AIIMS Paramedical Chemistry

Sample Paper – 6

Duration: 30 Minutes **Maximum Marks: 30**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer), modelled on the Chemistry portion of **AIIMS Paramedical** entrance.
- Each correct answer carries **+1 mark**. A penalty of $-\frac{1}{3}$ **mark** is deducted for each incorrect answer. Unattempted questions carry **0** marks (no negative marking).
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 NCERT Chemistry**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. When 5.4 g of aluminium reacts completely with excess oxygen to form aluminium oxide (Al_2O_3), the mass of the oxide formed is (atomic masses: $Al = 27$, $O = 16$):

$$4\,Al + 3\,O_2 \longrightarrow 2\,Al_2O_3$$

(A) 5.1 g

(B) 20.4 g

(C) 10.2 g

(D) 15.3 g

Q2. In a given atom, the maximum number of electrons that can have the quantum numbers $n = 3$ and $\ell = 2$ is:

(A) 6

(B) 10

(C) 2

(D) 14

Q3. The average translational kinetic energy of one mole of an ideal gas at temperature T is given by $\frac{3}{2}RT$. For one mole of an ideal gas at 300 K, this energy is (take $R = 8.314$ J K^{-1}mol^{-1}):

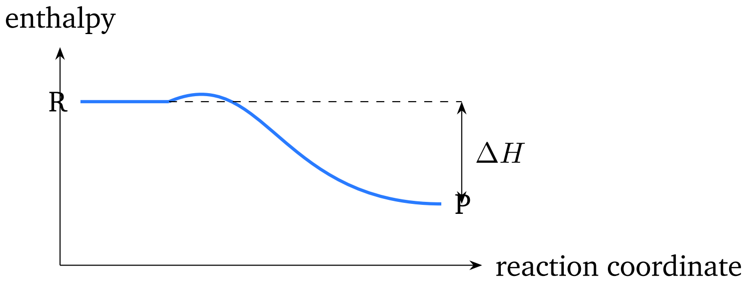
(A) 3741 J

(B) 2494 J

(C) 1247 J

(D) 7482 J

Q4. For a reaction, $\Delta H = -92$ kJ mol^{-1} and $\Delta S = -200$ J K^{-1}mol^{-1}. The reaction is spontaneous ($\Delta G < 0$) below a certain temperature. The energy profile below shows the products lying lower than the reactants. The temperature above which the reaction becomes non-spontaneous is:



(A) 200 K

(B) 92 K

(C) 300 K

(D) 460 K

Q5. For the equilibrium $\mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C} + \mathrm{D}$, the equilibrium constant $K_c = 4$. If 1 mol each of A and B are placed in a 1 L flask, the equilibrium concentration of C is:

(A) 0.67 mol L^{-1}

(B) 0.50 mol L^{-1}

(C) 0.33 mol L^{-1}

(D) 0.80 mol L^{-1}

Q6. An aqueous solution of which of the following salts will be basic (pH > 7) due to hydrolysis?

(A) NH_4Cl

(B) CH_3COONa

(C) NaCl

(D) NH_4NO_3

Q7. In the reaction $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$, the change in the oxidation state of manganese is:

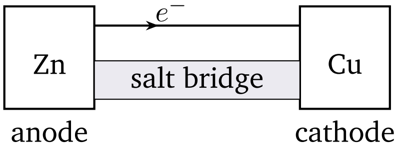
(A) from $+6$ to $+2$

(B) from $+4$ to $+2$

(C) from $+7$ to $+2$

(D) from $+7$ to $+4$

Q8. For a cell reaction involving the transfer of 2 mol of electrons, the standard cell potential is $E^\circ_{\text{cell}} = +1.10$ V. The standard Gibbs free energy change ΔG° for the reaction is (take $F = 96500$ C mol^{-1}):



(A) -106.2 kJ mol^{-1}

(B) $+212.3$ kJ mol^{-1}

(C) -53.1 kJ mol^{-1}

(D) -212.3 kJ mol^{-1}

Q9. A first-order reaction has a rate constant $k = 2.303 \times 10^{-3}$ s^{-1}. The time required for the reactant to reduce to $\frac{1}{10}$ of its initial concentration (i.e. 90% completion) is:

(A) 1000 s

(B) 2303 s

(C) 100 s

(D) 500 s

Q10. When 3.0 g of a non-volatile, non-electrolyte solute is dissolved in 100 g of water, the boiling point is elevated by 0.26 K. The molar mass of the solute is (take K_b of water $= 0.52$ K kg mol^{-1}):

(A) 30 g mol^{-1}

(B) 60 g mol^{-1}

(C) 120 g mol^{-1}

(D) 90 g mol^{-1}

Q11. Which of the following is the correct order of increasing ionic radius for the isoelectronic species Na^+, Mg^{2+}, F^- and O^{2-}?

(A) $O^{2-} < F^- < Na^+ < Mg^{2+}$

(B) $Na^+ < Mg^{2+} < F^- < O^{2-}$

(C) $Mg^{2+} < Na^+ < F^- < O^{2-}$

(D) $F^- < O^{2-} < Na^+ < Mg^{2+}$

Q12. The second ionization enthalpy of an element is always greater than its first ionization enthalpy. The main reason for this is that:

(A) the second electron is removed from a larger atom

(B) nuclear charge decreases after removing the first electron

(C) the second electron experiences less shielding only

(D) the electron is removed from a cation, which holds its electrons more tightly due to a higher effective nuclear charge

Q13. Among the following, the compound that has the highest boiling point owing to intermolecular hydrogen bonding is:

(A) H_2S

(B) H_2O

(C) H_2Se

(D) H_2Te

Q14. According to Fajans' rules, which of the following compounds is expected to have the greatest covalent character?

(A) NaCl

(B) NaBr

(C) $AlCl_3$

(D) $MgCl_2$

Q15. Lithium shows a diagonal relationship and resembles magnesium more than the other alkali metals. Which property of lithium is responsible for this anomalous behaviour?

(A) its very small size and high polarising power (charge/size ratio)

(B) its very low electronegativity

(C) its large atomic radius

(D) its low ionization enthalpy compared with sodium

Q16. Sulphur dioxide (SO_2) acts as a bleaching agent. Its bleaching action is:

(A) permanent and due to oxidation

(B) temporary and due to reduction

(C) permanent and due to reduction

(D) temporary and due to oxidation

Q17. The correct order of oxidising power of the halogens in aqueous solution is:

(A) $I_2 > Br_2 > Cl_2 > F_2$

(B) $Cl_2 > F_2 > Br_2 > I_2$

(C) $Br_2 > Cl_2 > F_2 > I_2$

(D) $F_2 > Cl_2 > Br_2 > I_2$

Q18. The lanthanide contraction is responsible for the fact that:

(A) lanthanides show only the $+2$ oxidation state

(B) the atomic radii increase steadily across the lanthanide series

(C) Zr and Hf have almost identical atomic radii

(D) lanthanides are strongly coloured in all oxidation states

Q19. In an octahedral complex, the five degenerate d-orbitals split into two sets. The colour of a transition-metal complex arises mainly from:

(A) d–d electronic transitions across the crystal-field splitting energy Δ_o

(B) transitions of electrons within the same d-orbital

(C) nuclear transitions in the metal

(D) rotation of the ligand molecules

Q20. Heavy water (D_2O) differs from ordinary water mainly because:

(A) it contains an extra oxygen atom

(B) the hydrogen is replaced by its isotope deuterium, giving it a higher density and boiling point

(C) it contains tritium in place of hydrogen

(D) it has the formula H_2O_2

Q21. The correct order of stability of the following free radicals is:

(A) methyl > primary > secondary > tertiary

(B) primary > secondary > tertiary > methyl

(C) secondary > tertiary > primary > methyl

(D) tertiary > secondary > primary > methyl

Q22. Which of the following pairs of compounds are functional isomers of each other?

CH_3CH_2OH (ethanol) and CH_3-O-CH_3 (dimethyl ether)

(A) propan-1-ol and propan-2-ol

(B) ethanol and dimethyl ether

(C) butane and isobutane

(D) but-1-ene and but-2-ene

Q23. Baeyer's reagent (cold, dilute alkaline $KMnO_4$) is used to test for unsaturation. When an alkene is treated with it, the observation is:

(A) the purple/pink colour is decolourised and a brown precipitate of MnO_2 appears

(B) the solution turns deep blue

(C) a white precipitate forms with no colour change

(D) the solution remains purple, showing no reaction

Q24. The addition of two moles of HBr to propyne ($CH_3\text{-}C\equiv CH$), following Markovnikov's rule, gives as the major product:

(A) $CH_3CHBr\text{-}CH_2Br$ (1,2-dibromopropane)

(B) $CH_2Br\text{-}CH_2\text{-}CH_2Br$

(C) $CH_3\text{-}CBr_2\text{-}CH_3$ (2,2-dibromopropane)

(D) CH_3-CH_2-$CHBr_2$

Q25. An optically active 2-bromobutane (a 3° or 2° halide reacting by S_N1) undergoes hydrolysis through a carbocation intermediate. The product alcohol is:

(A) optically active with retention of configuration only

(B) optically active with inversion of configuration only

(C) optically pure with the same rotation as the reactant

(D) a racemic mixture (optically inactive) due to a planar carbocation intermediate

Q26. When ethanol is heated with acetic acid in the presence of a few drops of concentrated H_2SO_4, the product formed (with its characteristic fruity smell) is:

(A) acetaldehyde

(B) ethyl acetate

(C) diethyl ether

(D) sodium acetate

Q27. Aldehydes are generally more reactive than ketones towards nucleophilic addition reactions. The main reason is:

(A) ketones have two electron-donating alkyl groups that reduce the positive charge on the carbonyl carbon and also cause more steric hindrance

(B) aldehydes have a higher molar mass

(C) ketones have a more electrophilic carbonyl carbon

(D) aldehydes do not contain a carbonyl group

Q28. In the acid-catalysed Fischer esterification of a carboxylic acid with an alcohol, the oxygen atom of the water molecule that is eliminated comes from:

(A) the alcohol's -OH group

(B) the catalyst H_2SO_4

(C) the -OH group of the carboxylic acid

(D) the carbonyl (C$=$O) oxygen of the acid

Q29. The carbylamine reaction (heating with chloroform and alcoholic KOH to give a foul-smelling isocyanide) is a test that is given by:

(A) secondary amines only

(B) tertiary amines only

(C) both secondary and tertiary amines

(D) primary amines only

Q30. The deficiency of which vitamin causes the disease scurvy?

(A) Vitamin A

(B) Vitamin C

(C) Vitamin D

(D) Vitamin K

Detailed Solutions

Q1.

Solution

Concept — Stoichiometry by mole ratio: The balanced equation fixes the ratio between moles of reactant and moles of product. Convert the given mass to moles, apply the mole ratio, then convert back to mass.

Step 1 — Moles of aluminium: The molar mass of Al is 27 g mol^{-1}.

$$n_{\text{Al}} = \frac{5.4}{27} = 0.2 \text{ mol}.$$

Step 2 — Apply the mole ratio: From $4\,\text{Al} \to 2\,\text{Al}_2\text{O}_3$, the ratio is $4 : 2 = 2 : 1$.

$$n_{\text{Al}_2\text{O}_3} = \frac{0.2}{2} = 0.1 \text{ mol}.$$

Step 3 — Mass of the oxide: The molar mass of Al_2O_3 is $2(27)+3(16) = 54+48 = 102$ g mol^{-1}.

$$m = 0.1 \times 102 = 10.2 \text{ g}.$$

Why other options are wrong:

- (A) 5.1 g halves the correct value (wrong mole ratio).
- (B) 20.4 g uses a $1 : 1$ ratio of Al to oxide.
- (D) 15.3 g comes from a $4 : 3$ ratio slip.

Final Answer: Mass of $\text{Al}_2\text{O}_3 = 10.2$ g $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 1

Q2.

Solution

Concept — Quantum numbers and orbital occupancy: The pair $n = 3,\ \ell = 2$ specifies the $3d$ subshell. A subshell with azimuthal quantum number ℓ contains $(2\ell + 1)$ orbitals, and each orbital holds at most 2 electrons.

Step 1 — Identify the subshell: $\ell = 2$ corresponds to a d subshell, so $n = 3,\ \ell = 2$ is the $3d$ subshell.

Step 2 — Number of orbitals:

$$\text{orbitals} = 2\ell + 1 = 2(2) + 1 = 5.$$

Step 3 — Maximum electrons:

$$\text{electrons} = 2 \times 5 = 10.$$

Why other options are wrong:

- (A) 6 is the capacity of a p subshell ($\ell = 1$).
- (C) 2 is the capacity of a single orbital (s subshell).
- (D) 14 is the capacity of an f subshell ($\ell = 3$).

Final Answer: Maximum electrons $= 10 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 2

Q3.

Solution

Concept — Kinetic energy of an ideal gas: For one mole of an ideal gas, the average translational kinetic energy depends only on the absolute temperature and is given by $E = \frac{3}{2}RT$.

Step 1 — Write the formula and insert values: $R = 8.314\,\text{J K}^{-1}\text{mol}^{-1}$, $T = 300\,\text{K}$.

$$E = \frac{3}{2} \times 8.314 \times 300.$$

Step 2 — Multiply step by step:

$$8.314 \times 300 = 2494.2.$$

Step 3 — Apply the factor $\frac{3}{2}$:

$$E = \frac{3}{2} \times 2494.2 = 3741.3 \approx 3741 \text{ J}.$$

Why other options are wrong:

- (B) 2494 J omits the $\frac{3}{2}$ factor (this is RT).

- (C) 1247 J uses $\frac{1}{2}RT$.
- (D) 7482 J doubles the correct value.

Final Answer: $E \approx 3741$ J $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 3

Q4.

Solution

Concept — Gibbs free energy and spontaneity: A reaction is spontaneous when $\Delta G = \Delta H - T\Delta S < 0$. When both ΔH and ΔS are negative, the reaction is spontaneous only below the temperature where $\Delta G = 0$.

Step 1 — Set $\Delta G = 0$ at the crossover temperature:

$$\Delta H - T\Delta S = 0 \;\Rightarrow\; T = \frac{\Delta H}{\Delta S}.$$

Step 2 — Convert units consistently: $\Delta H = -92$ kJ $= -92000$ J, $\Delta S = -200$ J K^{-1}.

$$T = \frac{-92000}{-200}.$$

Step 3 — Evaluate:

$$T = 460 \text{ K}.$$

Above 460 K the $-T\Delta S$ term (positive, since $\Delta S < 0$) outweighs ΔH, making $\Delta G > 0$.

Why other options are wrong:

- (A) and (C) ignore the unit conversion of ΔH from kJ to J.
- (B) 92 K uses the bare numbers without the factor of 1000.

Final Answer: $T = 460$ K $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 4

Q5.

Solution

Concept — Equilibrium concentration from K_c: Set up an ICE table with extent of reaction x, write K_c in terms of x, and solve.

Step 1 — ICE table: Start with $[\text{A}] = [\text{B}] = 1$, $[\text{C}] = [\text{D}] = 0$. Let x react.

$$[\text{A}] = [\text{B}] = 1 - x, \qquad [\text{C}] = [\text{D}] = x.$$

Step 2 — Write the equilibrium expression:

$$K_c = \frac{[\text{C}][\text{D}]}{[\text{A}][\text{B}]} = \frac{x^2}{(1-x)^2} = 4.$$

Step 3 — Take the square root and solve:

$$\frac{x}{1-x} = 2 \;\Rightarrow\; x = 2(1-x) = 2 - 2x \;\Rightarrow\; 3x = 2 \;\Rightarrow\; x = \frac{2}{3} \approx 0.67.$$

Thus $[\text{C}] = 0.67$ mol L^{-1}.

Why other options are wrong:

- (B) 0.50 would correspond to $K_c = 1$.
- (C) 0.33 is $(1 - x)$, the leftover reactant, not C.
- (D) 0.80 overshoots the equilibrium extent.

Final Answer: $[\text{C}] = 0.67$ mol $\text{L}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 5

Q6.

Solution

Concept — Salt hydrolysis and pH: A salt of a weak acid and a strong base hydrolyses to give a basic solution (pH > 7); a salt of a strong acid and weak base gives an acidic solution; a salt of a strong acid and strong base is neutral.

Step 1 — Classify each salt:

- CH_3COONa: weak acid (CH_3COOH) + strong base (NaOH) $\Rightarrow$ basic.
- NH_4Cl and NH_4NO_3: weak base (NH_4OH) + strong acid $\Rightarrow$ acidic.
- NaCl: strong acid + strong base $\Rightarrow$ neutral.

Step 2 — Identify the basic salt: The acetate ion hydrolyses:

$$\mathrm{CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-}.$$

The released $\mathrm{OH^-}$ makes the solution basic.

Why other options are wrong:

- (A) and (D) give acidic solutions ($\mathrm{pH} < 7$).
- (C) NaCl is neutral ($\mathrm{pH} = 7$).

Final Answer: $\mathrm{CH_3COONa}$ gives a basic solution $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q 6

Q7.

Solution

Concept — Oxidation state of Mn: Assign oxidation numbers using the rules that O is -2 and the overall charge of the species equals the sum of oxidation states.

Step 1 — Mn in $\mathrm{MnO_4^-}$: Let the oxidation state of Mn be x. With four O at -2 and a net charge of -1:

$$x + 4(-2) = -1 \;\Rightarrow\; x - 8 = -1 \;\Rightarrow\; x = +7.$$

Step 2 — Mn in $\mathrm{Mn^{2+}}$: The oxidation state equals the ionic charge:

$$x = +2.$$

Step 3 — State the change: Mn goes from $+7$ to $+2$, a gain of 5 electrons (reduction), consistent with the $5e^-$ in the half-reaction.

Why other options are wrong:

- (A) and (B) assign the wrong initial state to Mn.
- (D) ends at $+4$, which would correspond to $\mathrm{MnO_2}$, not $\mathrm{Mn^{2+}}$.

Final Answer: Mn changes from $+7$ to $+2 \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q 7

Q8.

Solution

Concept — Free energy and cell potential: The maximum useful work from a cell is related to its EMF by $\Delta G^\circ = -nFE^\circ_{\text{cell}}$, where n is the number of moles of electrons transferred and F is the Faraday constant.

Step 1 — Write the relation and insert values: $n = 2$, $F = 96500$ C mol^{-1}, $E^\circ = +1.10$ V.

$$\Delta G^\circ = -nFE^\circ = -(2)(96500)(1.10).$$

Step 2 — Multiply:

$$2 \times 96500 = 193000; \qquad 193000 \times 1.10 = 212300 \text{ J mol}^{-1}.$$

Step 3 — Convert to kJ and apply the sign:

$$\Delta G^\circ = -212300 \text{ J mol}^{-1} = -212.3 \text{ kJ mol}^{-1}.$$

The negative sign confirms a spontaneous cell reaction.

Why other options are wrong:

- (A) -106.2 uses $n = 1$ instead of 2.
- (B) $+212.3$ has the wrong sign (drops the minus).
- (C) -53.1 mis-scales by a factor of four.

Final Answer: $\Delta G^\circ = -212.3$ kJ mol^{-1} $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 8

Q9.

Solution

Concept — Integrated first-order rate law: For a first-order reaction, $t = \dfrac{2.303}{k} \log \dfrac{[\text{A}]_0}{[\text{A}]}$.

Step 1 — Set up the ratio: For 90% completion, $[\text{A}] = \frac{1}{10}[\text{A}]_0$, so

$$\frac{[\text{A}]_0}{[\text{A}]} = 10.$$

Step 2 — Substitute into the formula:

$$t = \frac{2.303}{k}\log 10 = \frac{2.303}{2.303 \times 10^{-3}} \times 1.$$

Step 3 — Evaluate (note $\log 10 = 1$):

$$t = \frac{1}{10^{-3}} = 1000 \text{ s}.$$

Why other options are wrong:

- (B) 2303 s forgets to cancel the 2.303 factor.
- (C) 100 s misplaces a power of ten.
- (D) 500 s would correspond to a different fraction.

Final Answer: $t = 1000$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 9

Q10.

Solution

Concept — Elevation of boiling point: The boiling-point elevation is $\Delta T_b = K_b\, m$, where m is the molality. Writing molality in terms of the unknown molar mass M lets us solve for M.

Step 1 — Express molality: With mass of solute $w = 3.0$ g and mass of solvent $W = 100 \text{ g} = 0.1$ kg,

$$m = \frac{w/M}{W(\text{in kg})} = \frac{3.0/M}{0.1}.$$

Step 2 — Substitute into $\Delta T_b = K_b m$:

$$0.26 = 0.52 \times \frac{3.0/M}{0.1} = 0.52 \times \frac{30}{M}.$$

Step 3 — Solve for M:

$$M = \frac{0.52 \times 30}{0.26} = \frac{15.6}{0.26} = 60 \text{ g mol}^{-1}.$$

Why other options are wrong:

- (A) 30 forgets to convert the solvent mass to kg correctly.

- (C) 120 doubles the molality term.
- (D) 90 comes from an arithmetic slip.

Final Answer: $M = 60\ \text{g mol}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 10

Q11.

Solution

Concept — Size of isoelectronic species: All four ions have 10 electrons. For isoelectronic species, the radius decreases as the nuclear charge (atomic number Z) increases, because a greater nuclear charge pulls the same number of electrons more tightly.

Step 1 — List the nuclear charges:

$$\text{O}^{2-}(Z = 8),\ \text{F}^{-}(Z = 9),\ \text{Na}^{+}(Z = 11),\ \text{Mg}^{2+}(Z = 12).$$

Step 2 — Rank by increasing Z (= decreasing radius): Larger Z means smaller ion, so increasing radius follows decreasing Z:

$$\text{Mg}^{2+} < \text{Na}^{+} < \text{F}^{-} < \text{O}^{2-}.$$

Step 3 — Match to the options: The smallest is Mg^{2+} and the largest is O^{2-}, exactly option (C).

Why other options are wrong:

- (A) reverses the trend (largest Z shown as largest ion).
- (B) and (D) jumble the order of charges.

Final Answer: $\text{Mg}^{2+} < \text{Na}^{+} < \text{F}^{-} < \text{O}^{2-} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 11

Q12.

Solution

Concept — Successive ionization enthalpies: Removing an electron from a positively charged ion is harder than removing it from a neutral atom, because the cation has a higher effective nuclear charge per remaining electron.

Step 1 — Compare the two steps: The first ionization removes an electron from a neutral atom; the second removes an electron from a $+1$ cation.

Step 2 — Effect of fewer electrons: In the cation the same nuclear charge now holds fewer electrons, so each remaining electron is attracted more strongly. Electron–electron repulsion also drops.

Step 3 — Conclusion: The increased effective nuclear charge makes the second electron much harder to remove, so $\text{IE}_2 > \text{IE}_1$ always.

Why other options are wrong:

- (A) is false: the cation is smaller, not larger.
- (B) is false: nuclear charge (proton number) does not change.
- (C) is incomplete; the dominant cause is the higher effective nuclear charge of the cation.

Final Answer: The electron is removed from a cation with higher effective nuclear charge $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q 12**

Q13.

Solution

Concept — Hydrogen bonding and boiling point: Hydrogen bonding occurs when H is bonded to the small, highly electronegative atoms N, O or F. It raises boiling points sharply above what molecular mass alone would predict.

Step 1 — Examine the hydrides of Group 16: H_2S, H_2Se and H_2Te have only weak van der Waals forces; their boiling points rise with molar mass.

Step 2 — Recognise the anomaly of water: In H_2O, the small, highly electronegative oxygen forms strong intermolecular hydrogen bonds, giving an abnormally high boiling point ($100°C$).

Step 3 — Compare: Despite its low molar mass, H_2O boils far higher than H_2S, H_2Se and H_2Te.

Why other options are wrong:

- (A), (C), (D): S, Se and Te are not electronegative enough to form hydrogen bonds.

Final Answer: H_2O has the highest boiling point $\Rightarrow \boxed{B}$

$\boxed{\textbf{Answer: (B)}}$ Go Back to Q 13

Q14.

Solution

Concept — Fajans' rules: Covalent character increases with (i) a smaller, more highly charged cation (greater polarising power) and (ii) a larger, more polarisable anion.

Step 1 — Compare the cations: Al^{3+} has a high charge ($+3$) and a very small size, giving it the greatest polarising power among Na^+, Mg^{2+} and Al^{3+}.

Step 2 — Effect on the anion: The strongly polarising Al^{3+} distorts the chloride electron cloud the most, producing the greatest covalent character.

Step 3 — Conclusion: Therefore $AlCl_3$ is the most covalent of the listed compounds.

Why other options are wrong:

- (A) NaCl and (B) NaBr have a large, low-charge Na^+ (mostly ionic).
- (D) $MgCl_2$ is more covalent than NaCl but less than $AlCl_3$ because Mg^{2+} polarises less than Al^{3+}.

Final Answer: $AlCl_3$ has the greatest covalent character $\Rightarrow \boxed{C}$

$\boxed{\textbf{Answer: (C)}}$ Go Back to Q 14

Q15.

Solution

Concept — Anomalous behaviour of lithium: The first member of a group often differs from the rest because of its very small size and high charge-to-size ratio (polarising power). This is the basis of lithium's diagonal relationship with magnesium.

Step 1 — Identify the key property: Among the alkali metals, Li^+ is the smallest cation, so it has the highest charge density and polarising power.

Step 2 — Link to diagonal relationship: The polarising power of Li^+ is close to that of Mg^{2+}, which is why their compounds (covalent character, solubility, thermal stability) resemble each other.

Step 3 — Conclusion: The small size and high polarising power of Li^+ cause lithium's anomalous, magnesium-like behaviour.

Why other options are wrong:

- (B) and (D): lithium actually has a relatively high ionization enthalpy among alkali metals, but that is not the cause of the diagonal relationship.
- (C) is false; lithium has the smallest atomic radius in its group.

Final Answer: Small size and high polarising power of $Li^+ \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q 15

Q16.

Solution

Concept — Bleaching action of SO_2: SO_2 bleaches by reduction. In the presence of moisture it produces nascent hydrogen, which reduces coloured substances to colourless products.

Step 1 — The reducing action:

$$SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2[H].$$

The nascent hydrogen reduces the colouring matter.

Step 2 — Why the colour returns: The bleaching is temporary because the reduced (colourless) material is slowly re-oxidised by air (atmospheric oxygen), restoring the original colour.

Step 3 — Conclusion: The action is temporary and due to reduction (contrast with chlorine, which bleaches permanently by oxidation).

Why other options are wrong:

- (A) and (D): SO_2 does not bleach by oxidation.
- (C): the action is reduction-based but it is temporary, not permanent.

Final Answer: Temporary bleaching due to reduction $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q 16

Q17.

Solution

Concept — Oxidising power of halogens: Oxidising power is the tendency to gain electrons (to be reduced). In aqueous solution it decreases down the group: $\mathrm{F_2} > \mathrm{Cl_2} > \mathrm{Br_2} > \mathrm{I_2}$.

Step 1 — Recall the standard reduction potentials: The E° values for X_2/X^- fall from fluorine to iodine, so fluorine is the strongest oxidant and iodine the weakest.

Step 2 — Account for the displacement reactions: A halogen higher in this order displaces a halide ion of one lower; e.g. $\mathrm{Cl_2}$ displaces $\mathrm{Br^-}$ and $\mathrm{I^-}$.

Step 3 — State the order:

$$\mathrm{F_2} > \mathrm{Cl_2} > \mathrm{Br_2} > \mathrm{I_2}.$$

Why other options are wrong:

- (A) completely reverses the trend.
- (B) and (C) wrongly place $\mathrm{F_2}$ below $\mathrm{Cl_2}$ or $\mathrm{Br_2}$.

Final Answer: $\mathrm{F_2} > \mathrm{Cl_2} > \mathrm{Br_2} > \mathrm{I_2} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q 17

Q18.

Solution

Concept — Lanthanide contraction: The steady decrease in atomic and ionic size across the lanthanide series, caused by poor shielding by $4f$ electrons, is called the lanthanide contraction.

Step 1 — Cause: As atomic number rises across the $4f$ series, the added $4f$ electrons shield the nuclear charge poorly, so the effective nuclear charge felt by the outer electrons increases and the radius shrinks.

Step 2 — Consequence for the next transition series: The contraction almost exactly offsets the expected size increase from the 4d to the 5d series. As a result, the second (Zr) and third (Hf) row transition metals of the same group have nearly identical radii.

Step 3 — Conclusion: Zr and Hf have almost identical atomic radii because of the lanthanide contraction (hence they are chemically very similar).

Why other options are wrong:

- (A) the common oxidation state is $+3$, unrelated to the contraction.
- (B) is the opposite of the truth; radii decrease across the series.
- (D) colour arises from f–f transitions, not from the contraction.

Final Answer: Zr and Hf have almost identical radii $\Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q 18**

Q19.

Solution

Concept — Crystal-field theory and colour: In an octahedral field the d-orbitals split into a lower t_{2g} set and a higher e_g set separated by the crystal-field splitting energy Δ_o. Light of energy equal to Δ_o promotes an electron between these sets.

Step 1 — The transition: An electron absorbs a photon and jumps from the t_{2g} level to the e_g level; this is a d–d transition.

Step 2 — Origin of colour: The wavelength absorbed corresponds to Δ_o; the complementary colour is transmitted/reflected, which we observe.

Step 3 — Conclusion: The colour arises from d–d electronic transitions across Δ_o.

Why other options are wrong:

- (B) transitions occur between the split d sets, not within one orbital.
- (C) nuclear transitions involve far higher (gamma-ray) energies.
- (D) ligand rotation is unrelated to visible colour.

Final Answer: d–d transitions across $\Delta_o \Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q 19**

Q20.

Solution

Concept — Heavy water: Heavy water is deuterium oxide, D_2O, in which both ordinary hydrogen atoms (^1H) are replaced by the heavier isotope deuterium (^2H or D).

Step 1 — Composition: The oxygen is unchanged; only the hydrogen isotope differs. Deuterium has one proton and one neutron, doubling the mass of each hydrogen.

Step 2 — Resulting properties: Because deuterium is heavier, D_2O has a higher density (≈ 1.106 g cm^{-3}), a higher boiling point ($101.4°$C) and a higher freezing point ($3.8°$C) than ordinary water.

Step 3 — Conclusion: The difference is due to replacing hydrogen by its isotope deuterium.

Why other options are wrong:

- (A) it has the same single oxygen atom as water.
- (C) tritium oxide is a different (radioactive) substance.
- (D) H_2O_2 is hydrogen peroxide, not heavy water.

Final Answer: Hydrogen is replaced by deuterium, raising density and boiling point $\Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q 20**

Q21.

Solution

Concept — Stability of free radicals: Like carbocations, free radicals are stabilised by the electron-releasing inductive effect (+I) and hyperconjugation from neighbouring alkyl groups. More alkyl substituents on the radical carbon means greater stability.

Step 1 — Count alkyl groups: A tertiary radical has three alkyl groups on the carbon bearing the unpaired electron, a secondary has two, a primary has one, and a methyl radical has none.

Step 2 — Apply hyperconjugation: More alkyl groups give more hyperconjugative structures and more electron donation, delocalising and stabilising the unpaired electron.

Step 3 — Order of stability:

$$\text{tertiary} > \text{secondary} > \text{primary} > \text{methyl}.$$

Why other options are wrong:

- (A) and (B) reverse the trend.
- (C) wrongly places secondary above tertiary.

Final Answer: tertiary $>$ secondary $>$ primary $>$ methyl $\Rightarrow \boxed{\text{D}}$

$\boxed{\textbf{Answer: (D)}}$ **Go Back to Q 21**

Q22.

Solution

Concept — Functional isomerism: Functional isomers have the same molecular formula but different functional groups (and therefore belong to different families).

Step 1 — Check the molecular formula: Both ethanol (CH_3CH_2OH) and dimethyl ether (CH_3OCH_3) have the molecular formula C_2H_6O.

Step 2 — Compare the functional groups: Ethanol contains an alcohol (-OH) group; dimethyl ether contains an ether (-O-) linkage. Different functional groups, same formula $\Rightarrow$ functional isomers.

Step 3 — Conclusion: The pair ethanol / dimethyl ether are functional isomers.

Why other options are wrong:

- (A) propan-1-ol and propan-2-ol are positional isomers (same -OH group).
- (C) butane and isobutane are chain isomers.
- (D) but-1-ene and but-2-ene are positional isomers of the double bond.

Final Answer: Ethanol and dimethyl ether are functional isomers $\Rightarrow \boxed{\text{B}}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Q 22**

Q23.

Solution

Concept — Baeyer's test for unsaturation: Cold, dilute, alkaline $KMnO_4$ (Baeyer's reagent) oxidises alkenes to vicinal diols (glycols). In the process the purple MnO_4^- is reduced to brown MnO_2.

Step 1 — The reaction with an alkene:

$$C{=}C + [O] + H_2O \xrightarrow{KMnO_4} \text{-C(OH)-C(OH)-}\ .$$

Step 2 — The visible change: The pink/purple colour of $KMnO_4$ disappears (decolourisation) and a brown precipitate of MnO_2 forms, confirming unsaturation.

Step 3 — Conclusion: A positive Baeyer's test shows decolourisation plus a brown MnO_2 precipitate.

Why other options are wrong:

- (B) no blue colour forms in this test.
- (C) no white precipitate is produced.
- (D) "no reaction" would be the result for a saturated alkane, not an alkene.

Final Answer: Decolourisation with brown MnO_2 precipitate $\Rightarrow \boxed{A}$

$\boxed{\text{Answer: (A)}}$ Go Back to Q 23

Q24.

Solution

Concept — Markovnikov addition of HX to an alkyne: Each HBr adds so that H goes to the carbon already bearing more hydrogens, placing Br on the more substituted carbon. Two successive additions put both Br atoms on the same carbon (gem-dihalide).

Step 1 — First addition to propyne:

$$CH_3\text{-}C{\equiv}CH + HBr \longrightarrow CH_3\text{-}CBr{=}CH_2\ (\text{Markovnikov}).$$

Br goes to C-2 (the more substituted carbon).

Step 2 — Second addition:

$$CH_3\text{-}CBr{=}CH_2 + HBr \longrightarrow CH_3\text{-}CBr_2\text{-}CH_3.$$

Again Br adds to C-2, giving the gem-dibromide.

Step 3 — Identify the product: The major product is CH_3-CBr_2-CH_3, i.e. 2,2-dibromopropane.

Why other options are wrong:

- (A) and (D) give vicinal or terminal dibromides, which are anti-Markovnikov.
- (B) is the product of two anti-Markovnikov additions.

Final Answer: 2,2-dibromopropane ($CH_3CBr_2CH_3$) $\Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q 24**

Q25.

Solution

Concept — S_N1 and racemisation: An S_N1 reaction goes through a planar (sp^2) carbocation intermediate. The nucleophile can attack from either face with nearly equal probability, so an optically active reactant gives a racemic (optically inactive) product.

Step 1 — Formation of the carbocation: The C–Br bond breaks first, giving a flat carbocation; the original chirality at that carbon is lost.

Step 2 — Attack by the nucleophile: Water attacks the planar carbocation from both the top and bottom faces with equal likelihood, producing equal amounts of the two enantiomers.

Step 3 — Result: Equal amounts of the (R) and (S) alcohols form, a racemic mixture, which is optically inactive (zero net rotation).

Why other options are wrong:

- (A) pure retention is not observed in S_N1.
- (B) complete inversion is the hallmark of S_N2, not S_N1.
- (C) the product is not optically pure; the planar intermediate scrambles configuration.

Final Answer: A racemic, optically inactive mixture forms $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q 25**

Q26.

Solution

Concept — Esterification: A carboxylic acid reacts with an alcohol in the presence of concentrated H_2SO_4 (acid catalyst and dehydrating agent) to give an ester and water. Esters have characteristic pleasant, fruity odours.

Step 1 — Write the reaction:

$$CH_3COOH + C_2H_5OH \underset{\Delta}{\overset{\text{conc. } H_2SO_4}{\rightleftharpoons}} CH_3COOC_2H_5 + H_2O.$$

Step 2 — Identify the product: Acetic acid + ethanol gives ethyl acetate ($CH_3COOC_2H_5$), an ester with a sweet, fruity smell.

Step 3 — Conclusion: The product is ethyl acetate.

Why other options are wrong:

- (A) acetaldehyde requires oxidation, not esterification.
- (C) diethyl ether forms from two alcohol molecules, not an acid + alcohol.
- (D) sodium acetate needs a base (NaOH), not this reaction.

Final Answer: Ethyl acetate $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 26

Q27.

Solution

Concept — Aldehydes vs ketones in nucleophilic addition: Reactivity towards nucleophilic addition is governed by the electrophilicity of the carbonyl carbon and the steric crowding around it. Aldehydes have at least one H on the carbonyl carbon; ketones have two alkyl groups.

Step 1 — Electronic effect: The two alkyl groups in a ketone donate electron density (+I effect) to the carbonyl carbon, reducing its partial positive charge and making it less electrophilic. An aldehyde has only one (or no) such group, so its carbonyl carbon is more electrophilic.

Step 2 — Steric effect: The two bulky alkyl groups in a ketone hinder the approach of the nucleophile, whereas an aldehyde's small H allows easier attack.

Step 3 — Conclusion: Both electronic and steric factors make aldehydes more reactive than ketones.

Why other options are wrong:

- (B) molar mass does not control nucleophilic addition reactivity.
- (C) is the opposite of the truth: the ketone carbonyl is less electrophilic.
- (D) aldehydes certainly contain a carbonyl group.

Final Answer: Ketones' alkyl groups lower electrophilicity and add steric hindrance $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q 27

Q28.

Solution

Concept — Mechanism of Fischer esterification: Isotopic labelling experiments show that in the acid-catalysed esterification, the water molecule eliminated is formed from the -OH of the carboxylic acid and the H of the alcohol. The alcohol oxygen ends up in the ester linkage.

Step 1 — Track the alcohol oxygen: When an ^{18}O-labelled alcohol is used, the label appears in the ester, not in the water. This shows the alcohol oxygen is retained in the ester.

Step 2 — Identify the source of water oxygen: Therefore the oxygen of the eliminated water must come from the acid, specifically from the -OH group of the carboxylic acid (after protonation and loss of water from the tetrahedral intermediate).

Step 3 — Conclusion: The oxygen of the water removed comes from the acid's -OH group.

Why other options are wrong:

- (A) the alcohol oxygen stays in the ester (proven by labelling).
- (B) the catalyst supplies only H^+, not the oxygen.
- (D) the carbonyl oxygen remains in the ester carbonyl.

Final Answer: Water oxygen comes from the acid's -OH group $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q 28

Q29.

Solution

Concept — Carbylamine (isocyanide) test: This test distinguishes primary amines. Only primary amines (aliphatic or aromatic) react with chloroform and alcoholic KOH to give a foul-smelling isocyanide (carbylamine).

Step 1 — The reaction (for a primary amine):

$$\text{R-NH}_2 + \text{CHCl}_3 + 3\text{KOH} \xrightarrow{\Delta} \text{R-NC} + 3\text{KCl} + 3\text{H}_2\text{O}.$$

Step 2 — Why only primary amines respond: The test needs two N–H bonds on the same nitrogen so that both hydrogens can be removed to form the isocyanide. Secondary and tertiary amines lack the required two N–H hydrogens on one nitrogen.

Step 3 — Conclusion: The carbylamine reaction is given only by primary amines (and primary amines alone).

Why other options are wrong:

- (A), (B), (C): secondary and tertiary amines do not give the carbylamine test.

Final Answer: Only primary amines give the carbylamine test $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 29

Q30.

Solution

Concept — Vitamins and deficiency diseases: Each vitamin has a specific deficiency disease. Vitamin C (ascorbic acid) is essential for healthy connective tissue, and its deficiency causes scurvy.

Step 1 — Recall the disease links:

- Vitamin A: night blindness.
- Vitamin C: scurvy (bleeding gums).
- Vitamin D: rickets / osteomalacia.
- Vitamin K: poor blood clotting.

Step 2 — Match scurvy: Scurvy, marked by swollen and bleeding gums, results from a lack of vitamin C (ascorbic acid).

Step 3 — Conclusion: The vitamin whose deficiency causes scurvy is vitamin C.

Why other options are wrong:

- (A) Vitamin A deficiency causes night blindness.
- (C) Vitamin D deficiency causes rickets.
- (D) Vitamin K deficiency impairs blood clotting.

Final Answer: Vitamin C deficiency causes scurvy $\Rightarrow \boxed{B}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Q 30**

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	A	4	D	5	A
6	B	7	C	8	D	9	A	10	B
11	C	12	D	13	B	14	C	15	A
16	B	17	D	18	C	19	A	20	B
21	D	22	B	23	A	24	C	25	D
26	B	27	A	28	C	29	D	30	B