most effective reagent for this direct conversion.

Answer: (B)

Q15.

Solution

Concept: Rosenmund Reduction

The Rosenmund reduction is a specific catalytic hydrogenation process used to reduce an **acyl chloride** to an **aldehyde**.

Solution:

1. **Identify the Catalyst Components:** The reaction requires hydrogen gas and a palladium catalyst. However, palladium is so reactive that it would normally reduce the aldehyde further to a primary alcohol.
2. **The Role of the "Poison":** To stop the reaction at the aldehyde stage, the catalyst is "poisoned" or partially deactivated. This is done by supporting palladium on **Barium Sulphate ($BaSO_4$)** and often adding small amounts of sulfur or quinoline.
3. **Reaction Equation:**

$$R - COCl + H_2 \xrightarrow{Pd/BaSO_4} R - CHO + HCl$$

4. **Conclusion:** The catalyst used is **Pd/BaSO$_4$**.

Answer: (A)

Q16.

Solution

Concept: The Iodoform Test (Haloform Reaction)

The Iodoform test is a diagnostic chemical test used to identify the presence of a **methyl ketone** group (CH_3CO-) or a **secondary alcohol** that can be oxidized to a methyl ketone (like $CH_3CH(OH)-$).

When such a compound reacts with iodine (I_2) in the presence of sodium hydroxide ($NaOH$), a yellow precipitate of Iodoform (CHI_3) is formed.

Solution:

1. **Analyze the Structural Formulas:**

- **(A) Pentan-2-one:** $CH_3 - CO - CH_2 - CH_2 - CH_3$. It contains a terminal methyl group directly attached to the carbonyl carbon (CH_3CO-). **(Positive Test)**
- **(B) Pentan-3-one:** $CH_3 - CH_2 - CO - CH_2 - CH_3$. The carbonyl group is flanked by two ethyl groups; there is no methyl group directly attached to the $C = O$. **(Negative Test)**
- **(C) Benzaldehyde:** $C_6H_5 - CHO$. This is an aldehyde without a methyl group attached to the carbonyl carbon. **(Negative Test)**
- **(D) Methanol:** $CH_3 - OH$. Although it has a methyl group, it cannot be oxidized to a CH_3CO- structure as it has only one carbon. **(Negative Test)**

2. **Chemical Reaction for Pentan-2-one:**

$$CH_3COCH_2CH_2CH_3 + 3I_2 + 4NaOH \rightarrow CHI_3 \downarrow (\text{Yellow}) + CH_3CH_2CH_2COONa + 3NaI + 3H_2O$$

3. **Conclusion:** Only **Pentan-2-one** satisfies the structural requirement for the iodoform reaction.

Answer: (A)

Q17.

Solution

Concept: Dehydration of Amides

Amides ($R - CONH_2$) can be converted into nitriles ($R - CN$) through a dehydration reaction. This involves the removal of one molecule of water (H_2O) from the amide functional group. This transformation requires strong dehydrating agents such as P_2O_5 or $POCl_3$ (Phosphorus oxychloride).

Solution:

1. **Identify the Reactant:** The starting material is Benzamide ($C_6H_5CONH_2$), which is a primary aromatic amide.
2. **Analyze the Reagent Action:** When Benzamide is heated with $POCl_3$, the reagent abstracts two hydrogen atoms from the nitrogen and one oxygen atom from the carbonyl group.

$$C_6H_5 - C(=O) - NH_2 \xrightarrow{POCl_3,\Delta} C_6H_5 - C \equiv N + H_2O$$

3. **Identify the Product:** The resulting compound, C_6H_5CN, is known as **Benzonitrile**.
4. **Conclusion:** Heating benzamide with $POCl_3$ yields Benzonitrile as the major organic product.

Answer: (B)

Q18.

Solution

Concept: The Hinsberg Test for Amines

The Hinsberg test uses **Benzene sulphonyl chloride** ($C_6H_5SO_2Cl$) to distinguish between primary (1°), secondary (2°), and tertiary (3°) amines based on the presence of replaceable hydrogen atoms on the nitrogen.

Solution:

1. **Mechanism for different Amines:**

- **Primary (1°):** Reacts to form an N-alkylbenzene sulphonamide. Because it has one remaining acidic hydrogen on the Nitrogen, the product is **soluble in alkali (NaOH)**.
- **Secondary (2°):** Reacts to form an N, N-dialkylbenzene sulphonamide. It has no acidic hydrogen left, so the product is **insoluble in alkali**.
- **Tertiary (3°):** Has no hydrogen atoms attached to the nitrogen. Therefore, it **does not react** with benzene sulphonyl chloride at all.

2. **Analyze Trimethylamine:** Trimethylamine, $(CH_3)_3N$, is a **tertiary amine**. The nitrogen is bonded to three methyl groups and possesses no N-H bonds.
3. **Conclusion:** Because it lacks a replaceable hydrogen, $(CH_3)_3N$ will not react with the Hinsberg reagent.

Answer: (C)

Q19.

Solution

Concept: Classification of Carbohydrates

Carbohydrates are classified based on the number of sugar units (monosaccharides) they yield upon hydrolysis:

- **Monosaccharides:** Cannot be hydrolyzed further (Glucose, Fructose).
- **Oligosaccharides:** Yield 2 to 10 monosaccharide units (Sucrose, Maltose, Lactose).
- **Polysaccharides:** Yield a very large number of monosaccharide units (Starch, Cellulose, Glycogen).

Solution:

1. **Evaluate the Options:**

- **(A) Sucrose:** A disaccharide (Glucose + Fructose).
- **(B) Maltose:** A disaccharide (Glucose + Glucose).
- **(C) Glycogen:** A highly branched polymer of glucose. It is the storage form of energy in animals and is a **polysaccharide**.
- **(D) Lactose:** A disaccharide (Glucose + Galactose).

2. **Conclusion:** Among the choices, only Glycogen consists of thousands of glucose units linked together, making it a polysaccharide.

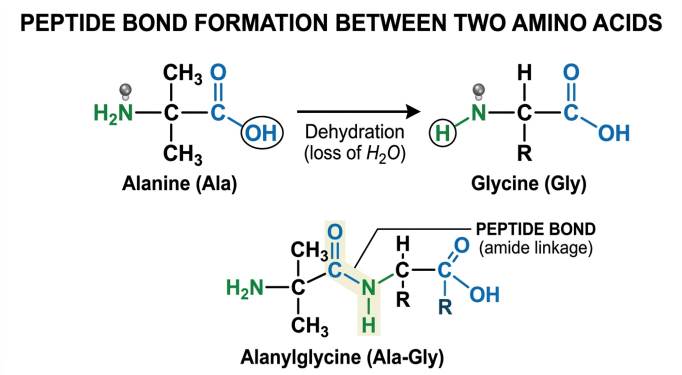
Answer: (C)

Q20.

Solution

Concept: Peptide Bond Formation in Proteins

Proteins are heteropolymers consisting of long chains of α-amino acids. These amino acids are joined together by a specific covalent bond known as a **peptide linkage**.



Solution:

1. **Chemical Mechanism:** The reaction occurs between the carboxyl group ($-COOH$) of one amino acid and the amino group ($-NH_2$) of the next amino acid. This is a condensation reaction that results in the elimination of a water molecule.

$$\mathrm{R_1} - CH(NH_2) - \mathbf{COOH} + \mathrm{H} - \mathbf{NH} - CH(R_2) - COOH \quad (1)$$

$$\rightarrow \mathrm{R_1} - CH(NH_2) - \mathbf{CO} - \mathbf{NH} - CH(R_2) - COOH + \mathbf{H_2O} \quad (2)$$

2. **Identify the Linkage:** The resulting group $-CO - NH-$ is an amide bond. In the specific context of biochemistry and protein structure, this is termed a **peptide linkage**.
3. **Distinguish other Linkages:**
   - **Glycosidic:** Joins monosaccharides in carbohydrates.
   - **Ester:** Joins glycerol and fatty acids in lipids.
   - **Phosphodiester:** Joins nucleotides in DNA/RNA.
4. **Conclusion:** Amino acids in proteins are exclusively held together by peptide linkages.

Answer: (B)

Q21.

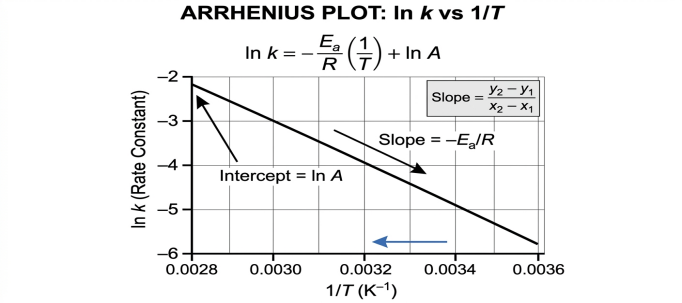
Solution

Concept: The Arrhenius Equation and Linear Plotting

The temperature dependence of the rate of a chemical reaction is quantitatively expressed by the **Arrhenius Equation**:

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

To analyze this relationship graphically, we transform the exponential equation into a linear form ($y = mx + c$) by taking the natural logarithm (ln) of both sides.



Solution:

1. **Mathematical Derivation:** Apply ln to the Arrhenius equation:

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

Using logarithmic properties ($\ln(ab) = \ln a + \ln b$ and $\ln e^x = x$):

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

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

2. **Rearranging for Graphing:** To match the straight-line equation $y = mx + c$, we write:

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

3. **Identify Graph Components:**

- **y-axis:** $\ln k$
- **x-axis:** $1/T$ (Inverse of absolute temperature)
- **Slope (m):** $-E_a/R$ (The slope is negative, indicating a downward-sloping line)
- **y-intercept (c):** $\ln A$

4. **Conclusion:** A plot of $\ln k$ versus $1/T$ yields a straight line. This graph is fundamental in physical chemistry for determining the activation energy (E_a) of a reaction from experimental data.

Answer: (A)

Q22.

Solution

Concept: Valence Bond Theory and Inner/Outer Orbital Complexes

In coordination chemistry, the hybridization of the central metal atom determines whether a complex is "Inner Orbital" or "Outer Orbital." This depends largely on the **strength of the ligand** (Spectrochemical Series):

- **Strong Field Ligands (SFL):** Cause pairing of electrons; use $(n-1)d$ orbitals (d^2sp^3 hybridization). These are **Inner Orbital Complexes**.
- **Weak Field Ligands (WFL):** Do not cause pairing; use nd orbitals (sp^3d^2 hybridization). These are **Outer Orbital Complexes**.

Solution:

1. **Analyze the Oxidation States and Ligands:**

- **(A)** $[Co(NH_3)_6]^{3+}$**:** Co^{3+} is $3d^6$. NH_3 acts as a strong field ligand for Co^{3+}, causing pairing. It uses $3d$ orbitals. **(Inner Orbital)**
- **(B)** $[Mn(CN)_6]^{3-}$**:** Mn^{3+} is $3d^4$. CN^- is a very strong ligand, causing pairing. It uses $3d$ orbitals. **(Inner Orbital)**
- **(C)** $[FeF_6]^{3-}$**:** Fe^{3+} is $3d^5$. Fluoride (F^-) is a **Weak Field Ligand**. It cannot force the five unpaired electrons in the $3d$ subshell to pair up. Thus, the complex must use the vacant $4d$ orbitals for hybridization (sp^3d^2). **(Outer Orbital)**
- **(D)** $[Fe(CN)_6]^{3-}$**:** Fe^{3+} is $3d^5$. CN^- is an SFL, causing pairing to the extent possible. It uses $3d$ orbitals. **(Inner Orbital)**

2. **Conclusion:** $[FeF_6]^{3-}$ is the only complex in the list that utilizes outer d-orbitals for bonding, making it an outer orbital complex.

Answer: (C)

Q23.

Solution

Concept: S_N1 Mechanism and Stereochemistry

Racemization is the process where an optically active compound is converted into an optically inactive mixture of equal amounts of dextrorotatory and levorotatory enantiomers. In haloalkanes, this typically occurs via the S_N1 **(Substitution Nucleophilic Unimolecular)** mechanism.

Solution:

1. **The S_N1 Process:** The first and rate-determining step is the ionization of the C-X bond to form a **carbocation intermediate**.

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

2. **Geometry of the Intermediate:** The carbocation is sp^2 hybridized and possesses a **planar structure**. The vacant p-orbital is perpendicular to the plane.
3. **Nucleophilic Attack:** Because the intermediate is flat, the nucleophile can attack from the "front side" (where the leaving group was) or the "back side" with equal probability (50% each).
4. **Requirement for Racemization:** For the resulting mixture to be racemic, the starting material must have been **chiral** (bonded to four different groups).

- **2-Chlorobutane ($CH_3CH(Cl)CH_2CH_3$):** The carbon is bonded to H, Cl, CH_3, and C_2H_5. It is chiral.

5. **Conclusion:** During hydrolysis via S_N1, chiral halides like 2-chlorobutane yield a racemic mixture of alcohols due to the planar nature of the carbocation intermediate.

Answer: (B)

Q24.

Solution

Concept: Chemical Differentiation of Aldehydes and Ketones

Aldehydes ($R-CHO$) and Ketones ($R-CO-R'$) differ significantly in their ease of oxidation. Aldehydes are very easily oxidized to carboxylic acids, whereas ketones require much harsher conditions. This difference is exploited in several diagnostic tests.

Solution:

1. **Tollen's Reagent (Silver Mirror Test):** Contains ammoniacal silver nitrate $[Ag(NH_3)_2]OH$. Aldehydes reduce Ag^+ to metallic silver (Ag^0), forming a mirror on the test tube. Ketones do not react.

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

2. **Fehling's Solution:** Consists of Fehling A ($CuSO_4$) and Fehling B (Sodium potassium tartrate). Aldehydes reduce blue Cu^{2+} to a red precipitate of Cu_2O. Ketones do not react.
3. **Schiff's Reagent:** A magenta dye (Rosaniline hydrochloride) decolorized by sulfur dioxide. Aldehydes restore the magenta/pink color, while ketones generally do not.
4. **Case Study:** Propanal is an aldehyde; Propanone is a ketone. All three reagents listed will react with Propanal but not with Propanone.
5. **Conclusion:** Since all these tests show a positive result for aldehydes and negative for ketones, they can all be used to distinguish between the two.

Answer: (D)

Q25.

Solution

Concept: Structural Components of DNA and RNA

Nucleic acids (DNA and RNA) are polymers of nucleotides. Each nucleotide consists of a phosphate group, a pentose sugar, and a nitrogenous base. While they share several bases, there is a fundamental difference in their pyrimidine composition.

Solution:

1. **Nitrogenous Bases:** There are two types of bases:
   - **Purines:** Adenine (A) and Guanine (G). Both are found in DNA and RNA.
   - **Pyrimidines:** Cytosine (C), Thymine (T), and Uracil (U).
2. **Specific Pairing and Presence:**
   - **DNA Bases:** A, G, C, and **Thymine (T)**.
   - **RNA Bases:** A, G, C, and **Uracil (U)**.
3. **Comparing DNA and RNA:** When comparing the nitrogenous base content, **Thymine** is the base that is present exclusively in DNA (except in very rare tRNA modifications) and is replaced by Uracil in RNA.
4. **Conclusion:** Among the options, Thymine is the base characteristic of DNA.

Answer: (B)

Q26.

Solution

Concept: Determination of Molar Mass of Polymers

Colligative properties (Relative lowering of vapor pressure, Elevation of boiling point, Depression of freezing point, and Osmotic pressure) are used to calculate the molar mass of solutes. However, for biomolecules like proteins and polymers, **Osmotic Pressure** (π) is the most suitable method.

Solution:

1. **Magnitude of the Property:** Polymers have very high molar masses. At a given concentration, the number of moles is very small. This results in extremely small changes in ΔT_b or ΔT_f, which are difficult to measure accurately. In contrast, the osmotic pressure ($\pi = CRT$) is large enough to be measured with high precision even for very dilute solutions.
2. **Temperature Sensitivity:** Biomolecules like proteins are unstable at high temperatures and can undergo **denaturation**. Measurements of boiling point elevation require heating, which would destroy the sample. Osmotic pressure is conveniently measured at **room temperature**.
3. **Concentration Measurement:** Osmotic pressure uses Molarity (M), which is easier to calculate for these types of substances than molality (m).
4. **Conclusion:** Due to its significant magnitude at room temperature and the sensitivity of proteins to heat, osmotic pressure is the preferred method for determining their molar mass.

Answer: (C)

Q27.

Solution

Concept: Molar conductivity (Λ_m) is related to conductivity (κ) by:

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

Conductivity (κ) is related to resistance (R) and cell constant (G^*) by:

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

Solution: 1. Find κ:

$$100 = \frac{\kappa \times 1000}{0.05} \Rightarrow \kappa = \frac{100 \times 0.05}{1000} = 0.005 \text{ S cm}^{-1}$$

2. Find R:

$$0.005 = \frac{0.5}{R} \Rightarrow R = \frac{0.5}{0.005} = 100\ \Omega$$

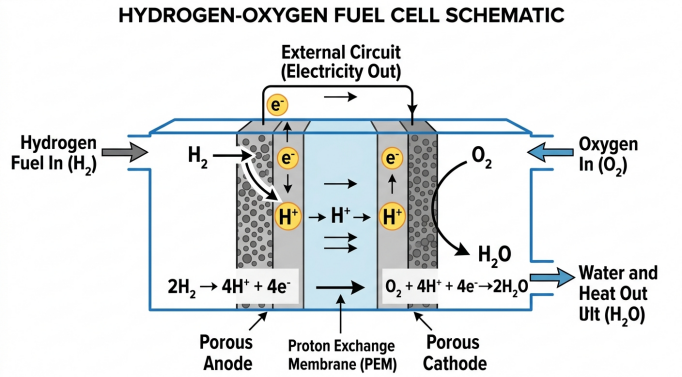
Answer: (A)

Q28.

Solution

Concept: Fuel Cells and Energy Efficiency

A **Fuel Cell** is an electrochemical cell that converts the chemical energy of a fuel (such as hydrogen, methane, or methanol) and an oxidizing agent (oxygen) directly into electrical energy through redox reactions. Unlike conventional batteries, fuel cells do not "die"; they produce electricity as long as fuel is supplied.



Solution:

1. **The Hydrogen-Oxygen Fuel Cell:** In the $H_2 - O_2$ fuel cell, hydrogen and oxygen gases are bubbled through porous carbon electrodes into a concentrated aqueous sodium hydroxide or potassium hydroxide electrolyte.

[Image of hydrogen fuel cell]

2. **Electrode Reactions:**

- **At Anode:** $2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$
- **At Cathode:** $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
- **Overall Reaction:** $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

3. **Advantages over Conventional Power Plants:** Conventional thermal power plants burn fossil fuels to produce steam, which turns turbines. This multi-step process (Chemical $\rightarrow$ Thermal $\rightarrow$ Mechanical $\rightarrow$ Electrical) is limited by Carnot's efficiency and usually operates at only 40%. Fuel cells bypass these steps, achieving theoretical efficiencies of 70 – 100%.

4. **Environmental Impact:** The only byproduct of the $H_2 - O_2$ cell is water, making it a "green" technology that does not cause the thermal or chemical pollution associated with burning coal or oil.

5. **Conclusion:** Fuel cells are highly efficient and eco-friendly compared to conventional methods.

Answer: (B)

Q29.

Solution

Concept: Units of Rate Constant and Reaction Order

The rate of a chemical reaction is expressed as Rate $= k[A]^n$, where n is the order of the reaction. The units of the rate constant (k) vary depending on the value of n.

Solution:

1. **General Formula for Units of k:** The rate of reaction always has units of concentration divided by time: $\text{mol L}^{-1}\ \text{s}^{-1}$. Substituting into the rate law:

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

Rearranging for k:

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

2. **Analyze the Given Units:** The question provides units: $L^2\ \text{mol}^{-2}\ \text{s}^{-1}$. This can be rewritten in the standard form: $(\text{mol L}^{-1})^{-2}\ \text{s}^{-1}$.

3. **Solve for n:** Compare the powers of the concentration term:

$$1 - n = -2$$

Subtracting 1 from both sides:

$$-n = -3 \implies n = 3$$

4. **Verify for Third-Order Reaction:** If $n = 3$, then unit $= (\text{mol L}^{-1})^{1-3}\ \text{s}^{-1} = (\text{mol L}^{-1})^{-2}\ \text{s}^{-1} = \text{mol}^{-2}L^2\ \text{s}^{-1}$. This matches the given units exactly.

5. **Conclusion:** The reaction described by these units is a third-order reaction.

Answer: (C)

Q30.

Solution

Concept: Factors Affecting the Rate Constant (k)

The **Rate Constant** (k) is a proportionality constant in the rate law equation that is specific to a particular reaction at a constant temperature. While the *rate* of a reaction depends on concentration, the *rate constant* does not.

Solution:

1. **Understanding the Arrhenius Relationship:** The value of k is primarily determined by the Arrhenius equation:

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

From this equation, we can see that k is a function of:

- **Temperature (T):** As T increases, the exponent becomes less negative, and k increases exponentially.
- **Activation Energy (E_a):** A lower E_a (e.g., due to a catalyst) results in a larger k.

2. **Evaluating Concentration:** The rate of reaction is defined as: Rate $= k[Reactant]^n$. If you increase the concentration of the reactants, the **Rate** will increase because there are more collisions per unit volume. However, the **Rate Constant** (k) remains the same because it represents the rate *per unit concentration*. It is an intrinsic property of the reaction's mechanism at a specific temperature.

3. **Conclusion:** Out of the factors listed, the concentration of reactants is the only one that **does not** change the value of the rate constant k.

Answer: (C)

Q31.

Solution

Concept: Magnetic Properties of Transition Metals

The magnetic moment of transition metal ions is primarily determined by the number of unpaired electrons in their d-subshell. This is calculated using the **spin-only formula**:

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

Where:

- μ_s is the magnetic moment in Bohr Magnetons (BM).
- n is the number of unpaired electrons.

Solution:

1. **Determine the Oxidation State:** The ion given is Ti^{3+}. Titanium (Ti) has the atomic number $Z = 22$.
2. **Write the Electronic Configuration:**
   - Ground state Ti: $[Ar]3d^2 4s^2$.
   - To form Ti^{3+}, three electrons are removed (two from $4s$ and one from $3d$).
   - Configuration of Ti^{3+}: $[Ar]3d^1$.
3. **Count Unpaired Electrons (n):** The $3d^1$ configuration contains only **1 unpaired electron**. Thus, $n = 1$.
4. **Calculate the Magnetic Moment:**

$$\mu_s = \sqrt{1(1+2)} = \sqrt{3}$$

$$\mu_s \approx 1.732 \text{ BM}$$

5. **Conclusion:** The spin-only magnetic moment for Ti^{3+} is approximately 1.73 BM.

Answer: (A)

Q32.

Solution

Concept: Oxidation States in Transition Elements

Transition elements exhibit variable oxidation states because both $(n-1)d$ and ns electrons can participate in bond formation. The maximum oxidation state usually increases up to the middle of the series and then decreases.

Solution:

1. **Analyze the 3d Series (Sc to Zn):** In the first transition series, Manganese (Mn) shows the highest oxidation state of +7 in compounds like $KMnO_4$.
2. **Analyze Heavier Transition Elements (4d and 5d):** As we move to the $4d$ and $5d$ series, the stability of higher oxidation states increases.

- **Ruthenium** (Ru) and **Osmium** (Os) belong to the same group as Iron (Fe) but can expand their coordination and bonding much further.
- Osmium exhibits a maximum oxidation state of +8 in its oxide, Osmium tetroxide (OsO_4).
- Similarly, Ruthenium shows +8 in RuO_4.

3. **Conclusion:** Among the transition elements, the maximum oxidation state of +8 is exhibited by **Osmium**.

Answer: (B)

Q33.

Solution

Concept: Coordination Number and Oxidation State

In coordination chemistry, it is essential to distinguish between the number of coordinate bonds formed (Coordination Number) and the formal charge of the metal (Oxidation State).

Solution:

1. **Identify the Ligand Type:** The ligand in $K_3[Cr(C_2O_4)_3]$ is the **Oxalate ion** ($C_2O_4^{2-}$).
   - It is a **didentate** (chelating) ligand.
   - Each oxalate molecule coordinates through two oxygen atoms, forming two coordinate bonds with the central metal.

2. **Calculate Coordination Number (CN):** The coordination number is the total number of ligand donor atoms to which the metal is directly bonded.

$$\text{CN} = (\text{Number of ligands}) \times (\text{Denticity})$$

$$\text{CN} = 3 \times 2 = 6$$

The Chromium atom is in an octahedral geometry, surrounded by 6 oxygen atoms.

3. **Calculate Oxidation State (OS):** Let the oxidation state of Chromium be x.
   - Potassium (K) has a charge of $+1$.
   - Oxalate (C_2O_4) has a charge of -2.

The sum of charges in a neutral compound must be zero:

$$3(+1) + x + 3(-2) = 0$$

$$3 + x - 6 = 0$$

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

4. **Conclusion:** The coordination number of Chromium is **6** and its oxidation state is **+3**.

Answer: (C)

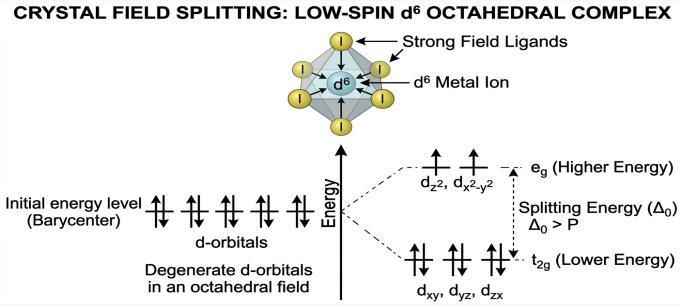
Q34.

Solution

Concept: High-Spin vs Low-Spin Complexes (CFT)

The nature of the complex (high-spin or low-spin) depends on the **Crystal Field Splitting Energy** (Δ_o) relative to the **Pairing Energy** (P):

- **Low-Spin:** Occurs with **Strong Field Ligands** where $\Delta_o > P$. Electrons pair up in the lower t_{2g} orbitals.
- **High-Spin:** Occurs with **Weak Field Ligands** where $\Delta_o < P$. Electrons occupy e_g orbitals before pairing.



Solution:

1. **Analyze the Ligand Field:**
   - F^-, Cl^-, and H_2O are positioned at the lower end of the spectrochemical series and are **Weak Field Ligands**.
   - NH_3 is a relatively **Strong Field Ligand**, especially when coordinating with Co^{3+}.
2. **Evaluate the Complexes:**
   - (A) $[CoF_6]^{3-}$: F^- is weak; High-spin (d^6 has 4 unpaired electrons).
   - (B) $[Co(NH_3)_6]^{3+}$: NH_3 is strong; it forces the $3d^6$ electrons of Co^{3+} to pair up in the t_{2g} level. It has **zero unpaired electrons** (Low-spin).
   - (C) $[Fe(H_2O)_6]^{3+}$: H_2O is weak; High-spin.
   - (D) $[MnCl_6]^{3-}$: Cl^- is weak; High-spin.
3. **Conclusion:** $[Co(NH_3)_6]^{3+}$ is a low-spin complex.

Answer: (B)

Q35.

Solution

Concept: Ammonolysis of Alkyl Halides

The reaction of an alkyl halide with an alcoholic solution of ammonia (NH_3) is a nucleophilic substitution reaction (S_N2). Ammonia acts as a nucleophile, attacking the carbon and displacing the halide ion.

Solution:

1. **The Reaction Chain:** The reaction proceeds in stages:

   (a) $R - X + NH_3 \rightarrow R - NH_2$ (Primary Amine)

   (b) $R - NH_2 + R - X \rightarrow R_2 - NH$ (Secondary Amine)

   (c) $R_2 - NH + R - X \rightarrow R_3 - N$ (Tertiary Amine)

   (d) $R_3 - N + R - X \rightarrow [R_4N]^+X^-$ (Quaternary Salt)

2. **Effect of Excess Ammonia:** When **Ammonia is in excess**, the probability of the alkyl halide molecule colliding with an NH_3 molecule is significantly higher than colliding with a newly formed primary amine molecule.

3. **Result:** The reaction largely stops after the first step because the alkyl halide is consumed by the abundant NH_3 before it can react with the primary amine produced. This makes the **Primary Amine** ($R - NH_2$) the major product.

4. **Conclusion:** Using excess ammonia yields a primary amine as the main product.

Answer: (A)

Q36.

Solution

Concept: Boiling Points of Alkyl Halides

The boiling point of organic compounds is primarily determined by the strength of **intermolecular forces**. For alkyl halides, these forces include dipole-dipole interactions and, more significantly, **van der Waals dispersion forces**.

Solution:

1. **Role of Molecular Mass and Size:** As the size and mass of the halogen atom increase, the electron cloud becomes more polarizable. This leads to stronger London dispersion forces between the molecules.

2. **Comparison of Halogens:** The atomic mass and size of halogens increase in the following order:

$$F < Cl < Br < I$$

3. **Analyze the Options:** Since the alkyl group (methyl, $-CH_3$) is the same in all options, the boiling point depends entirely on the halogen:

- **(A)** CH_3F**:** Smallest mass, weakest van der Waals forces.
- **(B)** CH_3Cl**:** Higher boiling point than fluoride.
- **(C)** CH_3Br**:** Higher boiling point than chloride.
- **(D)** CH_3I**:** Iodine has the largest atomic size and highest polarizability.

4. **Conclusion:** Methyl iodide (CH_3I) possesses the strongest intermolecular attractions, resulting in the **highest boiling point** among the given methyl halides.

Answer: (D)

Q37.

Solution

Concept: Nucleophilic Substitution in Alcohols

The conversion of an alcohol to an alkyl halide involves the replacement of a hydroxyl group ($-OH$) with a halide ion (X^-). This is a classic example of **Nucleophilic Substitution** (S_N).

Solution:

1. **Identify the Reactants and Products:** Reactants: Ethanol (CH_3CH_2OH) and Hydrochloric acid (HCl). Product: Ethyl chloride (CH_3CH_2Cl) and Water (H_2O).
2. **Analyze the Mechanism:**

- The $-OH$ group is a poor leaving group. In the presence of HCl and $ZnCl_2$ (Lucas reagent), the alcohol is protonated to form $R-OH_2^+$.
- Water (H_2O) then leaves as a stable neutral molecule.
- The chloride ion (Cl^-), acting as a **nucleophile**, attacks the carbon atom to form the C-Cl bond.

3. **Classification:** Since a nucleophile (Cl^-) is substituting a leaving group ($-OH$, via H_2O), the reaction is classified as **Nucleophilic Substitution**.
4. **Conclusion:** The reaction follows the S_N2 or S_N1 pathway (depending on the alkyl group) to effect substitution.

Answer: (C)

Q38.

Solution

Concept: Dehydration of Alcohols and Carbocation Stability

Dehydration is an elimination reaction where an alcohol loses a molecule of water to form an alkene. The ease of this reaction is directly linked to the stability of the **carbocation intermediate** formed during the process.

Solution:

1. **Reactivity Order:** The ease of dehydration follows the order:

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

2. **Mechanism for Tertiary Alcohols ($E1$):**

- **Protonation:** The $-OH$ group accepts a proton from the acid catalyst.
- **Ionization:** The $C - O$ bond breaks, leaving a carbocation. A 3° carbocation is highly stabilized by **inductive effects** and **hyperconjugation** from three alkyl groups.
- **Deprotonation:** A base removes a proton from an adjacent carbon to form the double bond.

3. **Comparison:** Primary alcohols often require high temperatures and concentrated acids because primary carbocations are unstable. Tertiary alcohols react under much milder conditions.

4. **Conclusion:** Tertiary alcohols are the **most easily dehydrated** due to the high stability of the resulting tertiary carbocation.

Answer: (A)

Q39.

Solution

Concept: Reduction of Nitriles (Cyanides)

Nitriles ($R - C \equiv N$) can be reduced to amines using various reducing agents. The type of amine formed depends on the structure of the nitrile and the strength of the reductant.

Solution:

1. **Role of $LiAlH_4$:** Lithium Aluminium Hydride ($LiAlH_4$) is a powerful nucleophilic reducing agent that provides hydride ions (H^-) to attack the electron-deficient carbon of the nitrile group.
2. **Mechanism of Reduction:** The reduction occurs in two main stages:
   - The $C \equiv N$ triple bond is reduced to a $C = N$ imine-like intermediate.
   - Further hydride attack reduces the imine to an amine.

$$R - C \equiv N \xrightarrow{LiAlH_4} [R - CH = NH] \xrightarrow{LiAlH_4} R - CH_2 - NH_2$$

3. **Identify the Product:** The carbon of the nitrile group becomes a CH_2 group, and the nitrogen becomes an NH_2 group. The resulting product is always a **Primary Amine** (1° amine).
4. **Conclusion:** The complete reduction of alkyl cyanides yields primary amines.

Answer: (C)

Q40.

Solution

Concept: Acidity of Carboxylic Acids and the Inductive Effect

The acidity of a carboxylic acid ($R-COOH$) depends on the stability of the **carboxylate anion** ($R-COO^-$) formed after deprotonation. Electron-withdrawing groups (EWG) increase acidity through the **Inductive Effect** ($-I$ effect).

Solution:

1. **Analyze the Effect of Chlorine:** Chlorine is highly electronegative. When attached to the α-carbon, it pulls electron density away from the $O-H$ bond, making it easier for the proton to leave. It also stabilizes the negative charge on the resulting COO^- group.
2. **Compare the Options:** The magnitude of the $-I$ effect increases with the **number** of electronegative atoms:

- **(A)** CH_3COOH**:** No EWG; weakest acid.
- **(B)** $ClCH_2COOH$**:** Monochloroacetic acid (One Cl atom).
- **(C)** $Cl_2CHCOOH$**:** Dichloroacetic acid (Two Cl atoms).
- **(D)** Cl_3CCOOH**:** Trichloroacetic acid (Three Cl atoms).

3. **Ranking:** Trichloroacetic acid has three chlorine atoms pulling electrons simultaneously, providing the maximum stabilization to the conjugate base.
4. **Conclusion:** Cl_3CCOOH is the **strongest acid** among the given options.

Answer: (D)

Q41.

Solution

Concept: The Hinsberg Test for Amines

The **Hinsberg Test** is a classic chemical method used to distinguish between primary (1°), secondary (2°), and tertiary (3°) amines. The reagent used is an aromatic acid chloride that reacts differently based on the number of replaceable hydrogen atoms on the nitrogen.

Solution:

1. **Identify the Reagent:** The chemical name for the Hinsberg reagent is **Benzene sulphonyl chloride** ($C_6H_5SO_2Cl$).
2. **Reaction with Amines:**
   - **Primary Amines:** Form an N-alkylbenzene sulphonamide. Due to the presence of a highly acidic hydrogen on nitrogen (flanked by the strong SO_2 group), the product dissolves in alkali (NaOH).
   - **Secondary Amines:** Form an N,N-dialkylbenzene sulphonamide. It has no acidic hydrogen, so the product is **insoluble** in alkali.
   - **Tertiary Amines:** Do not react at all as they lack an N-H bond.
3. **Conclusion:** Benzene sulphonyl chloride is the active component of the Hinsberg reagent.

Answer: (A)

Q42.

Solution

Concept: Azo Coupling Reactions

Coupling reactions are electrophilic aromatic substitution reactions where a diazonium salt acts as an electrophile and reacts with an electron-rich aromatic ring (like phenol or aniline) to produce brightly colored azo compounds ($Ar - N = N - Ar'$).

Solution:

1. **Identify the Reactants:** The reactants are Benzene diazonium chloride ($C_6H_5N_2^+Cl^-$) and Phenol (C_6H_5OH).
2. **Reaction Conditions:** The reaction takes place in a **mildly alkaline medium** (pH 9-10). In this medium, phenol is converted to the phenoxide ion, which is a much stronger activating group, facilitating the attack of the diazonium cation at the **para position**.
3. **Determine the Product and Color:** The product formed is p-hydroxyazobenzene. This compound contains an extended conjugated system (chromophore) involving two benzene rings linked by the $-N = N-$ group.

$$C_6H_5N_2^+Cl^- + C_6H_5OH \xrightarrow{OH^-} C_6H_5 - N = N - C_6H_4(OH) + HCl$$

This specific azo dye is **Orange** in color. (Note: Coupling with aniline gives a yellow dye).

4. **Conclusion:** The coupling of benzene diazonium chloride with phenol yields an orange dye.

Answer: (B)

Q43.

Solution

Concept: Reducing and Non-Reducing Sugars

Carbohydrates that can reduce Tollen's reagent or Fehling's solution are called **reducing sugars**. This property depends on the presence of a free **hemiacetal** or **hemiketal** group (an "anomeric" carbon not involved in a glycosidic bond).

Solution:

1. **Analyze Monosaccharides:** All monosaccharides (like Glucose, Fructose, Galactose) are reducing sugars because they can exist in an open-chain form with a free aldehyde or ketone group.
2. **Analyze Disaccharides:**

- **Maltose:** Consists of two glucose units. The anomeric carbon of the second glucose is free. **(Reducing)**
- **Lactose:** Consists of glucose and galactose. The anomeric carbon of glucose is free. **(Reducing)**
- **Sucrose:** Consists of glucose and fructose. The glycosidic linkage is formed between the **C1 of glucose** and **C2 of fructose**. Since both anomeric carbons are locked in the bond, there is no free carbonyl group.

3. **Conclusion:** Sucrose is a **non-reducing sugar** because it lacks a free aldehydic or ketonic group.

Answer: (C)

Q44.

Solution

Concept: Classification of Proteins by Molecular Shape

Proteins are categorized into two major types based on their three-dimensional structure: **Fibrous** and **Globular**.

Solution:

1. **Fibrous Proteins:** These consist of polypeptide chains that run parallel to each other and are held together by hydrogen and disulfide bonds. They form fiber-like structures, are generally **insoluble in water**, and provide structural support.

- **Example: Keratin** (found in hair, nails, wool) and **Myosin** (found in muscles).

2. **Globular Proteins:** These result when the polypeptide chains fold around to give a spherical shape. They are usually **soluble in water** and act as biological catalysts or transporters.

- **Example: Insulin**, **Albumin**, and **Hemoglobin**.

3. **Conclusion:** Among the options, Keratin is the only fibrous protein.

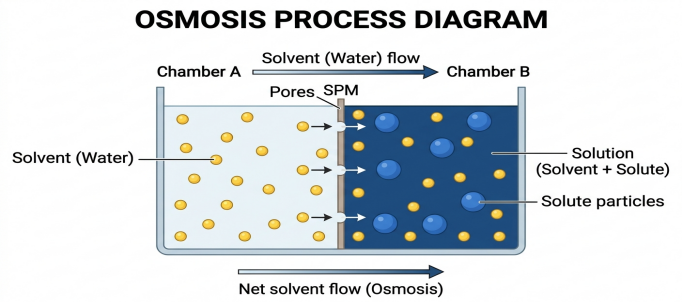
Answer: (C)

Q45.

Solution

Concept: Osmosis and Osmotic Pressure

Osmosis is the spontaneous movement of solvent molecules through a semi-permeable membrane (SPM) from a region of **lower solute concentration** (more solvent) to a region of **higher solute concentration** (less solvent).



Solution:

1. **Analyze the Direction of Flow:** The problem states that the liquid (solvent) flows from Chamber A to Chamber B.
2. **Apply the Principle of Osmosis:** Solvent always moves toward the side that is "thirstier" for solvent—the more concentrated side.
   - Side A → Side B
   - Solvent source → Solvent destination
3. **Compare Concentrations:** Because the solvent is moving **into Chamber B**, it implies that Chamber B has a **higher concentration** of solute (higher molarity) than Chamber A.
4. **Conclusion:** The concentration of solution B is greater than that of solution A.

Answer: (B)

Q46.

Solution

Concept: Pseudo-First-Order Reactions

A **Pseudo-First-Order** reaction is a chemical reaction that is fundamentally of a higher order (e.g., second-order) but behaves kinetically as a first-order reaction. This occurs when one of the reactants is present in a **large excess** compared to the others.

Solution:

1. **The Rate Law:** Consider a second-order reaction: $A + B \rightarrow$ Products. The differential rate equation is:

$$\text{Rate} = k[A]^1[B]^1$$

2. **Effect of Large Excess:** If reactant **B** is present in such a large quantity (e.g., as a solvent like water) that its concentration change during the reaction is negligible, we can consider $[B]$ to be constant.

$$[B] \approx [B]_0$$

3. **Mathematical Simplification:** We can combine the rate constant k and the constant concentration $[B]$ into a new "pseudo" rate constant k':

$$\text{Rate} = (k[B])[A] = k'[A]$$

4. **Conclusion:** The rate of the reaction now depends only on the concentration of **A**. A common example is the **acid-catalyzed inversion of cane sugar** or the **hydrolysis of an ester**, where water is in large excess.

Answer: (B)

Q47.

Solution

Concept: Electronic Configuration of Lanthanoids

Gadolinium (Gd) is the 8th element in the Lanthanoid series ($Z = 64$). Its electronic configuration is unique due to the **extra stability** associated with a half-filled f-subshell ($4f^7$).

Solution:

1. **Ground State Configuration of Gd:** The expected configuration following the Aufbau principle might be $[Xe]4f^8 6s^2$. However, to achieve a stable half-filled f^7 state, one electron resides in the $5d$ orbital:

$$Gd(Z = 64) : [Xe]4f^7 5d^1 6s^2$$

2. **Ionization to Gd^{3+}:** When forming the trivalent ion (Gd^{3+}), electrons are removed in the following order:

- First, two electrons from the $6s$ orbital.
- Next, one electron from the $5d$ orbital.

3. **Final Configuration:** After losing three electrons, the remaining configuration is:

$$Gd^{3+} : [Xe]4f^7$$

4. **Conclusion:** The Gd^{3+} ion has a **half-filled** $4f^7$ configuration, which accounts for its significant magnetic properties and chemical stability.

Answer: (A)

Q48.

Solution

Concept: IUPAC Nomenclature of Coordination Compounds

For ionic coordination compounds containing both a complex cation and a complex anion, specific rules apply:

- Name the **cation** first, then the **anion**.
- Use Greek prefixes (di, tri) for the number of ligands.
- For the **anionic complex**, the metal name must end in the suffix **"-ate"**.
- The oxidation state is indicated in Roman numerals in parentheses.

Solution:

1. **Identify the Cation and Anion:** Compound: $[Ag(NH_3)_2][Ag(CN)_2]$ Cation: $[Ag(NH_3)_2]^+$ | Anion: $[Ag(CN)_2]^-$
2. **Determine Oxidation States:** Let the oxidation state of both Silver (Ag) atoms be x. Sum of charges: $x + 2(0) + x + 2(-1) = 0 \implies 2x = 2 \implies x = +1$.
3. **Construct the Name:**
   - **Cation:** 2 NH_3 (ammine) + Silver(I) $\rightarrow$ **Diamminesilver(I)**
   - **Anion:** 2 CN (cyano) + Silver (Argentate for anion) $\rightarrow$ **Dicyanoargentate(I)**
4. **Conclusion:** Combining the parts, the name is **Diamminesilver(I) dicyanoargentate(I)**.

Answer: (A)

Q49.

Solution

Concept: The Wurtz-Fittig Reaction

The **Wurtz-Fittig reaction** is an extension of the Wurtz reaction. It involves the coupling of an **aryl halide** (aromatic) and an **alkyl halide** (aliphatic) in the presence of sodium metal in a dry ether solvent.

Solution:

1. **The Reaction Components:**

- Reactant 1: Aryl halide ($Ar - X$, e.g., Chlorobenzene).
- Reactant 2: Alkyl halide ($R - X$, e.g., Methyl chloride).
- Reagent: Sodium (Na) in dry ether.

2. **The Chemical Process:** The sodium atoms facilitate the removal of the halogen atoms, creating radical or ionic intermediates that bond the alkyl group directly to the aromatic ring.

$$Ar - X + 2Na + X - R \xrightarrow{\text{dry ether}} Ar - R + 2NaX$$

3. **Identify the Product:** The resulting compound is an **alkyl-substituted aromatic** hydrocarbon (an alkyl arene). For example, reacting chlorobenzene and methyl chloride yields **Toluene**.

4. **Conclusion:** The product is an alkyl arene.

Answer: (C)

Q50.

Solution

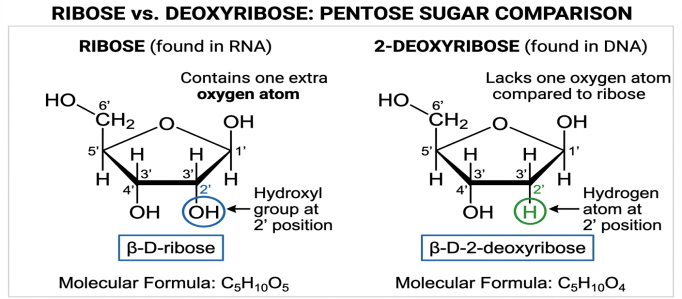
Concept: Structure of Pentose Sugars in Nucleic Acids

Nucleic acids (DNA and RNA) contain five-carbon sugars (pentoses). The fundamental structural difference between DNA and RNA lies in the oxygen content of these sugar molecules at a specific carbon position.

Solution:

1. **RNA Sugar:** The sugar in RNA is **β-D-ribose**. It has a hydroxyl ($-OH$) group at the C_2' position.

2. **DNA Sugar:** The sugar in DNA is **β-D-2-deoxyribose**. As the name "deoxy" implies, it lacks one oxygen atom compared to ribose.



3. **Structural Comparison:**

- **Ribose ($C_5H_{10}O_5$):** Contains $-OH$ at C_2'.
- **Deoxyribose ($C_5H_{10}O_4$):** Contains only $-H$ at C_2'.

4. **Conclusion:** The specific sugar found in DNA is 2-deoxyribose. This absence of the oxygen atom makes DNA more chemically stable than RNA.

Answer: (A)

Answer Key

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