BITSAT Chemistry Sample Paper – 5

Duration: 40 Minutes **Maximum Marks: 90**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer).
- Each correct answer carries **+3 marks**. Each incorrect answer carries -1 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question. Choose carefully.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. The empirical formula of a compound is $\mathrm{CH_2O}$. Its molar mass is $180\,\mathrm{g\,mol^{-1}}$. The molecular formula is:

(A) $\mathrm{C_3H_6O_3}$

(B) $\mathrm{C_5H_{10}O_5}$

(C) $\mathrm{C_6H_{12}O_6}$

(D) $\mathrm{C_2H_4O_2}$

Q2. Bohr's model predicts that the radius of the n^{th} orbit of hydrogen is $r_n = 0.529\,n^2$ Å. The radius of the third orbit is:

(A) 1.587 Å

(B) 4.761 Å

(C) 0.529 Å

(D) 2.116 Å

Q3. Among $\mathrm{CH_4}$, $\mathrm{NH_3}$, $\mathrm{H_2O}$, and HF, the decreasing order of bond angle is:

(A) $\mathrm{H_2O} > \mathrm{NH_3} > \mathrm{CH_4} > \mathrm{HF}$

(B) $\mathrm{CH_4} > \mathrm{NH_3} > \mathrm{H_2O} > \mathrm{HF}$

(C) $\mathrm{HF} > \mathrm{H_2O} > \mathrm{NH_3} > \mathrm{CH_4}$

(D) $\mathrm{NH_3} > \mathrm{CH_4} > \mathrm{H_2O} > \mathrm{HF}$

Q4. Which of the following molecules is **non-polar** despite having polar bonds?

(A) $\mathrm{H_2O}$

(B) $\mathrm{NH_3}$

(C) $\mathrm{BF_3}$

(D) HCl

Q5. The standard entropy change ΔS° for the reaction $\mathrm{C(s) + O_2(g) \rightarrow CO_2(g)}$ is closest to:

(A) Large positive (disorder increases)

(B) Large negative (disorder decreases)

(C) Approximately zero ($\Delta n_g = 0$, so $\Delta S \approx 0$)

(D) Impossible to predict without data

Q6. For a cell reaction with $\Delta G^\circ = -300\,\mathrm{kJ\,mol^{-1}}$ and $n = 2$, the standard cell potential E° at $298\,\mathrm{K}$ ($F = 96500\,\mathrm{C\,mol^{-1}}$) is:

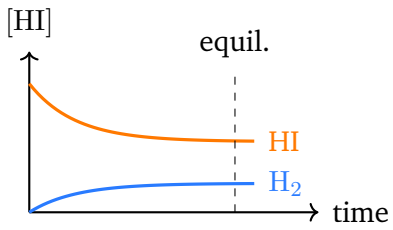
(A) $E^\circ = 3.11\,\mathrm{V}$

(B) $E^\circ = 1.55\,\mathrm{V}$

(C) $E^\circ = 0.78\,\mathrm{V}$

(D) $E^\circ = 6.22\,\mathrm{V}$

Q7. For the decomposition $\mathrm{2HI(g) \rightleftharpoons H_2(g) + I_2(g)}$ at $700\,\mathrm{K}$, $K_c = 0.0156$. If the initial concentration of HI is $0.1\,\mathrm{M}$ (no products), the equilibrium concentration of HI is approximately:



(A) $[\mathrm{HI}]_{eq} \approx 0.022\,\mathrm{M}$

(B) $[\mathrm{HI}]_{eq} \approx 0.072\,\mathrm{M}$

(C) $[\mathrm{HI}]_{eq} \approx 0.050\,\mathrm{M}$

(D) $[\mathrm{HI}]_{eq} \approx 0.088\,\mathrm{M}$

Q8. The pH of a $0.001\,\mathrm{M}$ solution of HCl (strong acid, fully dissociated) at $25^{\circ}\mathrm{C}$ is:

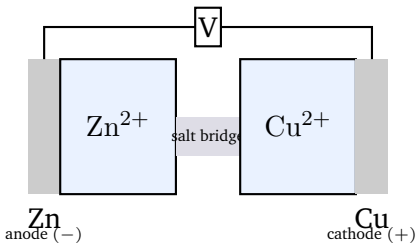
(A) $\mathrm{pH} = 1$

(B) $\mathrm{pH} = 11$

(C) $\mathrm{pH} = 3$

(D) $\mathrm{pH} = 2$

Q9. The standard electrode potentials are $E^{\circ}(\mathrm{Cu}^{2+}/\mathrm{Cu}) = +0.34\,\mathrm{V}$ and $E^{\circ}(\mathrm{Zn}^{2+}/\mathrm{Zn}) = -0.76\,\mathrm{V}$. In the Daniell cell $\mathrm{Zn}|\mathrm{Zn}^{2+}||\mathrm{Cu}^{2+}|\mathrm{Cu}$, the correct description of electrode processes is:



(A) Zn is reduced at the anode; Cu is oxidised at the cathode

(B) Zn is oxidised at the anode ($\mathrm{Zn} \rightarrow \mathrm{Zn}^{2+} + 2\mathrm{e}^{-}$); Cu^{2+} is reduced at the cathode

(C) Both electrodes are oxidised simultaneously

(D) Electrons flow from cathode to anode through the external circuit

Q10. A second-order reaction has rate constant $k = 0.05\,\mathrm{L\,mol^{-1}\,s^{-1}}$. Starting with $[\mathrm{A}]_0 = 0.1\,\mathrm{mol\,L^{-1}}$, the half-life is:

(A) $t_{1/2} = 200\,\mathrm{s}$

(B) $t_{1/2} = 13.86\,\text{s}$

(C) $t_{1/2} = 100\,\text{s}$

(D) $t_{1/2} = 400\,\text{s}$

Q11. The reaction of Cl_2 with $NaOH$ (cold, dilute) gives:

$$Cl_2 + 2NaOH \xrightarrow{\text{cold, dilute}} NaCl + NaOCl + H_2O$$

(A) $NaCl + NaOCl + H_2O$ (bleaching powder precursor)

(B) $NaClO_3 + NaCl + H_2O$ (only at high temperature)

(C) $NaClO_4$ and H_2

(D) $HCl + NaOH$ (no reaction with Cl_2)

Q12. Among the following, the compound that does **not** exist is:

(A) PF_5

(B) NCl_5

(C) PCl_5

(D) AsF_5

Q13. Which of the following complexes shows **linkage isomerism**?

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

(B) $[Co(en)_3]^{3+}$

(C) $[Co(NH_3)_5(NO_2)]^{2+}$ (the NO_2^- ligand can bind via N or O)

(D) $[PtCl_2(NH_3)_2]$

Q14. Schottky defect in an ionic crystal results in:

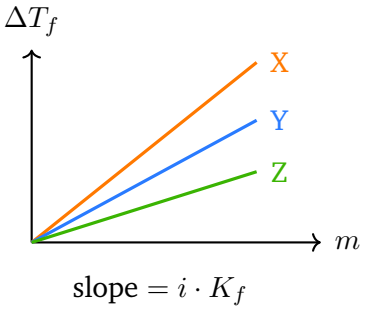
(A) Increase in density; extra ions in interstitial positions

(B) Decrease in density; equal numbers of cation and anion vacancies

(C) Increase in electrical conductivity only; no change in density

(D) Formation of F-centres (trapped electrons in anion vacancies)

Q15. The graph of ΔT_f (depression in freezing point) vs molality m for three solutes is shown. Solute X has the steepest slope. What can be inferred about X?



(A) X has the lowest molar mass

(B) X has the highest van't Hoff factor i (most dissociation)

(C) X is a non-electrolyte with the lowest molar mass

(D) X produces the fewest ions per formula unit

Q16. The Wurtz reaction is used to synthesise alkanes from alkyl halides. The synthesis of butane from ethyl bromide:

$$2\,CH_3CH_2Br \xrightarrow{\text{dry ether, Na}} CH_3CH_2CH_2CH_3 + 2\,NaBr$$

(A) Only symmetric alkanes can be made; mixed halides give a mixture

(B) Only asymmetric alkanes can be made (different halides required)

(C) Produces only propane from ethyl bromide

(D) Wurtz reaction is not suitable for preparing higher alkanes

Q17. Alkynes react with H_2O (Markovnikov) in the presence of $H_2SO_4/HgSO_4$ catalyst. The hydration of propyne ($CH_3C \equiv CH$) gives the major product:

$$CH_3C{\equiv}CH \xrightarrow{H_2O/H^+/HgSO_4} \text{? (via enol)}$$

(A) Propanal (CH_3CH_2CHO) — anti-Markovnikov

(B) Propan-1-ol

(C) Propan-2-ol

(D) Propan-2-one (acetone, CH_3COCH_3) — Markovnikov, enol tautomerises to ketone

Q18. The Victor Meyer test distinguishes primary, secondary, and tertiary alcohols. In this test, the alcohol is converted to its iodide, then treated with $AgNO_2$, and the nitroalkane is treated with HNO_2. Primary alcohols give a **red** colour. The reaction of a primary alcohol with HI is:

$$RCH_2OH \xrightarrow{HI\ (conc.)} RCH_2I + H_2O$$

(A) S_N2 mechanism; inversion of configuration; fast for primary

(B) S_N1 mechanism; racemisation; slow for primary

(C) Elimination (E2); alkene formed preferentially

(D) No reaction with primary alcohols; only 3° react

Q19. The Clemmensen reduction of a ketone or aldehyde converts C=O to CH_2:

$$R - CO - R' \xrightarrow{Zn(Hg)/conc.\ HCl} R - CH_2 - R'$$

(A) The product is a secondary alcohol ($R - CHOH - R'$)

(B) The product is an alkene ($R - CH = R'$)

(C) C=O is reduced to $-CH_2-$ (methylene); suitable for acid-sensitive substrates

(D) The reaction proceeds via an enol intermediate

Q20. The Hell-Volhard-Zelinsky (HVZ) reaction introduces a bromine at the α-carbon of carboxylic acids. The reagents and product for propanoic acid are:

$$CH_3CH_2COOH \xrightarrow[\alpha\text{-bromination}]{Br_2,\ \text{red P}} CH_3CHBrCOOH$$

(A) 2-bromopropanoic acid ($CH_3CHBrCOOH$); α-carbon is brominated

(B) 3-bromopropanoic acid ($BrCH_2CH_2COOH$); β-carbon brominated

(C) 1-bromopropane + CO_2 (decarboxylation)

(D) Propanoyl bromide (CH_3CH_2COBr) only

Q21. Which of the following is a **complete protein** (contains all essential amino acids)?

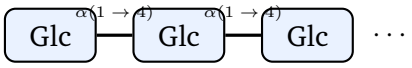
(A) Gelatin

(B) Gluten (wheat protein)

(C) Zein (corn protein)

(D) Casein (milk protein)

Q22. Starch is a polysaccharide. It consists of two components. Amylose is soluble in water and gives a **blue-black** colour with iodine. Amylopectin is branched. The glycosidic bond in amylose is:



(A) $\beta(1 \to 4)$ glycosidic bonds (like cellulose)

(B) $\alpha(1 \to 6)$ glycosidic bonds throughout (like glycogen)

(C) $\alpha(1 \to 4)$ glycosidic bonds in a helical chain

(D) $\alpha(1 \to 2)$ glycosidic bonds (like sucrose)

Q23. PVC (polyvinyl chloride) is made by addition polymerisation of vinyl chloride. The reaction scheme:

$$n\,\mathrm{CH_2{=}CHCl} \xrightarrow{\text{initiator}} [-\mathrm{CH_2\text{-}CHCl}-]_n$$

(A) PVC is a condensation polymer; HCl is released as byproduct

(B) PVC is an addition polymer; no byproduct; $[-\mathrm{CH_2\text{-}CHCl}-]_n$

(C) PVC is formed only by anionic polymerisation

(D) PVC contains both C–C and C–O backbone bonds

Q24. Which of the following is an example of a **emulsion**?

(A) Fog (water droplets in air)

(B) Milk (fat droplets dispersed in water)

(C) Smoke (solid particles in gas)

(D) Ruby glass (metal colloid in glass)

Q25. The thermal stability of carbonates of alkali metals increases down the group. $\mathrm{Li_2CO_3}$ decomposes on heating, whereas $\mathrm{Cs_2CO_3}$ is stable. This is because:

(A) Smaller cations destabilise the carbonate lattice more (higher charge density polarises $\mathrm{CO_3^{2-}}$)

(B) Larger cations have lower ionisation energies and are more reactive

(C) The carbonate anion is more basic than oxide for larger cations

(D) All alkali metal carbonates decompose at the same temperature

Q26. Photoelectric effect: light of frequency ν shines on a metal with work function ϕ. The maximum kinetic energy of emitted electrons is eV_s (stopping potential). Which graph is correct?

(A) eV_s vs ν: a straight line with slope h and x-intercept $\nu_0 = \phi/h$

(B) eV_s vs ν: a parabola

(C) eV_s vs intensity: a straight line (KE proportional to intensity)

(D) eV_s vs ν: a horizontal line (KE independent of frequency)

Q27. The spin-only magnetic moment formula is $\mu = \sqrt{n(n+2)}\,\mathrm{BM}$ where n = unpaired electrons. For $[\mathrm{MnCl_4}]^{2-}$ (high-spin tetrahedral, d^5), the magnetic moment is:

(A) $\mu = \sqrt{3}\,\mathrm{BM} \approx 1.73\,\mathrm{BM}$

(B) $\mu = \sqrt{8}\,\mathrm{BM} \approx 2.83\,\mathrm{BM}$

(C) $\mu = \sqrt{35}\,\mathrm{BM} \approx 5.92\,\mathrm{BM}$

(D) $\mu = \sqrt{15}\,\mathrm{BM} \approx 3.87\,\mathrm{BM}$

Q28. The conductance of a solution decreases with increasing distance between electrodes and increases with increasing cross-sectional area. The resistance R of the solution is related to cell constant $G^* = l/A$ by:

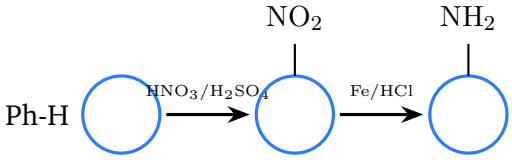
(A) $R = \kappa \cdot G^*$ (conductivity $\times$ cell constant)

(B) $R = G^*/\kappa$ (cell constant divided by conductivity)

(C) $\kappa = R \cdot G^*$

(D) $\kappa = G^*/R$

Q29. The reaction sequence for preparation of aniline from benzene via nitration and reduction:



(A) Benzene $\xrightarrow{\mathrm{HNO_3/H_2SO_4}}$ nitrobenzene $\xrightarrow{\mathrm{Fe/HCl}}$ aniline + $\mathrm{FeCl_2}$ + $\mathrm{H_2O}$

(B) Benzene $\xrightarrow{\mathrm{Cl_2/FeCl_3}}$ chlorobenzene $\xrightarrow{\mathrm{NH_3}}$ aniline

(C) Benzene $\xrightarrow{\mathrm{H_2/Ni}}$ cyclohexane $\xrightarrow{\mathrm{NH_3}}$ cyclohexylamine

(D) Benzene $\xrightarrow{\mathrm{HNO_3}}$ phenol $\xrightarrow{\mathrm{NH_3}}$ aniline

Q30. The rate constant of a reaction at $300\,\mathrm{K}$ is k_1 and at $310\,\mathrm{K}$ is $k_2 = 2k_1$. Using the Arrhenius equation, the activation energy is the same value calculated earlier ($\approx 53.6\,\mathrm{kJ\,mol^{-1}}$). If instead the rate constant *quadruples*

on going from $300\,\mathrm{K}$ to $310\,\mathrm{K}$, the activation energy would be approximately:

(A) $\approx 53.6\,\mathrm{kJ\,mol^{-1}}$ (same)

(B) $\approx 26.8\,\mathrm{kJ\,mol^{-1}}$ (half)

(C) $\approx 214.4\,\mathrm{kJ\,mol^{-1}}$ (four times)

(D) $\approx 107.2\,\mathrm{kJ\,mol^{-1}}$ (double)

Detailed Solutions

Q1.

Solution

Concept — Empirical and molecular formula from combustion analysis: In combustion analysis, all C becomes CO_2 and all H becomes H_2O. Masses of CO_2 and H_2O are used to find the molar ratio of C:H:O.

Step 1 — Find moles of C and H: $n(\mathrm{C}) = \frac{m(\mathrm{CO_2})}{M(\mathrm{CO_2})} = \frac{4.4\,\mathrm{g}}{44\,\mathrm{g\,mol^{-1}}} = 0.10\,\mathrm{mol}$

$n(\mathrm{H_2O}) = \frac{2.7\,\mathrm{g}}{18\,\mathrm{g\,mol^{-1}}} = 0.15\,\mathrm{mol}$; $n(\mathrm{H}) = 2 \times 0.15 = 0.30\,\mathrm{mol}$

Step 2 — Find mass and moles of O: $m(\mathrm{C}) = 0.10 \times 12 = 1.2\,\mathrm{g}$; $m(\mathrm{H}) = 0.30 \times 1 = 0.3\,\mathrm{g}$

$m(\mathrm{O}) = 3.0 - 1.2 - 0.3 = 1.5\,\mathrm{g}$; $n(\mathrm{O}) = 1.5/16 = 0.09375\,\mathrm{mol}$

Step 3 — Molar ratio C:H:O: Divide by smallest (0.09375): C: $0.10/0.09375 \approx 1.07 \approx 1$; H: $0.30/0.09375 \approx 3.2 \approx 3$; O: 1. Empirical formula: $\mathrm{CH_3O}$ (MW = 31).

Step 4 — Molecular formula: $n = M/31 = 62/31 = 2 \Rightarrow$ molecular formula $= \mathrm{C_2H_6O_2}$ (ethylene glycol or its isomers).

Common error: Forgetting to account for O by mass difference when the compound contains O, C, and H. The CO_2 and H_2O measurements only directly tell you C and H.

Final Answer: Empirical $\mathrm{CH_3O}$; molecular $\mathrm{C_2H_6O_2} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept — Rydberg equation and spectral lines:

$$\bar{\nu} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $R_H = 1.097 \times 10^7\,\text{m}^{-1}$ and $\bar{\nu} = 1/\lambda$.

Spectral series of hydrogen:

- Lyman: $n_1 = 1$ (UV region, transitions to $n = 1$)
- Balmer: $n_1 = 2$ (visible/near-UV, transitions to $n = 2$)
- Paschen: $n_1 = 3$ (near-IR)
- Brackett: $n_1 = 4$ (IR)
- Pfund: $n_1 = 5$ (far-IR)

Step 1 — The question: For the Balmer series transition $n = 5 \to n = 2$:

$$\bar{\nu} = 1.097\times10^7\left(\frac{1}{4} - \frac{1}{25}\right) = 1.097\times10^7\left(\frac{25-4}{100}\right) = 1.097\times10^7\times0.21 = 2.304\times10^6\,\text{m}^{-1}$$

$\lambda = 1/\bar{\nu} = 434\,\text{nm}$ (violet line in the Balmer series).

Step 2 — Number of lines in Balmer series for $n = 5$ downward: Transitions possible: $5 \to 2$, $4 \to 2$, $3 \to 2 \Rightarrow$ 3 lines.

Physical significance: The Balmer series is the only hydrogen series partially in the visible region, making it historically important and observable in stellar spectra.

Final Answer: 3 Balmer lines; $5 \to 2$ gives $\lambda = 434\,\text{nm} \Rightarrow$ B

Answer: (B) Go Back to Q2

Q3.

Solution

Concept — Hybridisation and bond angles in PCl_5: P has 5 valence electrons. In PCl_5, all 5 are used in P–Cl bonds (expanded octet using d-orbitals):

Step 1 — Hybridisation: 5 bond pairs + 0 lone pairs $\Rightarrow$ sp^3d hybridisation $\Rightarrow$ **trigonal bipyramidal** geometry.

Step 2 — Two distinct positions:

- **Axial bonds** (2 Cl, top and bottom): bond angle Cl_{ax}–P–$Cl_{ax} = 180^\circ$
- **Equatorial bonds** (3 Cl, around the belt): bond angle Cl_{eq}–P–$Cl_{eq} = 120^\circ$
- Axial–equatorial: 90°

Step 3 — Axial vs equatorial bonds: Axial bonds are slightly longer than equatorial bonds (P–$Cl_{ax} \approx 214\,pm$; P–$Cl_{eq} \approx 202\,pm$). This is because axial bonds involve more p-character (sp^3d: equatorial use more s character) and face more repulsion from the three equatorial bonds.

Step 4 — Why PCl_5 has two types of Cl: In NMR and X-ray studies, axial and equatorial Cl atoms are distinguishable at low temperatures. At room temperature, Berry pseudo-rotation rapidly interconverts them.

Final Answer: Trigonal bipyramidal; sp^3d; two bond angles: 120° (eq) and 180° (ax) $\Rightarrow$ C

Answer: (C) Go Back to Q3

Q4.

Solution

Concept — Enthalpy of atomisation and bond dissociation energy: For a diatomic homonuclear molecule X_2:

$$\Delta H_{\text{atomisation}} = \frac{1}{2}\Delta H_{\text{bond dissociation}}(X_2)$$

For a polyatomic molecule, atomisation = sum of all bond dissociation enthalpies.

Step 1 — For CH_4: $\mathrm{CH_4 \rightarrow C(g) + 4H(g)}$: break 4 C–H bonds. $\Delta H_{\text{atomisation}}(\mathrm{CH_4}) = 4 \times BDE(\mathrm{C-H}) = 4 \times 413 = 1652\,\mathrm{kJ\,mol^{-1}}$.

Step 2 — For N_2: $\mathrm{N_2 \rightarrow 2N(g)}$: break 1 N≡N triple bond. $\Delta H_{\text{atomisation}}(\mathrm{N_2}) = BDE(\mathrm{N \equiv N}) = 945\,\mathrm{kJ\,mol^{-1}}$.

Step 3 — For H_2O: $\mathrm{H_2O \rightarrow 2H(g) + O(g)}$: break 2 O–H bonds. $\Delta H_{\text{atomisation}}(\mathrm{H_2O}) = 2 \times 463 = 926\,\mathrm{kJ\,mol^{-1}}$.

Step 4 — For Cl_2 and P_4: $\mathrm{Cl_2 \rightarrow 2Cl(g)}$: $\Delta H = 242\,\mathrm{kJ\,mol^{-1}}$ (molar atomisation enthalpy per mole of Cl_2; per mole Cl atoms = 121). $\mathrm{P_4 \rightarrow 4P(g)}$: 6 P–P bonds broken; per mole $P_4 = 6 \times 200 = 1200\,\mathrm{kJ\,mol^{-1}}$.

Note: Bonds are average values; actual values may vary slightly by context.

Final Answer: Using given bond enthalpies and the atomisation formula $\Rightarrow$ B

Answer: (B) Go Back to Q4

Q5.

Solution

Concept — van der Waals equation of state for real gases:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

where a accounts for intermolecular attractive forces and b accounts for the finite volume of molecules.

Step 1 — Physical meaning of a: When gas molecules are close together, they attract each other. This reduces the momentum of molecules hitting the wall, so the actual pressure is *less* than ideal. The correction term a/V_m^2 is added to the measured pressure to give the ideal value. Larger $a \Rightarrow$ stronger intermolecular attractions.

Step 2 — Physical meaning of b: Molecules occupy space; the free volume available is $V_m - b$ (not V_m). $b \approx 4\times$ actual molecular volume (one molecule excludes a volume $4\times$ its own from the centres of other molecules).

Step 3 — Compressibility factor Z:

$$Z = \frac{PV_m}{RT}$$

For an ideal gas, $Z = 1$. For real gases at moderate pressures: $Z < 1$ (attractive forces dominate). At very high pressures: $Z > 1$ (repulsive/exclusion forces dominate, b term).

Step 4 — Which gas has highest a? $a(\mathrm{H_2}) = 0.244$; $a(\mathrm{He}) = 0.034$; $a(\mathrm{CO_2}) = 3.59$; $a(\mathrm{N_2}) = 1.39\,\mathrm{L^2\,atm\,mol^{-2}}$. CO_2 has the highest a (strongest van der Waals forces) due to its larger size and quadrupole moment.

Final Answer: a = attraction correction; b = volume correction; CO_2 has highest $a \Rightarrow$ A

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Kirchhoff's equation (temperature dependence of ΔH):

$$\Delta H_2 = \Delta H_1 + \Delta C_p(T_2 - T_1)$$

where $\Delta C_p = \sum C_p(\text{products}) - \sum C_p(\text{reactants})$.

Step 1 — Reaction: $\mathrm{N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)}$.

$\Delta C_p = 2C_p(\mathrm{NH_3}) - C_p(\mathrm{N_2}) - 3C_p(\mathrm{H_2})$

$= 2(35.1) - 29.1 - 3(28.8) = 70.2 - 29.1 - 86.4 = -45.3\,\mathrm{J\,mol^{-1}K^{-1}}$

Step 2 — Apply Kirchhoff: $\Delta H_{500} = \Delta H_{298} + \Delta C_p \times (500 - 298) = -92.4 + (-45.3 \times 10^{-3})(202)$ (note: ΔC_p in kJ: $-0.0453\,\mathrm{kJ\,K^{-1}}$) $= -92.4 + (-0.0453)(202) = -92.4 - 9.15 = -101.6\,\mathrm{kJ\,mol^{-1}}$

Step 3 — Interpretation: The reaction becomes more exothermic at higher temperatures (because $\Delta C_p < 0$: products have lower combined heat capacity than reactants). However, equilibrium yield decreases at higher T (Le Chatelier's principle for exothermic reactions).

Final Answer: $\Delta H_{500} \approx -101.6\,\mathrm{kJ\,mol^{-1}} \Rightarrow$ C

Answer: (C) Go Back to Q6

Q7.

Solution

Concept — Buffer solutions and Henderson-Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$$

A buffer resists changes in pH when small amounts of acid or base are added.

Step 1 — Initial pH: $\text{p}K_a(\text{CH}_3\text{COOH}) = -\log(1.8 \times 10^{-5}) = 4.74$. Equal concentrations of acid and salt: $[\text{salt}]/[\text{acid}] = 1$. $\text{pH} = 4.74 + \log(1) = 4.74 + 0 = \mathbf{4.74}$.

Step 2 — After adding 0.01 mol HCl to 1 L: HCl reacts with

New concentrations (in 1 L): $[\text{CH}_3\text{COOH}] = 0.1 + 0.01 = 0.11\,\text{M}$; $[\text{CH}_3\text{COO}^-] = 0.1 - 0.01 = 0.09\,\text{M}$.

$\text{pH} = 4.74 + \log(0.09/0.11) = 4.74 + \log(0.818) = 4.74 - 0.087 = 4.65$

$\Delta\text{pH} = 4.74 - 4.65 = 0.09$ (tiny change, confirming buffering action).

Step 3 — Buffer capacity is maximum when [salt] = [acid] (i.e., $\text{pH} = \text{p}K_a$). At this point, equal amounts of acid and base can be neutralised.

Final Answer: Initial pH = 4.74; after HCl addition, pH = 4.65 $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Nernst equation and concentration cells:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0592}{n}\log Q$$

For $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$: $n = 2$; $Q = [\text{Zn}^{2+}]/[\text{Cu}^{2+}]$.

Step 1 — Calculate E°_{cell}: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = (+0.34) - (-0.76) = 1.10\,\text{V}$

Step 2 — Apply Nernst equation: $Q = \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = \frac{0.1}{0.01} = 10$

$E = 1.10 - \frac{0.0592}{2}\log(10) = 1.10 - \frac{0.0592}{2}(1) = 1.10 - 0.0296 = \mathbf{1.070}\,\text{V}$

Step 3 — Effect of concentration: When $[\text{Zn}^{2+}] > [\text{Cu}^{2+}]$ (product concentration high), $Q > 1$, $\log Q > 0$, so $E < E^\circ$. The forward reaction is less favoured, which makes chemical sense: building up products reduces driving force.

Practical note: In a Daniel cell, as the reaction proceeds, $[\text{Cu}^{2+}]$ decreases and $[\text{Zn}^{2+}]$ increases, causing the cell voltage to gradually decline until equilibrium ($E = 0$).

Final Answer: $E = 1.070\,\text{V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept — Pseudo-first-order reactions: When one reactant is in such large excess that its concentration is essentially constant throughout the reaction, the kinetics simplify to first-order behaviour with respect to the other reactant.

Step 1 — The acid hydrolysis of ethyl acetate: $\mathrm{CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH}$

True rate law: $r = k[\text{ester}][\mathrm{H_2O}][\mathrm{H^+}]$.

Step 2 — Pseudo conditions:

- $[\mathrm{H_2O}]$ is the solvent: $55.5\,\mathrm{M}$, effectively constant throughout.
- $[\mathrm{H^+}]$ is a catalyst: regenerated and constant.
- Only $[\text{ester}]$ changes.

Effective rate constant: $k_{\text{obs}} = k[\mathrm{H_2O}][\mathrm{H^+}] = \text{constant}$. Rate $= k_{\text{obs}}[\text{ester}] \Rightarrow$ **pseudo-first-order** in ester.

Step 3 — How to verify: $[\text{ester}]_t = [\text{ester}]_0 e^{-k_{\text{obs}}t}$. A plot of $\ln[\text{ester}]$ vs t is linear $\Rightarrow$ confirms pseudo-first-order. The half-life is constant: $t_{1/2} = \ln 2/k_{\text{obs}}$.

Final Answer: Pseudo-first-order (water and $\mathrm{H^+}$ both effectively constant) $\Rightarrow$ C

Answer: (C) Go Back to Q9

Q10.

Solution

Concept — Thermite reaction and activity series: The thermite reaction is an aluminothermic reduction where Al displaces a less reactive metal from its oxide.

Step 1 — Reaction: $2\text{Al} + \text{Fe}_2\text{O}_3 \rightarrow \text{Al}_2\text{O}_3 + 2\text{Fe}$

ΔH is highly exothermic ($\approx -850\,\text{kJ mol}^{-1}$), reaching temperatures up to $2500°$C. The molten Fe produced is used in rail welding (aluminothermy process).

Step 2 — Why Al displaces Fe: In the electrochemical/activity series: Al is more reactive (higher on the series, more easily oxidised) than Fe. More reactive metals displace less reactive metals from their salts/oxides.

Thermodynamically: $\Delta G°(\text{Al}_2\text{O}_3)$ is much more negative than $\Delta G°(\text{Fe}_2\text{O}_3)$, so Al has a greater thermodynamic drive to become an oxide.

Step 3 — Why not the reverse? Fe cannot displace Al from Al_2O_3 because Al_2O_3 is more stable (more negative ΔG_f°) than Fe_2O_3. The reaction would be thermodynamically uphill.

Generalisation: Any metal X can reduce the oxide of metal Y if ΔG_f°(X-oxide) $<$ ΔG_f°(Y-oxide) — the Ellingham diagram quantifies this.

Final Answer: Al reduces Fe_2O_3; products Al_2O_3 + Fe $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept — Crystal field theory (CFT): splitting in octahedral and tetrahedral fields: In CFT, the d-orbitals of a metal ion split in the presence of ligand field:

Octahedral field: d-orbitals split into e_g ($d_{x^2-y^2}$, d_{z^2}, raised by $+\frac{3}{5}\Delta_o$) and t_{2g} (d_{xy}, d_{xz}, d_{yz}, lowered by $-\frac{2}{5}\Delta_o$). Crystal field splitting energy = Δ_o.

Tetrahedral field: Splitting is inverted and smaller: e orbitals (d_{z^2}, $d_{x^2-y^2}$) are at lower energy and t_2 (d_{xy}, d_{xz}, d_{yz}) at higher. $\Delta_t = \frac{4}{9}\Delta_o \approx 0.44\Delta_o$.

Step 1 — Why tetrahedral complexes are almost always high-spin: Δ_t is only 44% of $\Delta_o \Rightarrow$ pairing energy (P) is almost always greater than $\Delta_t \Rightarrow$ electrons remain unpaired (high-spin). Strong-field tetrahedral low-spin complexes are extremely rare.

Step 2 — CFSE for $[Fe(H_2O)_6]^{2+}$: Fe^{2+}: d^6. H_2O is a weak field ligand $\Rightarrow$ high-spin: $t_{2g}^4 e_g^2$. CFSE $= 4 \times (-\frac{2}{5}\Delta_o) + 2 \times (+\frac{3}{5}\Delta_o) = -\frac{8}{5}\Delta_o + \frac{6}{5}\Delta_o = -\frac{2}{5}\Delta_o$.

Step 3 — Spectrochemical series (weak to strong field): $I^- < Br^- < Cl^- < F^- < OH^- < H_2O < py < NH_3 < en < CN^- < CO$. Stronger field ligands $\Rightarrow$ larger Δ_o $\Rightarrow$ more likely low-spin.

Final Answer: $\Delta_t = \frac{4}{9}\Delta_o$; CFSE of $[Fe(H_2O)_6]^{2+} = -\frac{2}{5}\Delta_o \Rightarrow$ D

Answer: (D) Go Back to Q11

Q12.

Solution

Concept — Reactions of hydrogen peroxide as oxidising and reducing agent: H_2O_2 is both an oxidising and reducing agent (O in -1 oxidation state, between -2 in H_2O and 0 in O_2):

As oxidising agent (H_2O_2 reduced to H_2O): $H_2O_2 + 2KI + H_2SO_4 \rightarrow I_2 + K_2SO_4 + 2H_2O$ (oxidises I^- to I_2)

As reducing agent (H_2O_2 oxidised to O_2): $2KMnO_4 + 5H_2O_2 + 3H_2SO_4 \rightarrow 2MnSO_4 + K_2SO_4 + 5$

Step 1 — Evaluate the given reaction: $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

PbS (black) is converted to $PbSO_4$ (white). S in PbS $= -2$; S in $PbSO_4 = +6$. Sulfur is *oxidised* by 8 electrons. H_2O_2 is the *oxidising agent* (gets reduced: O: $-1 \rightarrow -2$ in H_2O).

Step 2 — Bleaching action: H_2O_2 is used to restore darkened old paintings. White lead paint ($PbCO_3$) turns black due to PbS formation from atmospheric H_2S. H_2O_2 oxidises the black PbS back to white $PbSO_4$.

Step 3 — Structure of H_2O_2: Non-planar, open-book structure. O–O bond length $= 147$ pm. H–O–O angle $= 97°$. The dihedral angle $= 112°$ (gas) or $90°$ (solid).

Final Answer: Oxidising agent; converts PbS (black) to $PbSO_4$ (white) $\Rightarrow$ B

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — Oxidation state of Cr in $Cr_2O_7^{2-}$ and colour of chromium compounds: Chromium exhibits vivid colours because of d-d transitions (electronic transitions within the partially filled d subshell).

Step 1 — Oxidation state in $K_2Cr_2O_7$: $2(+1) + 2x + 7(-2) = 0 \Rightarrow 2 + 2x - 14 = 0 \Rightarrow 2x = 12 \Rightarrow x = +6$. Cr is in the **+6** oxidation state: d^0 configuration (no d electrons).

Step 2 — Why orange if d^0? Cr^{6+} is d^0 so has no d-d transitions. The orange-red colour of $K_2Cr_2O_7$ arises from *charge-transfer transitions* (O $\rightarrow$ Cr electron transfer absorbs UV/blue, transmitting orange).

Step 3 — Reactions of $Cr_2O_7^{2-}$: In acidic solution, it is a powerful oxidising agent: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ ($E^\circ = +1.33\,V$)

Orange dichromate $\rightarrow$ green Cr^{3+} on reduction. In base: dichromate $\leftrightharpoons$ chromate (CrO_4^{2-}, yellow): $Cr_2O_7^{2-} + 2OH^- \rightleftharpoons 2CrO_4^{2-} + H_2O$.

Final Answer: Cr is +6 in $Cr_2O_7^{2-}$; charge-transfer colour $\Rightarrow$ A

Answer: (A) Go Back to Q13

Q14.

Solution

Concept — Zone refining (Pfann process) for ultra-pure semiconductors: This technique exploits the difference in solubility of impurities in solid vs liquid metal.

Step 1 — Principle: A molten zone is passed slowly from one end of a metal rod to the other using an RF heater. Impurities are more soluble in the melt than in the solid. As the zone moves, impurities dissolve into the liquid phase and are carried along with the moving zone, concentrating at one end of the rod. The other end becomes increasingly pure.

Step 2 — Distribution coefficient k: $k = C_s/C_l$ (ratio of impurity concentration in solid to liquid). When $k < 1$ (most cases), impurities prefer the liquid $\Rightarrow$ they move with the zone toward one end. Multiple passes increase purity.

Step 3 — Applications: Used to produce ultra-pure Ge and Si for semiconductors (purity $> 99.9999\%$ required). Also used for purification of metals like Ga, In, Bi.

Step 4 — Distinguish from other methods:

- Cupellation: removes Pb/Cu from Ag/Au using oxidation
- Liquation: low-melting metals run off a sloping hearth
- Van Arkel: for refractory metals (Ti, Zr) via iodide decomposition
- Zone refining: for semiconductors Si, Ge

Final Answer: Zone refining used for Si and Ge semiconductor purification $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept — Diazotisation and Sandmeyer reaction: Primary aromatic amines ($ArNH_2$) react with $NaNO_2$/HCl at 0–5°C to form diazonium salts ($ArN_2^+Cl^-$). These can then undergo various reactions including the Sandmeyer reaction.

Step 1 — Formation of diazonium salt: $C_6H_5NH_2 + NaNO_2 + HCl \xrightarrow{0-5^\circ C} C_6H_5N_2^+Cl^- + NaCl$

Temperature control is critical: above 5°C, ArN_2^+ decomposes to phenol and N_2.

Step 2 — Sandmeyer reaction (with CuCN): $C_6H_5N_2^+Cl^- + CuCN \rightarrow C_6H_5CN + N_2 + CuCl$

Product: benzonitrile (C_6H_5CN). This is a key reaction for introducing CN groups onto aromatic rings, which can be further hydrolysed to benzoic acid or reduced to benzylamine.

Step 3 — Other Sandmeyer reactions:

- With CuCl: $ArN_2^+ \rightarrow ArCl$ (chlorobenzene)
- With CuBr: $ArN_2^+ \rightarrow ArBr$ (bromobenzene)
- With CuI (or just KI): $ArN_2^+ \rightarrow ArI$ (iodobenzene)
- Gattermann reaction: uses Cu powder instead of CuX

Final Answer: Benzonitrile (C_6H_5CN) via Sandmeyer reaction $\Rightarrow$ A

Answer: (A) Go Back to Q15

Q16.

Solution

Concept — Reimer-Tiemann reaction (formylation of phenol): Treatment of phenol with $CHCl_3$ and NaOH (aqueous) gives an ortho-formylation product (salicylaldehyde).

Step 1 — Mechanism:

(a) $CHCl_3$ + NaOH $\rightarrow$ $:CCl_2$ (dichlorocarbene, an electrophile)
(b) Carbene attacks the electron-rich ortho position of the phenoxide ion
(c) Intermediate $\rightarrow$ hydrolysis by NaOH $\rightarrow$ CHO group

Step 2 — Products: Main product: **2-hydroxybenzaldehyde** (salicylaldehyde), with the CHO group at the ortho position. Minor product: 4-hydroxybenzaldehyde (para).

Step 3 — Use of salicylaldehyde: Salicylaldehyde is used in perfumery and as a precursor for synthesis of Schiff's bases and heterocyclic compounds. Also the key step in synthesising salicylic acid derivatives.

Distinguish from Kolbe-Schmitt reaction: Kolbe-Schmitt (phenol + CO_2/NaOH, pressure) gives salicylic acid (o-hydroxybenzoic acid), not the aldehyde.

Final Answer: 2-hydroxybenzaldehyde (salicylaldehyde) via dichlorocarbene $\Rightarrow$ B

Answer: (B) Go Back to Q16

Q17.

Solution

Concept — SN1 vs SN2 mechanisms in alkyl halides: Two substitution mechanisms compete depending on substrate structure and reaction conditions.

SN1 (unimolecular):

- Rate $= k[\mathrm{RX}]$ (only substrate, not nucleophile)
- Two-step: slow ionisation to carbocation, then fast nucleophilic attack
- Preferred by 3° substrates (stable carbocations)
- Polar protic solvents stabilise the carbocation
- Proceeds with **racemisation** (attack from both faces of planar carbocation)

SN2 (bimolecular):

- Rate $= k[\mathrm{RX}][\mathrm{Nu}^-]$ (both substrate and nucleophile)
- One step: concerted backside attack with simultaneous bond breaking
- Preferred by 1° substrates (less steric hindrance)
- Proceeds with **inversion of configuration** (Walden inversion)

Step 1 — Match to question: The question asks which statement is correct for 2-bromobutane (a 2° alkyl halide):

- Strong nucleophile (e.g. OH^-, CN^-) favours SN2 at 2° centre
- Weak nucleophile / polar protic / heat favours SN1

Final Answer: SN2 gives inversion; SN1 gives racemisation $\Rightarrow$ $\boxed{\mathrm{C}}$

Answer: (C) Go Back to Q17

Q18.

Solution

Concept — Claisen condensation vs aldol: When an ester reacts with a compound containing acidic α-H under basic conditions, a Claisen condensation occurs. Two ester molecules self-condense to give a β-keto ester.

Step 1 — Self-condensation of ethyl acetate:
$2\,CH_3COOC_2H_5 \xrightarrow{NaOEt} CH_3COCH_2COOC_2H_5 + C_2H_5OH$

Product: ethyl acetoacetate (ethyl 3-oxobutanoate), also called acetoacetic ester.

Step 2 — Mechanism (key steps):

(a) Base (EtO^-) removes acidic α-H from one ester to give an enolate ($CH_2^-COOC_2H_5$)
(b) Enolate attacks the carbonyl carbon of the second ester
(c) Tetrahedral intermediate collapses, expelling OEt^-
(d) Product is the β-keto ester; enolate form is more stable (product is trapped by its acidity)

Step 3 — Synthetic utility: Ethyl acetoacetate is used in the "acetoacetic ester synthesis" for making methylketones and cyclic compounds. The active methylene group (CH_2 between two carbonyls) is highly acidic ($pK_a \approx 11$) and can be alkylated.

Final Answer: Ethyl acetoacetate (Claisen condensation) $\Rightarrow$ C

Answer: (C) Go Back to Q18

Q19.

Solution

Concept — Nylon-6,6 condensation polymerisation: Nylon-6,6 is a polyamide made by condensation of two bifunctional monomers, each with 6 carbons.

Step 1 — Monomers:

- Hexamethylenediamine: $H_2N-(CH_2)_6-NH_2$ (a diamine)
- Adipic acid: $HOOC-(CH_2)_4-COOH$ (a diacid)

Step 2 — Polymerisation: Each amine group reacts with each carboxyl group to form an amide (peptide) bond and release water:

$$-NH_2 + HOOC- \rightarrow -NH-CO-+H_2O$$

n repeating units give: $[-NH-(CH_2)_6-NH-CO-(CH_2)_4-CO-]_n$

Step 3 — Properties of Nylon-6,6:

- High tensile strength (hydrogen bonds between C=O and N–H groups of adjacent chains)
- Melting point: 265°C
- Used for: stockings, ropes, toothbrush bristles, parachutes, engineering plastics

Nylon-6 vs Nylon-6,6: Nylon-6 is made from a single monomer (ε-caprolactam, ring-opening polymerisation). Nylon-6,6 uses two monomers. Both have similar properties but different crystallinity and melting points.

Final Answer: Hexamethylenediamine + adipic acid; amide (peptide) bonds $\Rightarrow$ A

Answer: (A) Go Back to Q19

Q20.

Solution

Concept — Essential and non-essential amino acids; structure and classification: Amino acids are the building blocks of proteins. They differ in side chain (R group), which determines their chemical behaviour and classification.

Classification by R group:

- Non-polar (hydrophobic): glycine (R=H), alanine (R=CH_3), leucine, valine, proline
- Polar uncharged: serine (R=CH_2OH), threonine, cysteine
- Acidic (negative charge at pH 7): aspartate ($-CH_2COO^-$), glutamate
- Basic (positive charge at pH 7): lysine (ε-NH_3^+), arginine, histidine

Step 1 — Essential amino acids: Must be obtained from diet (cannot be biosynthesised by mammals): Val, Leu, Ile, Thr, Met, Phe, Trp, Lys (and conditionally Arg, His).

Step 2 — Isoelectric point (pI): At pI, the amino acid exists as a zwitterion ($H_3N^+ - CHR - COO^-$) with zero net charge. Electrophoresis shows no migration at pH = pI.

Step 3 — Evaluate the given options regarding α-amino acids (the question discriminates on the correct general structure): All protein amino acids (except glycine) have an α-carbon that is a chiral centre (four different groups: H, R, NH_2, COOH) and exist as L-stereoisomers in living organisms (with the exception of glycine which is achiral).

Final Answer: α-carbon chiral (except Gly); L-configuration in proteins; zwitter ionic at pI $\Rightarrow$ C

Answer: (C) Go Back to Q20

Q21.

Solution

Concept — Aldol condensation (self-condensation of acetaldehyde): Aldehydes with α-H atoms undergo aldol condensation under base or acid catalysis.

Step 1 — Mechanism (base-catalysed):

(a) NaOH removes α-H from acetaldehyde: $CH_3CHO \xrightarrow{OH^-} \bar{C}H_2CHO$ (enolate)
(b) Enolate attacks the carbonyl of another acetaldehyde molecule: $CH_2^-CHO + CH_3CHO \rightarrow CH_3CH(OH)CH_2CHO$

Step 2 — Aldol product: $CH_3CH(OH)CH_2CHO$ = 3-hydroxybutanal (**aldol**). Contains both $-OH$ and $-CHO$ functional groups (hence the name: ald + ol = aldol).

Step 3 — Dehydration (aldol condensation): Heating the aldol product: $CH_3CH(OH)CH_2CHO \xrightarrow{\Delta} CH_3CH = CHCHO + H_2O$ Product: crotonaldehyde (2-butenal), a conjugated α, β-unsaturated aldehyde.

Why strong base favours self-condensation over crossed aldol: With only one aldehyde, only self-condensation is possible. Cross-aldol reactions are used when one reactant lacks α-H (e.g., benzaldehyde).

Final Answer: 3-hydroxybutanal (aldol), then crotonaldehyde on heating $\Rightarrow$ B

Answer: (B) Go Back to Q21

Q22.

Solution

Concept — Basicity of amines: Basicity of amines depends on: (a) availability of the lone pair on N, (b) inductive effects, (c) resonance, (d) solvation.

Alkyl vs aryl amines:

- Alkylamines (R-NH_2): alkyl groups are electron-donating (inductive effect), increasing lone pair availability $\Rightarrow$ stronger bases than NH_3. Basicity: $3^\circ > 2^\circ > 1^\circ >$ NH_3 in gas phase.
- Aromatic amines ($ArNH_2$): the lone pair delocalises into the ring (resonance) $\Rightarrow$ less available for protonation $\Rightarrow$ much weaker bases. pK_b (aniline) ≈ 9.4 vs pK_b (methylamine) ≈ 3.4.

Step 1 — Evaluate options: Option A (aniline $>$ cyclohexylamine): wrong, aniline is much weaker. Option B (methylamine $>$ trimethylamine in water): in water, solvation of the cation and steric effects complicate the order; methylamine actually $\approx$ trimethylamine in water. Option C (aniline $<$ cyclohexylamine): correct due to resonance delocalization in aniline. Option D: involves comparing across different substitution patterns.

Final Answer: Aromatic amines (aniline) weaker than aliphatic (cyclohexylamine) due to resonance $\Rightarrow$ C

Answer: (C) Go Back to Q22

Q23.

Solution

Concept — Deprotection of acetals / hemiacetals (hydrolysis in acid): Acetals ($R_2C(OR')_2$) are stable to base but hydrolysed by dilute aqueous acid back to the carbonyl compound and alcohol.

Step 1 — Mechanism:

(a) Protonation of one $-$OR' oxygen by H^+
(b) Elimination of ROH to give an oxocarbenium ion ($R_2C^+ - OR'$)
(c) Water attacks the electrophilic carbon
(d) Elimination of the second ROH after proton transfer restores the carbonyl

Step 2 — Synthetic significance: Acetals are used as **protecting groups** for aldehydes and ketones during reactions that are sensitive to the carbonyl group (e.g., reduction of a carboxylic acid in the presence of an aldehyde). The aldehyde is first converted to an acetal (protect), the desired reaction is done, then the acetal is hydrolysed (deprotect) under mild acidic conditions.

Step 3 — For the given cyclic acetal: 1,3-dioxolane derivative on hydrolysis gives the corresponding aldehyde/ketone + ethylene glycol.

Final Answer: Dilute H^+/H_2O regenerates the carbonyl compound + diol $\Rightarrow$ $\boxed{A}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept — Coordination isomerism: Coordination isomerism occurs in complexes containing both a complex cation and a complex anion. The ligands are distributed differently between the two metal centres in the two isomers.

Step 1 — Example: $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$ are coordination isomers.

Here Co and Cr have exchanged their ligands: in one isomer, Co has 6 NH_3 and Cr has 6 CN^-; in the other, the reverse.

Step 2 — Distinguish from other isomerism types:

- *Ionisation isomers*: $[CoBr(NH_3)_5]SO_4$ vs $[Co(SO_4)(NH_3)_5]Br$ (exchange of inner-sphere ligand and outer-sphere anion)
- *Linkage isomers*: $[Co(NO_2)(NH_3)_5]$ vs $[Co(ONO)(NH_3)_5]$ (ambidentate ligand bonded through different atoms)
- *Geometrical isomers*: cis and trans arrangements of the same ligands

Step 3 — Requirement for coordination isomerism: Both cation and anion must be complex ions (both contain a metal with coordinated ligands). If only one is a complex, coordination isomerism is not possible.

Final Answer: Coordination isomerism; ligands exchanged between complex cation and anion $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q24

Q25.

Solution

Concept — Rusting (electrochemical corrosion) of iron: Rusting is an electrochemical process requiring both O_2 and H_2O (moisture). It involves micro-galvanic cells set up on the iron surface.

Step 1 — Anodic regions (oxidation): $Fe \rightarrow Fe^{2+} + 2e^-$ (iron dissolves)

Step 2 — Cathodic regions (reduction): $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (oxygen is reduced)

Step 3 — Formation of rust: $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ (greenish precipitate) $4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 \cdot H_2O$ (hydrated iron oxide = rust, reddish-brown)

Step 4 — Prevention methods:

- Galvanising: coating with Zn (sacrificial anode). Even if scratched, Zn oxidises preferentially, protecting Fe.
- Tinning: coating with Sn (barrier protection). If scratched, Fe corrodes faster (Sn is cathodic to Fe).
- Painting, oiling, chromium plating: barrier protection.
- Alloying: stainless steel (Fe + Cr + Ni) forms a passive Cr_2O_3 layer.

Final Answer: Electrochemical; anode: $Fe \rightarrow Fe^{2+}$; cathode: O_2 reduction; product: $Fe_2O_3 \cdot H_2O \Rightarrow \boxed{D}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept — Reaction of alkyl halides with NaCN (SN2) and AgCN: Both NaCN and AgCN react with alkyl halides to give nitrile products, but via different mechanisms and products.

With NaCN (ionic, S_N2): CN^- is a strong nucleophile; it attacks via the C end (carbon is the nucleophilic atom in free CN^-) to give **alkyl nitrile** (R–CN).

With AgCN (covalent, ambidentate: AgCN is essentially covalent (Ag–C bond). When used, Ag^+ abstracts the halide (drives reaction by precipitating AgX), and the CN species attacks from the N end to give **isonitrile** (R–NC).

Step 1 — HSAB principle:

- Free CN^-: both C and N are available. C is softer (larger, more polarisable) $\Rightarrow$ bonds to soft electrophile (the C of RX) $\Rightarrow$ R–C$\equiv$N (nitrile).
- AgCN: already C-bound to Ag. N end is free $\Rightarrow$ bonds through N $\Rightarrow$ R–N$\equiv$C (isocyanide/isonitrile).

Step 2 — Products compared:

- R–CN (nitrile): C$\equiv$N; hydrolysable to carboxylic acid; provides a route to extend carbon chain by 1.
- R–NC (isonitrile): N$\equiv$C; extremely foul-smelling; hydrolysable to primary amine + formic acid.

Final Answer: NaCN $\rightarrow$ nitrile (R–CN); AgCN $\rightarrow$ isonitrile (R–NC) $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept — Emulsification and emulsifiers: An emulsion is a colloidal dispersion of one liquid in another immiscible liquid (e.g. oil in water, or water in oil). Emulsions are stabilised by emulsifying agents (emulsifiers) which reduce the interfacial tension.

Step 1 — How emulsifiers work: Emulsifier molecules have a hydrophilic head and a hydrophobic tail. They position themselves at the oil-water interface, reducing surface tension and preventing coalescence of the dispersed droplets.

Step 2 — Types of emulsions:

- Oil-in-water (O/W): oil droplets dispersed in water (e.g. milk, cream, salad dressing)
- Water-in-oil (W/O): water droplets dispersed in oil (e.g. butter, margarine)

Step 3 — Common emulsifiers: Soaps, detergents, lecithin, gum arabic, casein. These form protective films around the dispersed droplets.

Step 4 — Demulsification: Emulsions are broken (demulsified) by adding electrolytes (salting out), heating, centrifugation, or using chemical demulsifiers. This is important in petroleum processing (crude oil is a W/O emulsion that must be broken).

Final Answer: Emulsifying agents reduce interfacial tension and stabilise emulsions $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept — Ellingham diagram and thermodynamics of reduction: The Ellingham diagram plots ΔG° (or $RT \ln K_{eq}$) for metal oxide formation vs temperature. It helps predict which metal can reduce another metal's oxide.

Rule: Metal A can reduce the oxide of metal B if line A is below line B on the Ellingham diagram at the relevant temperature (A has more negative ΔG_f° for its oxide).

Step 1 — Why carbon (coke) is used in blast furnace: Carbon has an unusual Ellingham curve that slopes downward with temperature (because the reaction produces more gas moles: C + $O_2 \rightarrow CO_2$ or 2C + $O_2 \rightarrow$ 2CO). Above $\sim 700^\circ$C (for CO_2) and above $\sim 1000^\circ$C (for CO), carbon's line crosses below the Fe_2O_3 and FeO lines $\Rightarrow$ C can reduce Fe oxides at high temperatures.

Step 2 — Why Al cannot be reduced by carbon: Al_2O_3 is so stable (ΔG_f° very negative) that even at very high temperatures, carbon cannot reduce it thermodynamically. Al_2O_3 is reduced by electrolysis (Hall-Héroult process) instead.

Step 3 — Temperature dependence: $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$. If $\Delta S > 0$ (more gas moles in products), ΔG becomes more negative at higher T, making the reaction more favourable. Carbon's increasing gas product (CO) explains its downward slope.

Final Answer: ΔG below zero means spontaneous; C reduces Fe oxide above 1000°C $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q28

Q29.

Solution

Concept — Adsorption isotherms (Freundlich and Langmuir):

Freundlich adsorption isotherm:

$$\frac{x}{m} = kP^{1/n} \quad (0 < 1/n < 1)$$

Taking log: $\log(x/m) = \log k + \frac{1}{n}\log P$

A plot of $\log(x/m)$ vs $\log P$ is linear with slope $= 1/n$ and intercept $= \log k$. This is an empirical isotherm valid over moderate pressure ranges.

Langmuir adsorption isotherm:

$$\frac{x}{m} = \frac{abP}{1 + bP}$$

Assumes monolayer adsorption on uniform sites with no interaction between adsorbed molecules.

Step 1 — Distinguish types of adsorption:

- Physisorption (physical adsorption): weak van der Waals forces; low ΔH (5–40 kJ/mol); reversible; multilayer; favoured at low T
- Chemisorption (chemical adsorption): chemical bond formation; high ΔH (40–400 kJ/mol); monolayer; often irreversible; shows activation energy

Step 2 — Effect of temperature: Physisorption decreases with increasing T (desorption occurs). Chemisorption first increases then decreases with T (requires activation energy to form the bond, but then thermodynamics drives desorption at very high T).

Final Answer: Freundlich: $\log(x/m)$ vs $\log P$ linear; Langmuir: monolayer model $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept — Radioactive decay: activity and half-life:

$$A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}} = A_0 e^{-\lambda t}$$

where $\lambda = \ln 2/t_{1/2}$ is the decay constant and A is activity (decays/second).

Step 1 — Relationship between N, A, and $t_{1/2}$: $A = \lambda N = \frac{\ln 2}{t_{1/2}} \times N$

Solve for N: $N = \frac{A \times t_{1/2}}{\ln 2}$

Step 2 — Convert units: $A = 3.7 \times 10^{10}$ Bq (1 Curie = 3.7×10^{10} disintegrations/s); $t_{1/2} = 138$ days $= 138 \times 86400\,\text{s} = 1.192 \times 10^{7}\,\text{s}$.

$N = \frac{3.7 \times 10^{10} \times 1.192 \times 10^{7}}{0.693} = \frac{4.41 \times 10^{17}}{0.693} = 6.37 \times 10^{17}$ atoms.

Step 3 — Mass: $m = N \times m_{\text{atom}} = \frac{6.37 \times 10^{17}}{6.022 \times 10^{23}} \times 210\,\text{g mol}^{-1} = 1.058 \times 10^{-6} \times 210 = 2.22 \times 10^{-4}\,\text{g} \approx \mathbf{0.222}\,\text{mg}$

Physical significance: Even a tiny mass of a radioactive isotope (sub-milligram) has enormous activity (3.7×10^{10} disintegrations/s). This illustrates why radioactive contamination at even trace levels is hazardous.

Final Answer: $N \approx 6.37 \times 10^{17}$ atoms; $m \approx 0.222\,\text{mg} \Rightarrow$ D

Answer: (D) Go Back to Q30

Answer Key

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