UP Board Class 12 Chemistry 2026 Set 347 EC Question Paper with Solutions

collegedunia

General Instructions

(i) This booklet contains 26 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 6 single-correct multiple-choice questions.

(iii) Attempt each question on your own before reviewing the given solution.

1. Lanthanide contraction is observed in —

(A) s-block element

(B) p-block element

(C) d-block element

(D) f-block element

Correct Answer: (D) f-block element

Solution:

Step 1: Lanthanide contraction is the steady decrease in the size (atomic and ionic radii) of the elements as we move across the lanthanide series from La (Z = 57) to Lu (Z = 71).

Step 2: The lanthanides are the 14 elements in which the last electron enters the inner $4f$ subshell. Hence they belong to the **f-block**.

Step 3: The contraction happens because the $4f$ electrons shield the nuclear charge very poorly, so the effective nuclear charge felt by the outer electrons increases along the series, pulling them closer.

Why the others are wrong: s-block and p-block elements have no f electrons, and in d-block elements the electron enters the d subshell

(that effect is called d-block or scandide contraction, not lanthanide contraction).
Therefore the correct answer is **(iv) f-block element**.

Quick Tip: The word lanthanide itself tells you the block; lanthanides are inner-transition elements filling the 4f subshell.

2. IUPAC name of $CH_3 - CH_2 - CH(OH) - CH_3$ is —

(A) Butan-2-ol

(B) Butan-1-ol

(C) Propan-2-ol

(D) Propan-1-ol

Correct Answer: (A) Butan-2-ol

Solution:

Step 1: Count the longest carbon chain. $CH_3 - CH_2 - CH(OH) - CH_3$ has four carbon atoms, so the parent alkane is butane.
Step 2: The functional group is $-OH$ (alcohol), so the suffix -e of butane is replaced by -ol, giving butanol.
Step 3: Number the chain from the end that gives the $-OH$ the lowest locant. The $-OH$ is on the third carbon counting from the left, but on the second carbon counting from the right. The lower number (2) is chosen.
Step 4: The name is therefore **butan-2-ol**.
Why the others are wrong: Butan-1-ol would need $-OH$ on a terminal carbon; propan-2-ol and propan-1-ol have only three

carbons.

Correct answer: **(i) Butan-2-ol**.

Quick Tip: Four carbons give the root but-; the OH sits on carbon 2 when numbered for the lowest locant.

3. Which of the following is a colourless ion?

(A) Cu^{+} ion

(B) Cu^{2+} ion

(C) Ni^{2+} ion

(D) Co^{2+} ion

Correct Answer: (A) Cu^{+} ion

Solution:

Step 1: Colour in transition-metal ions arises from d-d transitions, which are only possible when the d subshell is partially filled (has unpaired electrons and empty d orbitals to jump into).

Step 2: Work out the d-electron configurations:

Cu^{+}: $3d^{10}$ (completely filled, no d-d transition possible) $\rightarrow$ colourless.

Cu^{2+}: $3d^{9}$ (one unpaired electron) $\rightarrow$ blue.

Ni^{2+}: $3d^{8}$ (unpaired electrons) $\rightarrow$ green.

Co^{2+}: $3d^{7}$ (unpaired electrons) $\rightarrow$ pink.

Step 3: Only Cu^{+} has a fully filled $3d^{10}$ configuration, so no d-d transition and no colour.

Correct answer: **(i) Cu^{+} ion**.

Quick Tip: Colour needs a partly filled d subshell; a fully filled d10 ion cannot show d-d transitions.

4. Unit of rate constant of a first order reaction is —

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

(B) s^{-1}

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

(D) None of these

Correct Answer: (B) s^{-1}

Solution:

Step 1: For a reaction of order n, the unit of the rate constant is $(mol\,L^{-1})^{1-n}\,s^{-1}$.

Step 2: For a first order reaction, rate $= k[A]$. Rearranging, $k = \dfrac{\text{rate}}{[A]}$.

Step 3: Substitute the units: rate has units $mol\,L^{-1}\,s^{-1}$ and concentration $[A]$ has units $mol\,L^{-1}$.

$$k = \frac{mol\,L^{-1}\,s^{-1}}{mol\,L^{-1}} = s^{-1}$$

Step 4: The concentration units cancel, leaving s^{-1}.

Correct answer: **(ii)** s^{-1}. Options (i) and (iii) are the units for zero and second order respectively.

Quick Tip: Use unit = (mol L-1) ^ (1-n) s ^ -1 with n = 1; the concentration term cancels out.

5. $CH_3 - CH_2 - CH = CH_2 + HBr \xrightarrow{Peroxide}$ product. In this reaction, the main product is —

(A) $CH_3 - CH_2 - CH_2 - CH_2 - Br$

(B) $CH_3 - CH_2 - CHBr - CH_3$

(C) Both are main products

(D) None of these

Correct Answer: (A) $CH_3 - CH_2 - CH_2 - CH_2 - Br$

Solution:

Step 1: When HBr adds to an unsymmetrical alkene in the presence of a peroxide, the addition follows the anti-Markovnikov rule. This is called the peroxide effect or Kharasch effect.

Step 2: The reaction goes by a free-radical mechanism. The bromine radical $Br^{\bullet}$ adds first, and it adds to the double-bond carbon that gives the more stable free radical.

Step 3: In $CH_3 - CH_2 - CH = CH_2$, $Br^{\bullet}$ adds to the terminal CH_2 carbon, generating a more stable secondary carbon radical. Hydrogen then adds to the terminal carbon.

Step 4: So bromine ends up on the terminal (less substituted) carbon, giving $CH_3 - CH_2 - CH_2 - CH_2 - Br$ (1-bromobutane) as the main product.

Correct answer: **(i)**. Option (ii) would be the Markovnikov product formed without peroxide.

Quick Tip: Peroxide means anti-Markovnikov addition; bromine attaches to the terminal carbon.

6. The unit of rate constant of a zero order reaction is —

(A) min^{-1}

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

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

(D) Dimensionless

Correct Answer: (C) $mol\,L^{-1}\,min^{-1}$

Solution:

Step 1: For a zero order reaction the rate does not depend on concentration: rate $= k[A]^0 = k$.

Step 2: This means the rate constant k has the same units as the rate itself.

Step 3: Rate is measured as change in concentration per unit time, so its units are $mol\,L^{-1}\,min^{-1}$ (or $mol\,L^{-1}\,s^{-1}$).

$$k = \text{rate} = mol\,L^{-1}\,min^{-1}$$

Step 4: Therefore the unit of the zero order rate constant is $mol\,L^{-1}\,min^{-1}$.

Correct answer: **(iii)**. Option (i) is for first order, option (ii) is for second order.

Quick Tip: For zero order rate equals k, so k has the units of rate, concentration over time.

7. Explain first order reaction with example.

Correct Answer: —

Solution:

Step 1: Definition. A first order reaction is a reaction whose rate depends on the concentration of only one reactant raised to the power one. If a reactant is A, then

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

where k is the rate constant.

Step 2: Integrated rate law. On integrating the above expression, the rate constant of a first order reaction is given by

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

where $[A]_0$ is the initial concentration and $[A]$ is the concentration after time t.

Step 3: Characteristics. The unit of k is s^{-1} (time^{-1}), and the half-life $t_{1/2} = \frac{0.693}{k}$ is independent of the initial concentration.

Step 4: Example. Decomposition of dinitrogen pentoxide:

$$N_2O_5 \rightarrow 2NO_2 + \tfrac{1}{2}O_2, \quad \text{Rate} = k[N_2O_5]$$

Other examples are the decomposition of H_2O_2 and all radioactive disintegrations.

Quick Tip: Rate depends on the first power of one reactant, rate = k[A]; recall the integrated form and an example like N2O5 decomposition.

8. Differentiate between order and molecularity of a reaction.

Correct Answer: —

Solution:

Step 1: Order of a reaction.

1) It is the sum of the powers to which the concentration terms are raised in the experimentally determined rate law.

2) It is an **experimental** quantity, found from the rate expression, not from the balanced equation.

3) It can be zero, a whole number, or even a fraction (e.g. $\frac{1}{2}$, **1.5**).

4) It applies to the overall reaction as well as to elementary steps.

Step 2: Molecularity of a reaction.

1) It is the number of reacting species (atoms, ions or molecules) that collide simultaneously in an **elementary** step to bring about the reaction.

2) It is a **theoretical** quantity, obtained from the mechanism of the reaction.

3) It is always a whole number (1, 2 or 3) and can never be zero or fractional.

4) It is defined only for a single elementary step, not for a complex overall reaction.

Step 3: Key point. For an elementary reaction, order and molecularity are usually the same; for a complex (multi-step) reaction the order is decided by the slowest (rate-determining) step, so order and molecularity may differ.

Quick Tip: Order is experimental and can be fractional or zero; molecularity is theoretical and always a small whole number from an elementary step.

9. Write the Nernst equation and also explain the relation between electrode potential (E_{cell}) and the equilibrium constant (K_c).

Correct Answer: —

Solution:

Step 1: Nernst equation. For a general cell reaction

$$aA + bB \rightarrow cC + dD$$

the Nernst equation gives the cell potential at any concentration:

$$E_{cell} = E^{\circ}_{cell} - \frac{RT}{nF} \ln Q$$

where E°_{cell} is the standard cell potential, R is the gas constant, T the temperature, n the number of electrons transferred, F the Faraday constant, and Q the reaction quotient.

Step 2: Form at 298 K. Substituting the values of R, F and converting ln to log:

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

Step 3: At equilibrium. When the cell reaction reaches equilibrium, the cell can do no more work, so $E_{cell} = 0$, and the reaction quotient becomes the equilibrium constant, $Q = K_c$. Substituting:

$$0 = E^{\circ}_{cell} - \frac{0.0591}{n} \log K_c$$

Step 4: Relation. Rearranging gives the link between standard cell potential and the equilibrium constant:

$$\boxed{E^{\circ}_{cell} = \frac{0.0591}{n} \log K_c}$$

A large positive E°_{cell} means a large K_c, i.e. the cell reaction proceeds nearly to completion.

Quick Tip: Write Ecell = E cell standard minus (0.0591/n) log Q; at equilibrium Ecell = 0 and Q = Kc.

10. How will you prepare phenol from the following reagents (write only chemical equation)?

i) Benzene

ii) Aniline

Correct Answer: —

Solution:

i) Phenol from benzene (sulphonation route).

Step 1: Benzene is sulphonated with concentrated sulphuric acid to give benzenesulphonic acid.

$$C_6H_6 + H_2SO_4 \rightarrow C_6H_5SO_3H + H_2O$$

Step 2: Benzenesulphonic acid is heated (fused) with molten sodium hydroxide to give sodium phenoxide.

$$C_6H_5SO_3H \xrightarrow{NaOH,\ fuse} C_6H_5ONa$$

Step 3: Acidification of sodium phenoxide gives phenol.

$$C_6H_5ONa + H^+ \rightarrow C_6H_5OH + Na^+$$

ii) Phenol from aniline (diazotisation route).

Step 1: Aniline is treated with nitrous acid $(NaNO_2 + HCl)$ at 273 to 278 K to form benzenediazonium chloride.

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

Step 2: The diazonium salt is warmed with water, where it is hydrolysed to phenol with the release of nitrogen gas.

$$C_6H_5N_2^+Cl^- + H_2O \xrightarrow{warm} C_6H_5OH + N_2 \uparrow + HCl$$

Quick Tip: Benzene: sulphonate, fuse with NaOH, then acidify. Aniline: diazotise at low temperature, then warm the diazonium salt with water.

11. Write two characteristics of transition elements.

Correct Answer: —

Solution:

Transition elements are the d-block elements in which the d subshell is partly filled either in the free atom or in one of their common oxidation states. Two important characteristics are:

Step 1: Variable oxidation states. Because the energies of the $(n-1)d$ and ns electrons are very close, both sets of electrons can take part in bonding. Hence transition metals show several oxidation states. For example, manganese shows +2, +3, +4, +6 and +7, and iron shows

+2 and +3.

Step 2: Formation of coloured compounds/ions. Transition metal ions have partly filled d orbitals, so electrons can undergo d-d transitions by absorbing visible light. The complementary colour is seen. For example, Cu^{2+} is blue and Fe^{3+} is yellow.

(Other characteristics, not required here, include paramagnetism due to unpaired electrons, catalytic activity, and formation of complex and interstitial compounds.)

Quick Tip: Pick any two, for example variable oxidation states, coloured ions, paramagnetism, catalytic activity or complex formation, and justify each.

12. Write the reason of the following: Ethylamine is soluble in water, while aniline is not soluble in water.

Correct Answer: —

Solution:

Step 1: Solubility of ethylamine. Ethylamine ($C_2H_5NH_2$) has a small hydrocarbon part and an $-NH_2$ group. The nitrogen and hydrogen of the amino group form hydrogen bonds with water molecules. Because the ethyl group is small, this hydrogen bonding is strong enough to dissolve ethylamine in water.

Step 2: Insolubility of aniline. In aniline ($C_6H_5NH_2$) the $-NH_2$ group is attached to a large hydrophobic benzene ring. This bulky non-polar phenyl group cannot form hydrogen bonds with water and it dominates the molecule.

Step 3: Effect of lone pair delocalisation. In aniline the lone pair of electrons on nitrogen is delocalised into the benzene ring (resonance).

This reduces the availability of the nitrogen lone pair for hydrogen bonding with water, further lowering its solubility.

Step 4: Conclusion. The large hydrophobic aromatic ring plus reduced hydrogen bonding make aniline almost insoluble in water, whereas the small ethylamine, with a freely available lone pair, hydrogen bonds well and dissolves.

Quick Tip: Compare the size of the carbon part and the availability of the nitrogen lone pair for hydrogen bonding with water.

13. $[NiCl_4]^{2-}$ is paramagnetic, while $Ni(CO)_4$ is diamagnetic, although both are tetrahedral. Why?

Correct Answer: —

Solution:

Step 1: Find the oxidation state and d-electron count of nickel in each complex.

In $[NiCl_4]^{2-}$: each Cl carries -1 and the overall charge is -2, so Ni is $+2$. Ni ($Z = 28$) is $[Ar]3d^8 4s^2$; removing the two 4s electrons gives $Ni^{2+} = 3d^8$, which has 2 unpaired electrons.

In $Ni(CO)_4$: CO is neutral and the complex is neutral, so Ni is 0, i.e. $3d^8 4s^2$.

Step 2: Compare the ligand field strengths.

Cl^- is a weak field ligand and cannot pair the d electrons, so the $3d^8$ set keeps its 2 unpaired electrons. Ni^{2+} uses sp^3 hybridisation (one 4s + three 4p orbitals) giving a tetrahedral shape, and the 2 unpaired electrons make it paramagnetic.

CO is a strong field ligand; it forces the $4s^2$ electrons of Ni(0) to pair and shift into 3d, giving $3d^{10}4s^0$. The empty 4s and 4p orbitals form sp^3 hybrids, again tetrahedral, but now every electron is paired, so it is diamagnetic.

Step 3: Conclusion. Both are sp^3 tetrahedral, yet the weak Cl^- leaves 2 unpaired electrons (paramagnetic) while the strong CO pairs all electrons (diamagnetic).

Quick Tip: Compare the ligand field strength: Cl^- is weak so Ni^{2+} (d^8) keeps 2 unpaired electrons, while CO is strong and pairs all electrons to $3d^{10}$. Both remain sp^3 tetrahedral.

14. The two strands of DNA are not identical, but complementary to each other. Explain.

Correct Answer: —

Solution:

Step 1: DNA is a double helix made of two polynucleotide strands held together by hydrogen bonds between the nitrogen bases that point inward.

Step 2: Base pairing follows fixed rules. Adenine (A) pairs only with Thymine (T) through 2 hydrogen bonds, and Guanine (G) pairs only with Cytosine (C) through 3 hydrogen bonds. A purine always pairs with a pyrimidine.

Step 3: Because of these rules, the base sequence of one strand fixes the sequence of the other. Wherever one strand has A, the partner strand has T; wherever it has G, the partner has C. So the two sequences are different (not identical) but each is the exact partner, or

complement, of the other.

Step 4: The two strands also run antiparallel (one 5' to 3', the other 3' to 5'). Therefore the strands are complementary, not identical.

Quick Tip: Use the base pairing rule: A pairs with T and G pairs with C. One strand therefore decides the other, making them complementary, not identical.

15. A 200 cm^3 aqueous solution of a protein contains 1.26 g of protein. The osmotic pressure at 300 K was found to be 2.57×10^{-3} bar. Calculate the molar mass of the protein. (R = 0.083 L bar K^{-1} mol^{-1})

Correct Answer: —

Solution:

Step 1: Write the osmotic pressure formula. For a dilute solution $\pi = \frac{n}{V}RT = \frac{wRT}{MV}$, where w is mass of solute, M its molar mass, V the volume in litres, R the gas constant and T the temperature.

Step 2: Rearrange for molar mass: $M = \frac{wRT}{\pi V}$.

Step 3: List the data: w = 1.26 g, R = 0.083 L bar K^{-1} mol^{-1}, T = 300 K, $\pi = 2.57 \times 10^{-3}$ bar, V = 200 cm^3 = 0.200 L.

Step 4: Substitute: $M = \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times 0.200}$.

Step 5: Arithmetic. Numerator = 1.26 x 0.083 x 300 = 31.374.

Denominator = $2.57 \times 10^{-3} \times 0.200 = 5.14 \times 10^{-4}$.

$M = \frac{31.374}{5.14 \times 10^{-4}} = 6.10 \times 10^4$ g mol^{-1}.

$$\boxed{M \approx 61039 \text{ g mol}^{-1}}$$

Quick Tip: Use $M = \frac{wRT}{\pi V}$ with R = 0.083 L bar K^{-1} mol^{-1} and V in litres (0.200 L).

16. Define conductivity and molar conductivity of an electrolyte solution. Discuss the change in their value with the change in concentration of electrolyte.

Correct Answer: —

Solution:

Step 1: Conductivity (kappa). Conductivity is the conductance of a solution held between two electrodes each of 1 cm^2 cross-section and placed 1 cm apart, that is the conductance of 1 cm^3 of the solution. It is the reciprocal of resistivity: $\kappa = \frac{1}{\rho} = G \times \frac{l}{A}$, where G is conductance and l/A is the cell constant. Unit: S cm^{-1} (or S m^{-1}).

Step 2: Molar conductivity ($Lambda_m$). It is the conducting power of all the ions produced by one mole of electrolyte, that is the conductivity of a solution containing one mole of electrolyte between electrodes 1 cm apart. $\Lambda_m = \frac{\kappa \times 1000}{C}$, with kappa in S cm^{-1} and C in mol L^{-1}. Unit: S cm^2 mol^{-1}.

Step 3: Effect on conductivity. On dilution (decreasing concentration) the conductivity decreases, because the number of ions present in each unit volume falls.

Step 4: Effect on molar conductivity. On dilution the molar conductivity increases, because the volume holding one mole of electrolyte increases. For strong electrolytes the rise is small (ions move more freely as inter-ionic attraction weakens); for weak

electrolytes the rise is large near infinite dilution due to the greater degree of dissociation.

Quick Tip: Conductivity = conductance of 1 cm^3 of solution (S cm^{-1}); molar conductivity $\Lambda_m = \kappa \times 1000/C$ (S cm^2 mol^{-1}). On dilution kappa falls but molar conductivity rises.

17. For the first-order reaction $N_2O_5(g) \rightarrow 2NO_2(g) + O_2(g)$, the initial concentration of N_2O_5 at 318 K was 1.24×10^{-2} mol L^{-1}, which decreased to 0.20×10^{-2} mol L^{-1} after 60 minutes. Calculate the rate constant at 318 K.

Correct Answer: —

Solution:

Step 1: For a first-order reaction the integrated rate law is $k = \frac{2.303}{t}\log\frac{[A]_0}{[A]}$, where $[A]_0$ is the initial concentration and [A] the concentration after time t.

Step 2: Data: $[A]_0 = 1.24 \times 10^{-2}$ mol L^{-1}, $[A] = 0.20 \times 10^{-2}$ mol L^{-1}, t = 60 min.

Step 3: Ratio $\frac{[A]_0}{[A]} = \frac{1.24}{0.20} = 6.2$.

Step 4: Substitute: $k = \frac{2.303}{60}\log(6.2)$. Since $\log 6.2 = 0.7924$, $k = 0.03838 \times 0.7924 = 0.0304$ min^{-1}.

$$\boxed{k \approx 0.0304\ \text{min}^{-1} = 5.07 \times 10^{-4}\ \text{s}^{-1}}$$

Quick Tip: Use the first-order law $k = \frac{2.303}{t} \log \frac{[A]_0}{[A]}$ with the ratio 6.2 over t = 60 min.

18. Explain, giving reasons:

i) Transition metals and most of their compounds are paramagnetic.

ii) Transition metals generally form coloured compounds.

Correct Answer: —

Solution:

Step 1 (part i): Paramagnetism is caused by the presence of unpaired electrons. Transition metals have partly filled (n-1)d orbitals, so their atoms and most of their ions carry one or more unpaired d electrons and are therefore paramagnetic. The strength of paramagnetism is given by the spin-only magnetic moment $\mu = \sqrt{n(n+2)}$ BM, where n is the number of unpaired electrons; more unpaired electrons means a larger moment.

Step 2: Species with no unpaired electrons, such as Sc^{3+} (d^0) and Zn^{2+} (d^{10}), are diamagnetic, which confirms the link between unpaired d electrons and paramagnetism.

Step 3 (part ii): In the presence of ligands the five d orbitals split into two energy levels (t_{2g} lower and e_g higher). Because the d subshell is only partly filled, an electron can jump from the lower to the higher d level by absorbing a definite wavelength of visible light, called a d-d transition.

Step 4: The colour we see is the complementary colour of the light absorbed. Ions with empty (d^0) or completely filled (d^{10}) d orbitals

cannot undergo d-d transitions and are therefore colourless, for example Sc^{3+} and Zn^{2+}.

Quick Tip: Unpaired d electrons cause paramagnetism (moment $\mu = \sqrt{n(n+2)}$ BM); d-d transitions in partly filled d orbitals cause colour. Empty or full d (Sc^{3+}, Zn^{2+}) are colourless and diamagnetic.

19. Write the IUPAC names of the following coordination compounds:

i) $[Pt(NH_3)_2ClNO_2]$

ii) $[Co(NH_3)_5(CO_3)]Cl$

iii) $[Ni(CO)_4]$

iv) $[Co(NH_3)_5ONO]^{2+}$ (1+1+1+1)

Correct Answer: —

Solution:

Rule used: In a coordination compound the ligands are named first in alphabetical order (by ligand name, ignoring the multiplying prefixes di, tri, tetra), then the central metal, followed by its oxidation state in Roman numerals in brackets. For a cationic complex the counter-anion is written after the complex ion.

i) $[Pt(NH_3)_2ClNO_2]$: Ligands are 2 ammine (NH_3, neutral), 1 chlorido (Cl^-), 1 nitrito-N (NO_2^-, bonded through N).

Charge balance: complex is neutral, so $x + 0 + (-1) + (-1) = 0 \Rightarrow x = +2$.

Alphabetical ligand order: ammine, chlorido, nitrito.

Name: **Diamminechloridonitrito-N-platinum(II)**.

ii) $[Co(NH_3)_5(CO_3)]Cl$**:** Ligands are 5 ammine (neutral) and 1 carbonato (CO_3^{2-}); Cl^- is the counter-ion.
Complex ion charge $= +1$ (to balance one Cl^-); so $x + 0 + (-2) = +1 \Rightarrow x = +3$.
Alphabetical order: ammine, carbonato.
Name: **Pentaamminecarbonatocobalt(III) chloride**.

iii) $[Ni(CO)_4]$**:** Four carbonyl ligands (CO, neutral); complex is neutral, so oxidation state of Ni $= 0$.
Name: **Tetracarbonylnickel(0)**.

iv) $[Co(NH_3)_5ONO]^{2+}$**:** Ligands are 5 ammine (neutral) and 1 nitrito-O (ONO, bonded through O, -1).
Charge balance: $x + 0 + (-1) = +2 \Rightarrow x = +3$.
Name: **Pentaamminenitrito-O-cobalt(III) ion**.

Quick Tip: Name ligands alphabetically then the metal with its oxidation state; remember NO_2 bonded through N is nitrito-N (nitro) while ONO bonded through O is nitrito-O.

20. Differentiate between primary, secondary and tertiary alcohols, showing their structure. In the presence of which enzyme does glucose convert to ethyl alcohol? (3+1)

Correct Answer: —

Solution:

Concept: Alcohols are classified by the number of carbon atoms directly attached to the carbon that carries the $-OH$ group (the

carbinol carbon).

Step 1 (Primary, 1° alcohol): The $-OH$ bearing carbon is joined to only **one** other carbon atom. General form $R-CH_2-OH$.
Example: Ethanol, CH_3-CH_2-OH.

Step 2 (Secondary, 2° alcohol): The $-OH$ bearing carbon is joined to **two** other carbon atoms. General form R_2CH-OH.
Example: Propan-2-ol, $CH_3-CH(OH)-CH_3$.

Step 3 (Tertiary, 3° alcohol): The $-OH$ bearing carbon is joined to **three** other carbon atoms. General form R_3C-OH.
Example: 2-methylpropan-2-ol, $(CH_3)_3C-OH$.

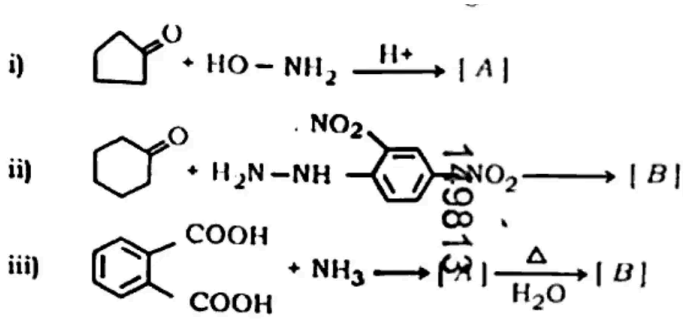
Step 4 (Enzyme): Glucose is converted to ethyl alcohol (ethanol) by the enzyme **zymase**:

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2\,C_2H_5OH + 2\,CO_2$$

$$\boxed{\text{Enzyme} = \text{zymase}}$$

Quick Tip: Classify by the number of carbons bonded to the C-OH carbon (one, two, three). The yeast enzyme that ferments glucose to ethanol is zymase.

21.



Identify the product of the following reactions:

i) cyclopentanone $+ HO - NH_2 \xrightarrow{H^+}$ [A] (1)

ii) cyclohexanone + 2,4-dinitrophenylhydrazine $(H_2N - NH - C_6H_3(NO_2)_2) \rightarrow$ [B] (1)

iii) benzene-1,2-dicarboxylic acid (phthalic acid) $+ NH_3 \rightarrow$ [A] $\xrightarrow[-H_2O]{\Delta}$ [B] (2)

Correct Answer: —

Solution:

Concept: The carbonyl group of aldehydes and ketones reacts with ammonia derivatives $H_2N - Z$ by nucleophilic addition followed by loss of water, giving $> C = N - Z$ products; carboxylic acids form amides with ammonia.

i) Cyclopentanone + hydroxylamine ($HO - NH_2$), H+:

Hydroxylamine adds across the C=O and water is eliminated, giving the oxime.

Product [A] = **cyclopentanone oxime**, $C_5H_8 = N - OH$ (cyclopentanone oxime).

$$\text{cyclopentanone} + H_2N - OH \rightarrow \text{cyclopentanone oxime} + H_2O$$

ii) Cyclohexanone + 2,4-dinitrophenylhydrazine (2,4-DNP):
The reagent adds to C=O and loses water to give the hydrazone.
Product [B] = **cyclohexanone 2,4-dinitrophenylhydrazone**, $C_6H_{10} = N - NH - C_6H_3(NO_2)_2$ (an orange-yellow solid, a test for the carbonyl group).

iii) Phthalic acid (benzene-1,2-dicarboxylic acid) + NH_3, then heat:
Step 1: The two $-COOH$ groups react with ammonia to form the ammonium salt.
Product [A] = **ammonium phthalate** (diammonium salt of phthalic acid).
Step 2: On strong heating this salt loses water (and NH_3) and cyclises through the ortho carboxyl groups.
Product [B] = **phthalimide** (benzene-1,2-dicarboximide), a five-membered cyclic imide fused to the benzene ring.

$$\boxed{[A] = \text{ammonium phthalate}, \quad [B] = \text{phthalimide}}$$

Quick Tip: Ketone + NH_2OH gives an oxime; ketone + 2,4-DNP gives a 2,4-dinitrophenylhydrazone; phthalic acid + NH_3 then heat gives phthalimide via the ammonium salt.

22. i) Explain the Hell-Volhard-Zelinsky reaction with example. (2)
ii) Explain the Hofmann bromamide degradation reaction with example. (2)

Correct Answer: —

Solution:

i) Hell-Volhard-Zelinsky (HVZ) reaction:

Concept: Carboxylic acids that possess an α-hydrogen atom react with chlorine or bromine in the presence of a small amount of **red phosphorus** to give α-halogenated carboxylic acids. Only the α-hydrogen is replaced by the halogen.

Example: Ethanoic (acetic) acid with chlorine and red P gives chloroacetic acid.

$$CH_3COOH + Cl_2 \xrightarrow{\text{red P}} ClCH_2COOH + HCl$$

(α-chloroacetic acid). Excess halogen can give di- and tri-halogenated acids.

ii) Hofmann bromamide degradation reaction:

Concept: When an aliphatic or aromatic **primary amide** is treated with **bromine and an aqueous (or ethanolic) solution of NaOH/KOH**, it is converted to a **primary amine containing one carbon atom less** than the starting amide. The carbon of the $-CONH_2$ group is lost as carbonate.

Example: Acetamide gives methanamine (methylamine).

$$CH_3CONH_2 + Br_2 + 4NaOH \rightarrow CH_3NH_2 + 2NaBr + Na_2CO_3 + 2H_2O$$

HVZ: α-halo acid; Hofmann: amine with one C less

Quick Tip: HVZ: carboxylic acid with an alpha-H plus X_2 and red phosphorus gives an alpha-halo acid. Hofmann bromamide: primary amide plus Br_2 and NaOH gives a primary amine with one carbon less.

23. What are nucleic acids? Explain the difference between DNA and RNA and state their two important biological functions.

OR

How can vitamins be classified? Write the name of a fat soluble vitamin. Which vitamin is responsible for blood clotting?

Correct Answer: —

Solution:

Option 1:

Step 1: What are nucleic acids? Nucleic acids are long-chain biomolecules (polynucleotides) found mainly in the nucleus of living cells. They are polymers made of repeating units called nucleotides. Each nucleotide is built from three parts: a nitrogen-containing base, a pentose sugar and a phosphate group. The two nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

Step 2: Difference between DNA and RNA.

(a) Sugar: DNA contains 2-deoxy-D-ribose, whereas RNA contains D-ribose.

(b) Bases: DNA has adenine, guanine, cytosine and thymine, while in RNA thymine is replaced by uracil (adenine, guanine, cytosine and uracil).

(c) Structure: DNA is a double-stranded helix, whereas RNA is usually single-stranded.

(d) Occurrence and role: DNA is the store of genetic information,

while RNA mainly takes part in protein synthesis.

Step 3: Two important biological functions.

(i) DNA is responsible for heredity, that is, the transfer of genetic characters from one generation to the next through the process of replication.

(ii) Nucleic acids (acting through the different RNA molecules) control the synthesis of proteins in the cell.

Option 2:

Step 1: Classification of vitamins. On the basis of their solubility, vitamins are divided into two groups.

(a) Fat-soluble vitamins: vitamins A, D, E and K. They dissolve in fats and oils and are stored in the liver and in adipose (fat) tissue.

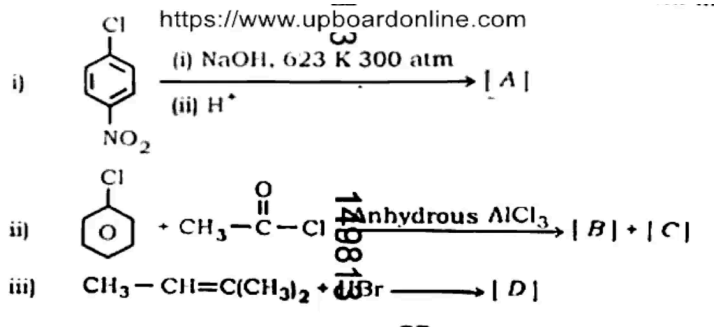
(b) Water-soluble vitamins: the B-group vitamins (B_1, B_2, B_6, B_{12} and others) and vitamin C. They dissolve in water, are not stored in the body and must be supplied regularly through the diet.

Step 2: A fat-soluble vitamin. Example: Vitamin A (retinol). Vitamins D, E and K are also fat soluble.

Step 3: Vitamin responsible for blood clotting. Vitamin K is responsible for the clotting (coagulation) of blood.

Quick Tip: For Option 1, recall that a nucleotide is base plus sugar plus phosphate, and that DNA has deoxyribose and thymine while RNA has ribose and uracil. For Option 2, classify vitamins by their solubility and remember that Vitamin K aids blood clotting.

24.



Write the product of the following reactions along with their mechanism:

i) p-nitrochlorobenzene + NaOH (623 K, 300 atm), then $H^+ \rightarrow$ [A]

ii) Chlorobenzene + CH_3COCl (anhydrous $AlCl_3$) $\rightarrow$ [B] + [C]

iii) CH_3–CH=$C(CH_3)_2$ + HBr $\rightarrow$ [D]

OR

Write short notes on the following: i) D.D.T. ii) Freon iii) Carbon tetrachloride

Correct Answer: —

Solution:

Option 1:

Step 1: Reaction (i) product. Plain chlorobenzene needs very drastic conditions (NaOH, 623 K, 300 atm) for the chlorine to be replaced by an OH group. When a strong electron-withdrawing group such as NO_2 is present at the ortho or para position, this replacement becomes much easier. Here the para nitro group activates the ring, so the product [A] after acidification is **p-nitrophenol (4-nitrophenol)**.

Mechanism (nucleophilic aromatic substitution, addition-elimination): The hydroxide ion OH^- attacks the carbon that carries the Cl atom, giving a negatively charged intermediate (a carbanion / Meisenheimer complex). This negative charge is spread out by

resonance and is stabilised mainly by the para NO_2 group. In the next step the chloride ion Cl^- leaves and the ring becomes aromatic again, giving sodium p-nitrophenoxide. On treatment with H^+ this gives p-nitrophenol.

Step 2: Reaction (ii) products. This is a Friedel-Crafts acylation. Anhydrous $AlCl_3$ reacts with acetyl chloride to form the acylium ion CH_3CO^+. In chlorobenzene the Cl atom is an ortho/para directing group, so the two products [B] and [C] are **p-chloroacetophenone (major)** and **o-chloroacetophenone (minor)**.

Mechanism (electrophilic aromatic substitution): (1) $CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$, forming the electrophile. (2) The acylium ion attacks the benzene ring at the position ortho or para to Cl, giving a resonance-stabilised arenium ion (carbocation). (3) Loss of H^+ restores aromaticity and regenerates $AlCl_3$, giving chloroacetophenone.

Step 3: Reaction (iii) product. The alkene $CH_3CH{=}C(CH_3)_2$ is 2-methylbut-2-ene. Since no peroxide is present, HBr adds by Markovnikov rule. Product [D] = **2-bromo-2-methylbutane**, that is $(CH_3)_2CBr–CH_2–CH_3$.

Mechanism (electrophilic addition): The H^+ of HBr adds to the $=CH$ carbon (the one already bearing more hydrogens), so the positive charge appears on the $C(CH_3)_2$ carbon, which is a tertiary (3 degree) carbocation and hence the most stable. The bromide ion Br^- then attacks this tertiary carbon to give the Markovnikov product.

Option 2:

Step 1: D.D.T. D.D.T. is p,p'-dichlorodiphenyltrichloroethane. It was the first chlorinated organic insecticide, prepared by reacting chlorobenzene with chloral (trichloroacetaldehyde) in the presence of

concentrated H_2SO_4. It is very effective against mosquitoes and lice, but it is stable and non-biodegradable and gets stored in fatty tissues, so its use is now banned or restricted in many countries.

Step 2: Freon. Freons are the common name for chlorofluorocarbons (CFCs), gaseous compounds of carbon with chlorine and fluorine. The most common one is Freon-12 (CCl_2F_2), prepared from CCl_4 and HF in the presence of $SbF_3/SbCl_5$. Freons are used as refrigerants in fridges and air conditioners and as propellants in aerosol sprays. In the upper atmosphere they release Cl atoms which destroy the ozone layer.

Step 3: Carbon tetrachloride. CCl_4 (tetrachloromethane) is a colourless, heavy, non-inflammable liquid used as an industrial solvent for oils and fats, in fire extinguishers (Pyrene) and formerly in dry cleaning. Its vapour is toxic and can cause liver damage, on heating in air it forms poisonous phosgene gas ($COCl_2$), and it also contributes to ozone depletion.

Quick Tip: For Option 1: the para NO2 group activates chlorobenzene toward nucleophilic substitution (gives p-nitrophenol), CH3COCl with AlCl3 is Friedel-Crafts acylation giving o- and p-chloroacetophenone, and HBr without peroxide follows Markovnikov rule. For Option 2: DDT is an insecticide, Freon is a CFC refrigerant, and CCl4 is a solvent and fire-extinguisher liquid.

25. If 2 g of benzoic acid is dissolved in 25 g of benzene, its depression in freezing point was found to be 1.62 K. Molal depression constant of benzene is 4.9 K kg mol^{-1}. If benzoic acid forms a dimer in this solution, what will be the percentage association of benzoic acid? (5)

OR

A 200 cm^3 aqueous solution of a protein contains 1.26 g of protein. The osmotic pressure of this solution at 300 K is 2.57×10^{-3} bar. Calculate the molar mass of this protein. (5)

Correct Answer: —

Solution:

Option 1 (Benzoic acid dimer):

Step 1 (Concept): Depression in freezing point is a colligative property, $\Delta T_f = i K_f m$, where i is the van't Hoff factor and m is molality. When solute molecules associate (form a dimer), $i < 1$.

Step 2 (Molar mass of benzoic acid): C_6H_5COOH has molar mass $= 122$ g mol^{-1}.

Step 3 (Molality): moles $= \frac{2}{122} = 0.01639$ mol; molality m $= \frac{0.01639}{0.025\ \text{kg}} = 0.6557$ mol kg^{-1}.

Step 4 (Theoretical depression, no association): $\Delta T_f(\text{calc}) = K_f m$ $= 4.9 \times 0.6557 = 3.213$ K.

Step 5 (van't Hoff factor): $i = \frac{\Delta T_f(\text{obs})}{\Delta T_f(\text{calc})} = \frac{1.62}{3.213} = 0.504$.

Step 6 (Association relation): For dimerisation $2A \rightarrow A_2$, if α is the degree of association, $i = 1 - \frac{\alpha}{2}$. So $\alpha = 2(1 - i) = 2(1 - 0.504)$ $= 0.992$.

Step 7 (Percentage association):

$$\boxed{\alpha = 99.2\%}$$

Option 2 (Molar mass of protein):

Step 1 (Concept): Osmotic pressure $\pi = \frac{n}{V}RT = \frac{w}{MV}RT$, so $M = \frac{wRT}{\pi V}$.

Step 2 (Data): $w = 1.26$ g, $V = 200\ \text{cm}^3 = 0.200$ L, $R = 0.083$ L bar $\text{K}^{-1}\ \text{mol}^{-1}$, $T = 300$ K, $\pi = 2.57 \times 10^{-3}$ bar.

Step 3 (Substitution): $M = \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times 0.200}$.

Step 4 (Arithmetic): Numerator $= 31.374$; Denominator $= 5.14 \times 10^{-4}$; $M = 61039$ g mol^{-1}.

Step 5 (Result):

$$\boxed{M \approx 6.1 \times 10^4\ \text{g mol}^{-1}}$$

Quick Tip: Option 1: find the van't Hoff factor i from $\Delta T_f = iK_f m$, then use $i = 1 - \alpha/2$ for dimerisation. Option 2: use $M = wRT/\pi V$ with R = 0.083 L bar $\text{K}^{-1}\text{mol}^{-1}$.

26. How would you convert:

i) Ethanoic acid to methanamine? (1)

ii) Aniline to 2,4,6-tribromoaniline? (1)

iii) Aniline to benzene diazonium chloride? (1)

iv) Aniline to phenyl isocyanide? (1)

v) Chlorobenzene to chlorobenzene sulphonic acid? (1)

OR

i) Write four chemical equations for the methods of preparation of aniline. (1+1+1+1)

ii) Write the chemical equation of any one method for the preparation of chlorobenzene. (1)

Correct Answer: —

Solution:

Option 1 (Conversions):

i) Ethanoic acid → methanamine: First convert the acid to its amide, then apply Hofmann bromamide degradation (which removes one carbon).

$$CH_3COOH + NH_3 \rightarrow CH_3COONH_4 \xrightarrow{\Delta} CH_3CONH_2 + H_2O$$

$$CH_3CONH_2 + Br_2 + 4NaOH \rightarrow CH_3NH_2 + 2NaBr + Na_2CO_3 + 2H_2O$$

The product methanamine CH_3NH_2 has one carbon less than acetamide.

ii) Aniline → 2,4,6-tribromoaniline: The $-NH_2$ group is strongly activating and o/p-directing, so aniline reacts with bromine water at all ortho and para positions.

$$C_6H_5NH_2 + 3Br_2 \rightarrow C_6H_2Br_3NH_2 + 3HBr$$

(2,4,6-tribromoaniline, white precipitate).

iii) Aniline → benzene diazonium chloride: Diazotisation with nitrous acid ($NaNO_2 + HCl$) at 273-278 K.

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

iv) Aniline → phenyl isocyanide: Carbylamine reaction of a primary amine with chloroform and alcoholic KOH.

$$C_6H_5NH_2 + CHCl_3 + 3KOH \xrightarrow{\Delta} C_6H_5NC + 3KCl + 3H_2O$$

v) Chlorobenzene → chlorobenzene sulphonic acid: Sulphonation with concentrated (fuming) sulphuric acid substitutes mainly at the para position.

$$C_6H_5Cl + H_2SO_4(\text{conc.}) \rightarrow ClC_6H_4SO_3H + H_2O$$

(p-chlorobenzenesulphonic acid).

Option 2:

i) Four preparations of aniline:

1) Reduction of nitrobenzene with tin and HCl:

$$C_6H_5NO_2 + 6[H] \xrightarrow{Sn/HCl} C_6H_5NH_2 + 2H_2O$$

2) Reduction of nitrobenzene with iron and HCl:

$$C_6H_5NO_2 + 6[H] \xrightarrow{Fe/HCl} C_6H_5NH_2 + 2H_2O$$

3) Catalytic hydrogenation of nitrobenzene:

$$C_6H_5NO_2 + 3H_2 \xrightarrow{Ni} C_6H_5NH_2 + 2H_2O$$

4) Hofmann bromamide degradation of benzamide:

$$C_6H_5CONH_2 + Br_2 + 4NaOH \rightarrow C_6H_5NH_2 + 2NaBr + Na_2CO_3 + 2H_2O$$

ii) One preparation of chlorobenzene: Chlorination of benzene in presence of anhydrous $AlCl_3$ (Lewis acid catalyst):

$$C_6H_6 + Cl_2 \xrightarrow{\text{anhyd. } AlCl_3} C_6H_5Cl + HCl$$

Quick Tip: Conversions: use Hofmann degradation (acid→amide→amine, one C less), bromine water for tribromoaniline, cold NaNO2/HCl for diazotisation, CHCl3 + KOH for carbylamine, and fuming H2SO4 for sulphonation. Aniline prep: reduce nitrobenzene (Sn/Fe/HCl or H2/Ni).