BITSAT Chemistry Sample Paper – 2

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. $10\,\mathrm{g}$ of $\mathrm{CaCO_3}$ is heated strongly. The mass of CaO formed and the volume of $\mathrm{CO_2}$ released at STP are: ($M_{\mathrm{CaCO_3}} = 100$, $M_{\mathrm{CaO}} = 56\,\mathrm{g\,mol^{-1}}$)

(A) $5.6\,\mathrm{g}$ CaO; $2.24\,\mathrm{L}$ $\mathrm{CO_2}$

(B) $11.2\,\mathrm{g}$ CaO; $4.48\,\mathrm{L}$ $\mathrm{CO_2}$

(C) $5.6\,\mathrm{g}$ CaO; $4.48\,\mathrm{L}$ $\mathrm{CO_2}$

(D) $2.8\,\mathrm{g}$ CaO; $2.24\,\mathrm{L}$ $\mathrm{CO_2}$

Q2. $100\,\mathrm{mL}$ of $0.1\,\mathrm{M}$ $\mathrm{H_2SO_4}$ is neutralised by NaOH. The number of moles of NaOH required and the mass of $\mathrm{Na_2SO_4}$ formed are:

(A) $0.01\,\mathrm{mol}$ NaOH; $0.71\,\mathrm{g}$ $\mathrm{Na_2SO_4}$

(B) $0.01\,\mathrm{mol}$ NaOH; $1.42\,\mathrm{g}$ $\mathrm{Na_2SO_4}$

(C) $0.02\,\mathrm{mol}$ NaOH; $2.84\,\mathrm{g}$ $\mathrm{Na_2SO_4}$

(D) $0.02\,\mathrm{mol}$ NaOH; $1.42\,\mathrm{g}$ $\mathrm{Na_2SO_4}$

Q3. Which of the following sets of quantum numbers is **not** allowed?

(A) $n = 3,\ l = 2,\ m_l = 0,\ m_s = +\frac{1}{2}$

(B) $n = 2,\ l = 1,\ m_l = -1,\ m_s = -\frac{1}{2}$

(C) $n = 3,\ l = 3,\ m_l = 2,\ m_s = +\frac{1}{2}$

(D) $n = 4,\ l = 0,\ m_l = 0,\ m_s = -\frac{1}{2}$

Q4. The dipole moment of CCl_4 is zero whereas that of $CHCl_3$ is non-zero. This is because:

(A) Both molecules have the same symmetry

(B) $C - H$ bonds are non-polar while $C - Cl$ bonds are polar

(C) The C–Cl bond length is longer in $CHCl_3$ than in CCl_4

(D) CCl_4 is tetrahedral with bond dipoles cancelling; $CHCl_3$ lacks this symmetry, leaving a net dipole

Q5. Arrange the following in decreasing order of bond order: N_2, O_2, O_2^+, O_2^-

(A) $N_2 > O_2^+ > O_2 > O_2^-$

(B) $O_2^+ > N_2 > O_2 > O_2^-$

(C) $N_2 > O_2 > O_2^+ > O_2^-$

(D) $N_2 > O_2^- > O_2 > O_2^+$

Q6. In hydrogen bonding, which of the following pairs exhibits **intermolecular** hydrogen bonding of the strongest type?

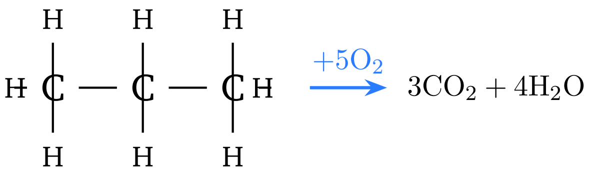
(A) CH_3OCH_3 (diethyl ether)

(B) o-nitrophenol

(C) HF molecules in liquid HF

(D) Ethanol in benzene solution

Q7. The standard enthalpy of combustion of propane $C_3H_8(g)$ is $-2220\,\mathrm{kJ\,mol^{-1}}$. Given bond enthalpies: $C - H = 413$, $C - C = 347$, $O = O = 498$, $C = O = 805$, $O - H = 463\,\mathrm{kJ\,mol^{-1}}$, the reaction scheme is:



$$\mathrm{H-C-C-C-H} \xrightarrow{+5O_2} 3CO_2 + 4H_2O$$

(A) $\Delta H^\circ_{\text{combustion}} \approx -2044\,\text{kJ mol}^{-1}$

(B) $\Delta H^\circ_{\text{combustion}} \approx -2218\,\text{kJ mol}^{-1}$

(C) $\Delta H^\circ_{\text{combustion}} \approx -1560\,\text{kJ mol}^{-1}$

(D) $\Delta H^\circ_{\text{combustion}} \approx -2750\,\text{kJ mol}^{-1}$

Q8. For a reaction with $\Delta H = +50\,\text{kJ mol}^{-1}$ and $\Delta S = +125\,\text{J mol}^{-1}\text{K}^{-1}$, the minimum temperature above which the reaction becomes spontaneous is:

(A) $T > 400\,\text{K}$

(B) $T > 625\,\text{K}$

(C) $T > 200\,\text{K}$

(D) $T > 100\,\text{K}$

Q9. For the equilibrium $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$, $K_c = 4.0 \times 10^{-4}$ at $2000\,\text{K}$. If 0.1 mol each of N_2 and O_2 are placed in a $1\,\text{L}$ flask, the equilibrium concentration of NO is approximately:

(A) $[\text{NO}] \approx 0.002\,\text{M}$

(B) $[\text{NO}] \approx 0.004\,\text{M}$

(C) $[\text{NO}] \approx 0.02\,\text{M}$

(D) $[\text{NO}] \approx 0.04\,\text{M}$

Q10. The solubility product of Ag_2CrO_4 is $K_{sp} = 1.12 \times 10^{-12}$. The molar solubility (s) of Ag_2CrO_4 in pure water is:

(A) $s = 6.5 \times 10^{-5}\,\text{mol L}^{-1}$

(B) $s = 1.06 \times 10^{-4}\,\text{mol L}^{-1}$

(C) $s = 3.34 \times 10^{-5}\,\text{mol L}^{-1}$

(D) $s = 5.0 \times 10^{-7}\,\text{mol L}^{-1}$

Q11. The standard electrode potentials are: $E^\circ(\mathrm{Zn}^{2+}/\mathrm{Zn}) = -0.76\,\mathrm{V}$ and $E^\circ(\mathrm{Fe}^{3+}/\mathrm{Fe}^{2+})$ $+0.77\,\mathrm{V}$. The standard cell EMF and ΔG° (in kJ) for the cell $\mathrm{Zn}|\mathrm{Zn}^{2+}||\mathrm{Fe}^{3+},\mathrm{Fe}^{2+}|\mathrm{Pt}$ are:

(A) $E^\circ_{\text{cell}} = 1.53\,\mathrm{V};\ \ \Delta G^\circ = -147.8\,\mathrm{kJ}$

(B) $E^\circ_{\text{cell}} = 0.01\,\mathrm{V};\ \ \Delta G^\circ = -0.97\,\mathrm{kJ}$

(C) $E^\circ_{\text{cell}} = 1.53\,\mathrm{V};\ \ \Delta G^\circ = -295.6\,\mathrm{kJ}$

(D) $E^\circ_{\text{cell}} = 1.53\,\mathrm{V};\ \ \Delta G^\circ = +147.8\,\mathrm{kJ}$

Q12. The molar conductivity Λ_m of a weak acid HA at concentration $c = 0.01\,\mathrm{M}$ is $7.2\,\mathrm{S\,cm^2\,mol^{-1}}$. The limiting molar conductivity $\Lambda^\circ_m = 360\,\mathrm{S\,cm^2\,mol^{-1}}$. The degree of dissociation and K_a are:

(A) $\alpha = 0.02;\ \ K_a = 2.04 \times 10^{-6}$

(B) $\alpha = 0.02;\ \ K_a = 4.08 \times 10^{-6}$

(C) $\alpha = 0.10;\ \ K_a = 1.11 \times 10^{-3}$

(D) $\alpha = 0.04;\ \ K_a = 1.67 \times 10^{-5}$

Q13. A first-order reaction has a half-life of $t_{1/2} = 693\,\mathrm{s}$. Starting with an initial concentration $[\mathrm{A}]_0 = 0.5\,\mathrm{M}$, the concentration after $2079\,\mathrm{s}$ is:

(A) $0.25\,\mathrm{M}$

(B) $0.125\,\mathrm{M}$

(C) $0.0625\,\mathrm{M}$

(D) $0.50\,\mathrm{M}$

Q14. Which of the following statements about the oxides of nitrogen is **correct**?

(A) N_2O is the anhydride of nitric acid (HNO_3)

(B) NO_2 dimerises to form N_2O_4 at low temperatures and is a paramagnetic brown gas

(C) N_2O_3 is the most stable oxide of nitrogen at room temperature

(D) NO is diamagnetic because all its electrons are paired

Q15. The reaction of XeF_4 with water gives an unexpected product due to disproportionation. The reaction is:

$$\boxed{XeF_4 + H_2O} \xrightarrow{\text{disproportionation}} ?$$

(A) $Xe + 2HF + \frac{1}{2}O_2$ only

(B) $XeO_3 + 6HF$ only

(C) $2Xe + 4HF + O_2$ and $XeO_3 + 6HF$ (mixture)

(D) $XeF_2 + H_2O_2$

Q16. Which of the following correctly differentiates the chemical behaviour of Li from other alkali metals?

(A) Li reacts with water to give $LiOH$ and H_2, unlike Na which gives Na_2O

(B) Li is less electropositive than Na because of its larger atomic size

(C) Li dissolves in liquid ammonia to give a blue solution unlike other alkali metals

(D) Li forms a nitride Li_3N directly with N_2, unlike Na and K which do not react directly with N_2

Q17. An ionic crystal has a rock salt (NaCl-type) structure. If the radius ratio $r_+/r_- = 0.52$, the coordination number of the cation and anion, and the unit cell type are:

(A) CN = 4 for both; zinc blende structure

(B) CN = 6 for both; face-centred cubic unit cell

(C) CN = 8 for both; body-centred cubic unit cell

(D) CN = 6 cation, 4 anion; mixed structure

Q18. A non-volatile solute is dissolved in water. The vapour pressure of pure water at $25^\circ\mathrm{C}$ is $23.8\,\mathrm{mmHg}$. When $18\,\mathrm{g}$ of glucose ($M = 180$) is dissolved in $180\,\mathrm{g}$ of water ($M = 18$), the lowering of vapour pressure is:

(A) $\Delta P = 0.238\,\mathrm{mmHg}$

(B) $\Delta P = 0.119\,\mathrm{mmHg}$

(C) $\Delta P = 2.38\,\mathrm{mmHg}$

(D) $\Delta P = 0.476\,\mathrm{mmHg}$

Q19. According to IUPAC nomenclature, the complex $[\mathrm{Co(NH_3)_4Cl_2}]^+$ is named:

(A) Dichlorotetraamminecobalt(II) ion

(B) Tetraaminedichlorocobalt(III) ion

(C) Tetraamminedichlorocobalt(III) ion

(D) Dichlorotetraamminecobalt(III) ion

Q20. The complex $[\mathrm{Cr(en)_3}]^{3+}$ (where en = ethylenediamine) exhibits which type of isomerism?

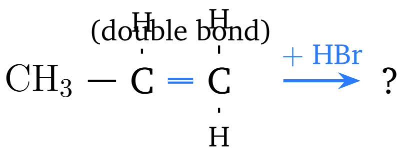
(A) Ionisation isomerism

(B) Linkage isomerism

(C) Optical isomerism (chirality, no plane of symmetry)

(D) Coordination isomerism

Q21. Propene undergoes Markovnikov addition of HBr. The major product is:



$$\mathrm{CH_3} - \overset{\mathrm{H}}{\mathrm{C}} \overset{\text{(double bond)}}{=} \underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}} \xrightarrow{+\,\mathrm{HBr}} ?$$

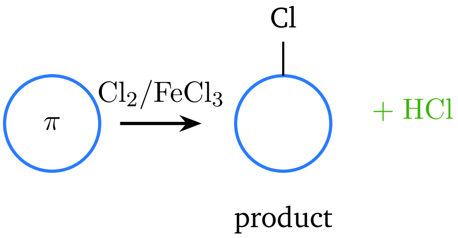
(A) 1-bromopropane ($\mathrm{CH_3CH_2CH_2Br}$)

(B) 2-bromopropane ($\mathrm{CH_3CHBrCH_3}$)

(C) 1,2-dibromopropane

(D) Allyl bromide ($CH_2 = CHCH_2Br$)

Q22. Benzene reacts with Cl_2 in the presence of $FeCl_3$ (Lewis acid catalyst) via electrophilic substitution. The electrophile and the product are:



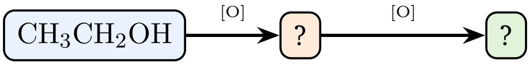
(A) Electrophile: Cl^-; product: 1,2-dichlorobenzene

(B) Electrophile: Cl^+ (chloronium); product: chlorobenzene $+HCl$

(C) Electrophile: Cl_2 directly; product: chlorobenzene

(D) Electrophile: $FeCl_3$; product: fluorobenzene

Q23. The oxidation of ethanol by acidified $K_2Cr_2O_7$ proceeds stepwise. The sequence of products is:



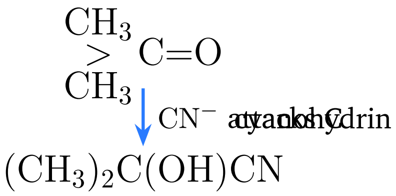
(A) CH_3CHO (ethanal), then CH_3COOH (ethanoic acid)

(B) CH_3COCH_3 (acetone), then CH_3COOH

(C) CH_3CHO, then CH_3CH_2COOH (propanoic acid)

(D) $CH_2 = CH_2$ (ethene), then CH_3COOH

Q24. Acetone (CH_3COCH_3) undergoes nucleophilic addition with HCN to form a cyanohydrin. The mechanism involves:



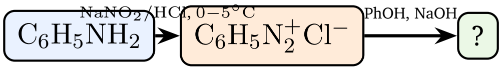
- (A) Electrophilic addition: H^+ from HCN attacks the oxygen first
- (B) Nucleophilic addition: CN^- attacks the electrophilic carbonyl carbon, then H^+ protonates the alkoxide
- (C) Free radical addition initiated by peroxides
- (D) Electrophilic substitution on the methyl group

Q25. Acetic acid reacts with PCl_5 to give acetyl chloride. This reaction is an example of:

$$\begin{tikzcd}
CH_3COOH + PCl_5 \arrow[d, "\text{what reaction type?}"] \\
CH_3COCl + POCl_3 + HCl
\end{tikzcd}$$

- (A) Esterification (nucleophilic acyl substitution with an alcohol)
- (B) Replacement of $-OH$ by $-Cl$ (formation of an acid chloride)
- (C) Electrophilic addition to the C=O of acetic acid
- (D) Reduction of the carboxylic acid group

Q26. Aniline ($C_6H_5NH_2$) is treated with $NaNO_2$ and HCl at $0–5°C$ to give a diazonium salt, which is then coupled with phenol in alkaline solution:



- (A) Diphenyl ether ($C_6H_5OC_6H_5$)
- (B) Benzene (C_6H_6) by loss of N_2
- (C) Nitrobenzene ($C_6H_5NO_2$)
- (D) *p*-Hydroxyazobenzene (an azo dye, $C_6H_5 - N = N - C_6H_4OH$)

Q27. Which of the following about DNA double helix is **correct**?

- (A) Adenine pairs with cytosine via two hydrogen bonds; guanine pairs with thymine via three hydrogen bonds

(B) The two strands are parallel (both $5' \rightarrow 3'$ direction) and held by covalent bonds

(C) Adenine pairs with thymine via two H-bonds; guanine pairs with cytosine via three H-bonds; strands are antiparallel

(D) The sugar in DNA is ribose and in RNA is deoxyribose

Q28. Enzymes are biological catalysts. Which of the following statements about enzyme action is **incorrect**?

(A) Enzymes lower the activation energy of a reaction

(B) Enzymes are consumed in the reaction and must be replenished

(C) The active site of an enzyme has a specific shape complementary to the substrate

(D) Enzyme activity can be inhibited by heavy metal ions

Q29. Bakelite is a thermosetting polymer formed by the condensation of phenol and formaldehyde. Its structure involves:

(A) Linear chains of alternating phenol and formaldehyde units

(B) Cross-linked three-dimensional network via methylene ($-CH_2-$) bridges at ortho and para positions

(C) Addition polymer of phenol monomers

(D) Polyester linkage between phenol and formaldehyde

Q30. In the preparation of a colloid by the Bredig's arc method, the sol produced is:

(A) Emulsion (liquid in liquid)

(B) Lyophilic sol (metal ions strongly solvated)

(C) Lyophobic metal sol (metal particles dispersed in water)

(D) A true solution of the metal salt

Detailed Solutions

Q1.

Solution

Concept — Stoichiometry of thermal decomposition: When $CaCO_3$ is heated strongly it undergoes complete thermal decomposition:

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

The molar ratio is exactly 1 : 1 : 1, so every mole of $CaCO_3$ gives 1 mol CaO and 1 mol CO_2.

Step 1 — Moles of $CaCO_3$:

$$n(CaCO_3) = \frac{m}{M} = \frac{10\,g}{100\,g\,mol^{-1}} = 0.1\,mol$$

Step 2 — Mass of CaO: $n(CaO) = 0.1\,mol; \quad m(CaO) = 0.1 \times 56 = \mathbf{5.6}\,g$.

Step 3 — Volume of CO_2 at STP: At STP (0°C, 1 atm), 1 mol of any ideal gas occupies 22.4 L.

$$V(CO_2) = 0.1\,mol \times 22.4\,L\,mol^{-1} = \mathbf{2.24}\,L$$

Common error: Confusing STP (22.4 L/mol) with SATP (24.8 L/mol at 25°C). BITSAT uses STP (0°C) unless stated otherwise.

Final Answer: $5.6\,g$ CaO and $2.24\,L$ $CO_2 \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept — Neutralisation stoichiometry: H_2SO_4 is a diprotic acid, so it furnishes 2 moles of H^+ per mole:

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

The molar ratios are: $H_2SO_4 : NaOH : Na_2SO_4 = 1 : 2 : 1$.

Step 1 — Moles of H_2SO_4:

$$n(H_2SO_4) = C \times V = 0.1\,\text{mol}\,\text{L}^{-1} \times 0.100\,\text{L} = 0.01\,\text{mol}$$

Step 2 — Moles of NaOH required:

$$n(\text{NaOH}) = 2 \times n(H_2SO_4) = 2 \times 0.01 = \mathbf{0.02}\,\text{mol}$$

Step 3 — Mass of Na_2SO_4 formed: $n(Na_2SO_4) = n(H_2SO_4) = 0.01\,\text{mol}$. $M(Na_2SO_4) = 2(23) + 32 + 4(16) = 46 + 32 + 64 = 142\,\text{g}\,\text{mol}^{-1}$.

$$m(Na_2SO_4) = 0.01 \times 142 = \mathbf{1.42}\,\text{g}$$

Key point: Option A gives 0.01 mol NaOH — that would only neutralise one of the two acidic protons of H_2SO_4. The complete neutralisation requires 0.02 mol.

Final Answer: $0.02\,\text{mol NaOH};\ \ 1.42\,\text{g}\ Na_2SO_4 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept — Rules for quantum numbers:

- Principal quantum number n: positive integer (1, 2, 3, . . .)
- Azimuthal quantum number l: integer from 0 to $(n-1)$
- Magnetic quantum number m_l: integer from $-l$ to $+l$
- Spin quantum number m_s: $+\frac{1}{2}$ or $-\frac{1}{2}$ only

Step 1 — Check each option:

Option A: $n = 3, l = 2$ — valid because $l \leq n-1 = 2$; $m_l = 0$ — valid (range -2 to $+2$); $m_s = +\frac{1}{2}$ — valid. **Allowed.**

Option B: $n = 2, l = 1$ — valid ($l \leq 1$); $m_l = -1$ — valid; $m_s = -\frac{1}{2}$ — valid. **Allowed.**

Option C: $n = 3, l = 3$ — **INVALID**. For $n = 3$, l can only be 0, 1, or 2. $l = 3$ is only possible when $n \geq 4$. This set is forbidden.

Option D: $n = 4, l = 0$ — valid; $m_l = 0$ — valid (only value for $l = 0$); $m_s = -\frac{1}{2}$ — valid. **Allowed.**

Physical meaning: $l = 3$ corresponds to the f subshell, which first appears in $n = 4$ (4f). There is no 3f subshell in any real atom.

Final Answer: $n = 3, l = 3$ violates $l \leq n-1 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept — Molecular polarity and symmetry: Net dipole moment of a molecule = vector sum of all bond dipoles. If the bond dipoles cancel due to molecular symmetry, $\mu = 0$ (non-polar). If they do not cancel, the molecule has a net dipole.

Step 1 — CCl_4 (tetrahedral): Each C–Cl bond is polar (δ^+ on C, δ^- on Cl) because Cl is more electronegative. However, the four C–Cl bond dipoles are arranged symmetrically at tetrahedral angles $(109.5°)$. Their vector sum is exactly zero $\Rightarrow$ $\mu(CCl_4) = 0$.

Step 2 — $CHCl_3$ (trigonal pyramidal/tetrahedral-like): Replacing one Cl with H breaks the perfect tetrahedral symmetry. The C–H bond is much less polar and points in a different direction from the three C–Cl bonds. The three C–Cl dipoles now have a resultant that does not cancel the C–H dipole $\Rightarrow \mu(CHCl_3) \neq 0$ (measured: $\approx 1.04\,D$).

Step 3 — Why other options are incomplete: Option C says "C–H bonds are non-polar" — this is partially true but not the *reason* for the dipole. The correct reason is the *loss of tetrahedral symmetry* when H replaces one Cl.

Final Answer: CCl_4 tetrahedral symmetry cancels dipoles; $CHCl_3$ lacks this symmetry $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Bond order from MO theory:

$$\text{Bond order} = \frac{1}{2}(\text{bonding electrons} - \text{antibonding electrons})$$

Step 1 — MO electron configurations:

N_2 (14 e^-): $(\sigma_{1s})^2(\sigma^*_{1s})^2(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2$

Bonding e^- = 10; antibonding e^- = 4; BO $= \frac{1}{2}(10-4) = \mathbf{3}$.

O_2 (16 e^-): same as above plus $(\pi^*_{2p})^2$

Bonding e^- = 10; antibonding e^- = 6; BO $= \frac{1}{2}(10-6) = \mathbf{2}$.

O_2^+ (15 e^-, one e^- removed from π^*):

Antibonding e^- = 5; BO $= \frac{1}{2}(10-5) = \mathbf{2.5}$.

O_2^- (17 e^-, one extra e^- in π^*):

Antibonding e^- = 7; BO $= \frac{1}{2}(10-7) = \mathbf{1.5}$.

Step 2 — Decreasing order: $N_2(3) > O_2^+(2.5) > O_2(2) > O_2^-(1.5)$

Physical significance: Higher bond order = shorter bond length and larger bond dissociation energy. N_2 has the strongest bond among common diatomic molecules $(945\,\text{kJ mol}^{-1})$.

Final Answer: $N_2 > O_2^+ > O_2 > O_2^- \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Types of hydrogen bonding: Hydrogen bonding: X–H$\cdots$Y where X and Y are highly electronegative atoms (F, O, N). Strength depends on electronegativity and whether the H-bond is intramolecular or intermolecular.

Step 1 — Evaluate each option:

Option A — Diethyl ether (CH_3OCH_3)*:* Has an electronegative O, but NO O–H bond, so it cannot act as a H-bond donor. Ether can only accept H-bonds from other molecules. No self-association via H-bonding.

Option B — o-nitrophenol: The –OH group forms an *intramolecular* H-bond with the adjacent nitro group ($O - H \cdots O = N$). This is within the same molecule, so it *reduces* intermolecular H-bonding.

Option C — Liquid HF: F is the most electronegative element ($\chi = 4.0$). The F–H bond is strongly polarised. In liquid HF, extensive F–H$\cdots$F chains form. The F–H$\cdots$F bond is the strongest intermolecular H-bond known (BDE $\approx 40\,\text{kJ}\,\text{mol}^{-1}$), explaining HF's anomalously high boiling point ($+19.5°$C) compared to HCl ($-85°$C).

Option D — Ethanol in benzene: Very dilute; H-bonding largely disrupted by the non-polar benzene solvent.

Final Answer: Liquid HF — strongest intermolecular H-bonding (F–H$\cdots$F) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept — Bond enthalpy method for $\Delta H_{\text{combustion}}$:

$$\Delta H_{\text{rxn}} = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds formed})$$

Energy is *absorbed* to break bonds and *released* when bonds form.

Balanced equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Step 1 — Bonds broken in reactants:

Propane (C_3H_8): 2 C–C bonds + 8 C–H bonds

$$= 2(347) + 8(413) = 694 + 3304 = 3998\,\text{kJ mol}^{-1}$$

5 O_2 *molecules:* 5 O=O bonds

$$= 5(498) = 2490\,\text{kJ mol}^{-1}$$

Total bonds broken $= 3998 + 2490 = \mathbf{6488}\,\text{kJ mol}^{-1}$

Step 2 — Bonds formed in products:

3 CO_2*:* each has 2 C=O bonds $\Rightarrow 3 \times 2 \times 805 = 4830\,\text{kJ mol}^{-1}$

4 H_2O*:* each has 2 O–H bonds $\Rightarrow 4 \times 2 \times 463 = 3704\,\text{kJ mol}^{-1}$

Total bonds formed $= 4830 + 3704 = \mathbf{8534}\,\text{kJ mol}^{-1}$

Step 3 — ΔH:

$$\Delta H = 6488 - 8534 = -2046 \approx -\mathbf{2044}\,\text{kJ mol}^{-1}$$

Note: The experimental value is $-2220\,\text{kJ mol}^{-1}$. Bond enthalpy calculations give approximate results because average bond enthalpies vary between different molecular environments.

Final Answer: $\Delta H_{\text{combustion}} \approx -2044\,\text{kJ mol}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A)

Go Back to Q7

Q8.

Solution

Concept — Spontaneity and the Gibbs equation:

$$\Delta G = \Delta H - T\Delta S$$

A reaction is spontaneous when $\Delta G < 0$. The crossover temperature T^* is where $\Delta G = 0$:

$$T^* = \frac{\Delta H}{\Delta S}$$

Step 1 — Identify signs: $\Delta H = +50\,\text{kJ}\,\text{mol}^{-1}$ (endothermic) and $\Delta S = +125\,\text{J}\,\text{mol}^{-1}\text{K}^{-1}$ (increasing disorder).

At low T: $T\Delta S < \Delta H \Rightarrow \Delta G > 0$ (non-spontaneous). At high T: $T\Delta S > \Delta H \Rightarrow \Delta G < 0$ (spontaneous).

Step 2 — Calculate T^*: Note: ΔH must be in J: $50\,\text{kJ} = 50000\,\text{J}$.

$$T^* = \frac{50000\,\text{J}\,\text{mol}^{-1}}{125\,\text{J}\,\text{mol}^{-1}\text{K}^{-1}} = \mathbf{400}\,\text{K}$$

Step 3 — Conclusion: For $T > 400\,\text{K}$: $\Delta G < 0 \Rightarrow$ spontaneous.

Common error: Forgetting to convert ΔH from kJ to J before dividing by ΔS in J/K. Mixing units is a frequent source of errors.

Final Answer: Spontaneous when $T > 400\,\text{K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept — ICE table for equilibrium: For $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$, the expression is:

$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$

Step 1 — Set up ICE table (volume = 1 L; concentrations equal moles):

	N_2	O_2	$2NO$
I	0.10	0.10	0
C	$-x$	$-x$	$+2x$
E	$0.10-x$	$0.10-x$	$2x$

Step 2 — Apply equilibrium expression:

$$K_c = \frac{(2x)^2}{(0.10-x)(0.10-x)} = \frac{4x^2}{(0.10-x)^2} = 4.0 \times 10^{-4}$$

Taking the square root of both sides:

$$\frac{2x}{0.10-x} = \sqrt{4.0 \times 10^{-4}} = 0.02$$

Step 3 — Solve for x:

$$2x = 0.02(0.10-x) = 0.002 - 0.02x$$

$$2x + 0.02x = 0.002 \implies 2.02x = 0.002 \implies x = 9.9 \times 10^{-4}\,\text{M}$$

Step 4 — Equilibrium concentration of NO:

$$[NO] = 2x = 2 \times 9.9 \times 10^{-4} \approx 2.0 \times 10^{-3} = \mathbf{0.002}\,\text{M}$$

Check: $K_c = (0.002)^2/(0.099)^2 = 4 \times 10^{-6}/9.8 \times 10^{-3} \approx 4 \times 10^{-4}$ ✓

Final Answer: $[NO]_{eq} \approx 0.002\,\text{M} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept — Solubility product and molar solubility: For $Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$:

Let s = molar solubility. Then $[Ag^+] = 2s$ and $[CrO_4^{2-}] = s$.

$$K_{sp} = [Ag^+]^2[CrO_4^{2-}] = (2s)^2 \cdot s = 4s^3$$

Step 1 — Solve for s:

$$4s^3 = 1.12 \times 10^{-12} \implies s^3 = \frac{1.12 \times 10^{-12}}{4} = 2.80 \times 10^{-13}$$

Step 2 — Calculate the cube root:

$$s = (2.80 \times 10^{-13})^{1/3}$$

Rewrite: $2.80 \times 10^{-13} = 2.80 \times 10^{-13}$. Take cube root: $(10^{-13})^{1/3} = 10^{-4.333} = 10^{-4} \times 10^{-0.333} = 10^{-4} \times 0.464$. $(2.80)^{1/3} \approx 1.409$.

$s = 1.409 \times 0.464 \times 10^{-4} = 0.654 \times 10^{-4} = \mathbf{6.5 \times 10^{-5}}\,\text{mol}\,\text{L}^{-1}$

Verification: $K_{sp} = 4 \times (6.5 \times 10^{-5})^3 = 4 \times 2.74 \times 10^{-13} = 1.10 \times 10^{-12} \approx 1.12 \times 10^{-12}$ ✓

Key point: The Ag_2CrO_4 formula gives *two* Ag^+ ions per formula unit — a common mistake is writing $K_{sp} = s \cdot s = s^2$, which is wrong.

Final Answer: $s \approx 6.5 \times 10^{-5}\,\text{mol}\,\text{L}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q10**

Q11.

Solution

Concept — Cell EMF, electron count, and Gibbs energy:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}$$

Step 1 — Half-reactions and n:

Anode (oxidation): $\mathrm{Zn} \rightarrow \mathrm{Zn}^{2+} + 2\mathrm{e}^-$

Cathode (reduction): $2\mathrm{Fe}^{3+} + 2\mathrm{e}^- \rightarrow 2\mathrm{Fe}^{2+}$

Total electrons transferred: $n = 2$.

Step 2 — Standard cell EMF:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = (+0.77) - (-0.76) = +1.53\,\mathrm{V}$$

The positive value confirms the reaction is spontaneous under standard conditions.

Step 3 — Standard Gibbs energy:

$$\Delta G^\circ = -nFE^\circ = -(2)(96500\,\mathrm{C\,mol^{-1}})(1.53\,\mathrm{V})$$

$$= -295590\,\mathrm{J\,mol^{-1}} \approx -\mathbf{295.6}\,\mathrm{kJ\,mol^{-1}}$$

Note on option A: It gives $-147.8\,\mathrm{kJ}$, which corresponds to $n = 1$. This would be correct only if we consider the half-reaction with 1 electron. But the overall balanced cell reaction transfers 2 electrons.

Final Answer: $E^\circ = 1.53\,\mathrm{V};\ \ \Delta G^\circ = -295.6\,\mathrm{kJ} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) **Go Back to Q11**

Q12.

Solution

Concept — Degree of dissociation and weak acid K_a:

$$\alpha = \frac{\Lambda_m}{\Lambda_m^\circ}, \qquad K_a = \frac{c\alpha^2}{1-\alpha}$$

where Λ_m is the molar conductivity at concentration c and Λ_m° is the limiting molar conductivity.

Step 1 — Degree of dissociation α:

$$\alpha = \frac{\Lambda_m}{\Lambda_m^\circ} = \frac{7.2\,\mathrm{S\,cm^2\,mol^{-1}}}{360\,\mathrm{S\,cm^2\,mol^{-1}}} = 0.02$$

So only 2% of the acid is dissociated at $c = 0.01\,\mathrm{M}$ — a typical weak acid.

Step 2 — Dissociation constant K_a:

$$K_a = \frac{c\alpha^2}{1-\alpha} = \frac{(0.01)(0.02)^2}{1-0.02} = \frac{0.01 \times 4 \times 10^{-4}}{0.98} = \frac{4 \times 10^{-6}}{0.98} \approx \mathbf{4.08 \times 10^{-6}}$$

Step 3 — pK$_a$: $\mathrm{p}K_a = -\log(4.08 \times 10^{-6}) \approx 5.39$. This is a very weak acid, similar to carbonic acid.

Common error: Forgetting to write $K_a = c\alpha^2/(1-\alpha)$ and instead using the simplified form $K_a \approx c\alpha^2$, which gives 4×10^{-6} — a valid approximation only when $\alpha \ll 1$.

Final Answer: $\alpha = 0.02;\ \ K_a \approx 4.08 \times 10^{-6} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — First-order kinetics and half-life: For a first-order reaction, the concentration after n half-lives is:

$$[A] = [A]_0 \left(\frac{1}{2}\right)^n$$

Each half-life reduces the concentration by exactly 50%, regardless of the current concentration (a unique property of first-order reactions).

Step 1 — Number of half-lives in $2079\,\text{s}$:

$$n = \frac{t}{t_{1/2}} = \frac{2079\,\text{s}}{693\,\text{s}} = 3 \text{ half-lives}$$

Step 2 — Remaining concentration:

$$[A] = 0.5\,\text{M} \times \left(\frac{1}{2}\right)^3 = 0.5 \times \frac{1}{8} = \mathbf{0.0625}\,\text{M}$$

Step 3 — Tracking concentration at each stage:

After	Time (s)	[A] (M)
$t = 0$	0	0.500
1st half-life	693	0.250
2nd half-life	1386	0.125
3rd half-life	2079	0.0625

Note: $t_{1/2} = \ln 2/k$, so $k = 0.693/693 = 0.001\,\text{s}^{-1}$ for this reaction.

Final Answer: $[\text{A}] = 0.0625\,\text{M}$ after 3 half-lives $\Rightarrow \boxed{\text{C}}$

Answer: (C)

Go Back to Q13

Q14.

Solution

Concept — Oxides of nitrogen: properties and structures:

Step 1 — Evaluate each statement:

Option A: "N_2O is the anhydride of HNO_3" — **Incorrect.** N_2O_5 is the acid anhydride of nitric acid ($N_2O_5 + H_2O \rightarrow 2HNO_3$). N_2O is laughing gas.

Option B: "NO_2 dimerises to N_2O_4 at low temperatures and is a paramagnetic brown gas" — **Correct.** NO_2 has one unpaired electron in a π^* orbital $\Rightarrow$ paramagnetic, brown colour. At low T or high pressure, the radical dimerises: $2NO_2 \rightleftharpoons N_2O_4$ (colourless, diamagnetic).

Option C: "N_2O_3 is the most stable" — **Incorrect.** N_2O_3 is actually very unstable and readily dissociates to NO and NO_2.

Option D: "NO is diamagnetic" — **Incorrect.** NO has 11 electrons; the odd electron occupies a π^* MO $\Rightarrow$ NO is paramagnetic (1 unpaired e^-), though it is weakly so due to its low-lying excited state.

Additional facts about NO_2: It is formed in photochemical smog; it contributes to acid rain by reacting with water ($3NO_2 + H_2O \rightarrow 2HNO_3 + NO$).

Final Answer: NO_2 is paramagnetic and dimerises to $N_2O_4 \Rightarrow \boxed{B}$

Answer: (B) **Go Back to Q14**

Q15.

Solution

Concept — Disproportionation reactions of xenon fluorides: XeF_4 has Xe in the $+4$ oxidation state. When hydrolysed, disproportionation occurs — Xe(+4) simultaneously goes to Xe(0) (lower) and Xe(+6) in XeO_3 (higher).

Step 1 — The reaction:

$$6XeF_4 + 12H_2O \rightarrow 4Xe + 24HF + 2XeO_3 + 3O_2$$

Xe(+4) $\rightarrow$ Xe(0): reduction (gains $4e^-$) Xe(+4) $\rightarrow$ Xe(+6) in XeO_3: oxidation (loses $2e^-$)

The ratio 4:2 = 2:1 balances the electron transfer (each Xe(0) gains $4e^-$; each Xe(+6) loses $2e^-$; two Xe(+6) are needed to oxidise one Xe(0) $\rightarrow$ balanced at 4 Xe(0) + 2 XeO_3 per 6 XeF_4).

Step 2 — Products: Both Xe metal gas (Xe atom, oxidation state 0) and XeO_3 (oxidation state $+6$) are formed simultaneously, along with HF and O_2.

Contrast: $XeF_2 + H_2O \rightarrow Xe + \frac{1}{2}O_2 + 2HF$ (no disproportionation; XeF_2 hydrolyses cleanly).

Final Answer: Both Xe and XeO_3 are produced (disproportionation) $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — Anomalous behaviour of Lithium (diagonal relationship): Lithium behaves anomalously compared to other Group 1 metals and resembles Magnesium (diagonal element in Period 3, Group 2). Key anomalies of Li:

Step 1 — Evaluate options:

Option A: Incorrect. Na also reacts with water to give NaOH + H_2 — this is common to all alkali metals, not a difference.

Option B: **Correct.** Li is the *only* alkali metal that reacts directly with atmospheric N_2 at room temperature:

$$6\text{Li} + \text{N}_2 \rightarrow 2\text{Li}_3\text{N}$$

Na, K, Rb, Cs do not form stable nitrides under normal conditions. This resembles Mg's reaction with N_2 ($3\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$) — part of the diagonal relationship.

Option C: Incorrect. Li is actually more electropositive than expected for its position, because despite its high ionisation energy, the very high hydration energy of the tiny Li^+ ion makes Li a powerful reducing agent in aqueous solution.

Option D: Incorrect. All alkali metals dissolve in liquid ammonia to give blue solutions (solvated electrons) — this is not unique to Li.

Other anomalies of Li vs. alkali metals: forms oxide (Li_2O, not peroxide); LiF, Li_2CO_3, Li_3PO_4 are sparingly soluble; Li_2CO_3 decomposes on heating.

Final Answer: Li uniquely forms Li_3N with $\text{N}_2 \Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ **Go Back to Q16**

Q17.

Solution

Concept — Radius ratio and ionic crystal structures: The radius ratio r_+/r_- predicts the most stable coordination geometry:

Radius ratio range	Coordination number	Structure
$0.155 - 0.225$	3	triangular planar
$0.225 - 0.414$	4	tetrahedral (zinc blende)
$0.414 - 0.732$	6	octahedral (**rock salt**)
$0.732 - 1.000$	8	cubic (CsCl)

Step 1 — Apply to the given ratio: $r_+/r_- = 0.52$, which falls in the range $0.414 - 0.732 \Rightarrow$ **octahedral coordination**, CN = 6 for both the cation and the anion.

Step 2 — Unit cell type: The NaCl (rock salt) structure is built on an FCC (face-centred cubic) arrangement of anions, with cations occupying all octahedral holes. There are 4 formula units per unit cell.

Step 3 — The question states it is rock salt, consistent: Rock salt structure ⇒ FCC unit cell with CN = 6 for both ions.

Real example: NaCl itself has $r_{Na^+}/r_{Cl^-} \approx 0.52$, exactly matching this scenario.

Final Answer: CN = 6 for both; FCC unit cell ⇒ $\boxed{\text{B}}$

Answer: (B) **Go Back to Q17**

Q18.

Solution

Concept — Raoult's Law and vapour pressure lowering: For a non-volatile solute in a volatile solvent:

$$\frac{\Delta P}{P^\circ} = x_{\text{solute}}$$

where x_{solute} is the mole fraction of the solute.

Step 1 — Calculate moles:

$$n_{\text{glucose}} = \frac{18\,\text{g}}{180\,\text{g mol}^{-1}} = 0.1\,\text{mol}$$

$$n_{\text{water}} = \frac{180\,\text{g}}{18\,\text{g mol}^{-1}} = 10.0\,\text{mol}$$

Step 2 — Mole fraction of glucose:

$$x_{\text{glucose}} = \frac{n_{\text{glucose}}}{n_{\text{glucose}} + n_{\text{water}}} = \frac{0.1}{0.1 + 10.0} = \frac{0.1}{10.1} = 0.00990$$

Step 3 — Vapour pressure lowering:

$$\Delta P = P^\circ \times x_{\text{solute}} = 23.8 \times 0.00990 = \mathbf{0.2356} \approx \mathbf{0.238}\,\text{mmHg}$$

Physical insight: Glucose is a non-volatile solute. It occupies surface sites on the liquid, reducing the fraction of water molecules that can escape to the vapour phase, thereby reducing vapour pressure.

Common trap: Using $x_{\text{solute}} \approx n_{\text{solute}}/n_{\text{solvent}}$ (dilute approximation) gives $0.1/10 = 0.01$, so $\Delta P = 0.238$ — same answer here due to dilute solution.

Final Answer: $\Delta P = 0.238\,\text{mmHg} \Rightarrow \boxed{\text{A}}$

Answer: (A)

Go Back to Q18

Q19.

Solution

Concept — IUPAC nomenclature of coordination complexes: Rules: (i) Ligands named alphabetically before the metal. (ii) Anionic ligands end in "-o" (chloro, cyano, hydroxo). (iii) Neutral ligands: "ammine" for NH_3, "aqua" for H_2O. (iv) Metal oxidation state in Roman numerals in parentheses.

Step 1 — Determine oxidation state of Co: The complex is $[\mathrm{Co(NH_3)_4Cl_2}]^+$. Let Co have oxidation state x: $x + 4(0) + 2(-1) = +1$ $x - 2 = 1 \implies x = +3$

Step 2 — Name the ligands in alphabetical order:

- 4 ammine (NH_3) ligands → "tetraammine"
- 2 chloro (Cl^-) ligands → "dichloro"
- Alphabetical order: **a**mmine before **c**hloro ⇒ tetraamminedichloro

Step 3 — Full name: Tetraamminedichlorocobalt(III) ion.

Common confusion: Options A and D differ only in the oxidation state (II vs III). Since Co is $+3$, options A and D are wrong. Option B reverses the alphabetical order of ligands ("tetraamine" before "dichloro" but written backward) — actually option B says "Tetraaminedichloro" while correct is "tetraamminedichloro". The key discriminator is the oxidation state.

Final Answer: Tetraamminedichlorocobalt(III) ion ⇒ $\boxed{\text{C}}$

$\boxed{\textbf{Answer: (C)}}$ **Go Back to Q19**

Q20.

Solution

Concept — Optical isomerism in tris-chelate complexes: A molecule is chiral (optically active) if it is non-superimposable on its mirror image. For octahedral complexes with three identical bidentate ligands $[M(\text{AA})_3]$:

Step 1 — Structure of $[\mathrm{Cr(en)_3}]^{3+}$: Three ethylenediamine (en) ligands span the six coordination sites of an octahedral Cr^{3+}. The three ligands wrap around the metal in a propeller-like fashion, giving two non-superimposable arrangements:

- Δ (delta, right-handed propeller)
- Λ (lambda, left-handed propeller)

These are enantiomers (mirror images) $\Rightarrow$ optical isomerism.

Step 2 — Why not other types: *Linkage isomerism:* requires an ambidentate ligand (e.g. NO_2^-). en is not ambidentate. *Ionisation isomerism:* requires a ligand that can exchange with an outer-sphere anion. $[\mathrm{Cr(en)_3}]^{3+}$ has no halide to exchange. *Coordination isomerism:* requires two different metal centres.

Practical note: $[\mathrm{Cr(en)_3}]^{3+}$ is a classic example of a tris-chelate complex whose optical activity was experimentally demonstrated by Werner (1914), confirming the octahedral geometry.

Final Answer: Optical isomerism (Δ and Λ enantiomers) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

Concept — Markovnikov's rule for electrophilic addition: In the addition of HX to an unsymmetrical alkene, the hydrogen adds to the carbon with more hydrogen atoms, and X adds to the carbon with fewer hydrogen atoms (more substituted). This is governed by the stability of the carbocation intermediate: more substituted carbocations are more stable.

Step 1 — Structure of propene:

$$\mathrm{CH_3 - \underset{C2}{CH} = \underset{C1}{CH_2}}$$

C1 (terminal, $=\mathrm{CH_2}$) has 2 H atoms. C2 (internal) has 1 H atom.

Step 2 — Apply Markovnikov's rule: H adds to C1 (more H), Br adds to C2 (less H, more substituted). Carbocation at C2: $\mathrm{CH_3 - \overset{+}{C}H - CH_3}$ is a *secondary* carbocation — more stable than the primary carbocation at C1.

Step 3 — Product: $\mathrm{CH_3CHBrCH_3}$ = 2-bromopropane.

Anti-Markovnikov product (from radical/peroxide conditions): 1-bromopropane ($\mathrm{CH_3CH_2CH_2Br}$) — occurs via free radical mechanism where Br adds to the less substituted end.

Final Answer: 2-bromopropane (Markovnikov's rule) $\Rightarrow \boxed{\text{B}}$

$\boxed{\text{Answer: (B)}}$ **Go Back to Q21**

Q22.

Solution

Concept — Electrophilic Aromatic Substitution (EAS) mechanism: Benzene undergoes substitution (not addition) to maintain aromaticity. The key steps are: 1. Generation of electrophile by Lewis acid catalyst 2. Electrophile attacks π system forming arenium (Wheland) ion 3. Loss of H^+ restores aromaticity

Step 1 — Generation of electrophile:

$$\mathrm{Cl_2 + FeCl_3 \rightarrow Cl^+ + FeCl_4^-}$$

$\mathrm{FeCl_3}$ is a Lewis acid that accepts a lone pair from one Cl of $\mathrm{Cl_2}$, generating the electrophilic $\mathrm{Cl^+}$ (chloronium).

Step 2 — Attack on benzene: $\mathrm{Cl^+}$ attacks the electron-rich benzene π cloud to form a sigma complex (arenium ion), disrupting aromaticity. This is the slow (rate-determining) step.

Step 3 — Restoration of aromaticity: $\mathrm{FeCl_4^-}$ acts as a base, abstracting H^+ from the arenium ion to restore the aromatic ring.

$$\text{Product: chlorobenzene} + \mathrm{HCl}$$

Why not addition? Addition would give 1,2-dichlorocyclohex-3-ene, which loses the stabilisation energy of aromaticity ($\sim 150\,\mathrm{kJ\,mol^{-1}}$) — energetically highly unfavourable.

Final Answer: Electrophile $\mathrm{Cl^+}$; product chlorobenzene + HCl $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept — Oxidation of primary alcohols: Primary alcohols are oxidised in two stages by mild oxidising agents like acidified $K_2Cr_2O_7$ or PCC:

$$\text{Primary alcohol} \xrightarrow{[O]} \text{Aldehyde} \xrightarrow{[O]} \text{Carboxylic acid}$$

Step 1 — First oxidation: CH_3CH_2OH (ethanol, primary) $\xrightarrow{[O]}$ CH_3CHO (ethanal/acetaldehyde). Oxidation state of C1: -1 in ethanol $\rightarrow +1$ in ethanal.

Step 2 — Second oxidation: $CH_3CHO \xrightarrow{[O]} CH_3COOH$ (ethanoic acid/acetic acid). Oxidation state of C1: $+1$ in ethanal $\rightarrow +3$ in acetic acid.

Step 3 — Control of oxidation depth:

- To stop at aldehyde stage: use PCC (pyridinium chlorochromate) in CH_2Cl_2, or distil off the aldehyde as it forms.
- To go all the way to acid: use excess acidified $K_2Cr_2O_7$ under reflux.

Note: Secondary alcohols are oxidised to ketones only (not further). Tertiary alcohols resist oxidation (no H on the carbon bearing OH).

Final Answer: Ethanal, then ethanoic acid $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept — Nucleophilic addition to the carbonyl group: The carbonyl carbon in ketones/aldehydes is electrophilic (δ^+) due to the electron-withdrawing effect of oxygen via the polar C=O bond. Strong nucleophiles attack this carbon.

Step 1 — Role of HCN: HCN is a weak acid. In the presence of base (or CN^- from NaCN), it provides the nucleophile CN^- (cyanide ion).

Step 2 — Mechanism:

(a) CN^- (nucleophile) attacks the electrophilic carbonyl carbon from above or below the plane $\to$ tetrahedral alkoxide intermediate: $(\mathrm{CH_3})_2\mathrm{C}(\mathrm{O}^-)(\mathrm{CN})$.

(b) The alkoxide O^- is protonated by HCN (or water) to give the cyanohydrin: $(\mathrm{CH_3})_2\mathrm{C}(\mathrm{OH})(\mathrm{CN})$.

Step 3 — Why not electrophilic? Aldehydes and ketones do not undergo electrophilic addition because: (a) there is no π bond between two carbons (as in alkenes), and (b) the carbon is already electron-deficient, making it resistant to attack by electrophiles.

Application: Cyanohydrins are valuable intermediates — the CN group can be hydrolysed to COOH (giving α-hydroxy acids) or reduced to CH_2NH_2 (giving amino alcohols).

Final Answer: Nucleophilic addition; CN^- attacks carbonyl C, then protonation $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept — Acid chloride formation (nucleophilic acyl substitution): Carboxylic acids react with PCl_5 (or $SOCl_2$) to give acid chlorides by replacing the $-$OH group with $-$Cl.

Step 1 — Reaction:

$$CH_3COOH + PCl_5 \rightarrow CH_3COCl + POCl_3 + HCl$$

Step 2 — Mechanism (simplified): PCl_5 coordinates to the carbonyl oxygen (Lewis acid-base interaction), making the carbonyl carbon more electrophilic. Cl$^-$ (from PCl_5) then attacks the carbonyl carbon and $-$OH leaves as part of $POCl_3 \cdot HO^- \rightarrow POCl_3$ + HCl.

Step 3 — Significance of acid chlorides: Acid chlorides ($RCOCl$) are the most reactive carboxylic acid derivatives. They react readily with:

- Water $\rightarrow$ carboxylic acid + HCl
- Alcohols $\rightarrow$ esters + HCl (Schotten-Baumann)
- Amines $\rightarrow$ amides + HCl
- Benzene/$AlCl_3$ $\rightarrow$ ketones (Friedel-Crafts acylation)

Final Answer: Replacement of $-$OH by $-$Cl (acid chloride formation) $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept — Diazonium coupling (azo dye formation): Diazonium ions ($\mathrm{ArN_2^+}$) are mild electrophiles that undergo electrophilic substitution on activated aromatic rings (phenols, anilines). This is called a *coupling reaction*.

Step 1 — Formation of diazonium salt: Aniline is diazotised with $\mathrm{NaNO_2/HCl}$ at $0-5$°C:

$$\mathrm{C_6H_5NH_2 + NaNO_2 + HCl \xrightarrow{0-5^\circ C} C_6H_5N_2^+Cl^- + NaCl + H_2O}$$

(Temperature must be kept low; above 5°C the diazonium salt decomposes.)

Step 2 — Coupling with phenol: In alkaline solution, phenol exists as phenoxide ion ($\mathrm{C_6H_5O^-}$), which is even more electron-rich than phenol. The diazonium ion attacks the *para* position (favoured by steric factors) of the phenoxide:

$$\mathrm{C_6H_5N_2^+ + C_6H_5O^- \rightarrow C_6H_5 - N = N - C_6H_4 - OH}$$

Step 3 — Product: p-Hydroxyazobenzene: an **azo dye** (orange-red colour). The $-$N=N$-$ (azo) chromophore is responsible for the intense colour. Azo dyes are the largest class of synthetic dyes.

Note: If para is blocked, coupling occurs at the ortho position.

Final Answer: p-Hydroxyazobenzene (azo dye) $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q26

Q27.

Solution

Concept — DNA double helix structure (Watson-Crick model): The complementary base pairing rules are fundamental to DNA replication and transcription.

Step 1 — Base pairing rules:

- Adenine (A) pairs with Thymine (T): **2 hydrogen bonds**
- Guanine (G) pairs with Cytosine (C): **3 hydrogen bonds**

(G–C has 3 H-bonds because G has two donor/acceptor pairs; A–T has 2.)

Step 2 — Strand polarity: The two strands run antiparallel: one from $5' \to 3'$ and the other from $3' \to 5'$. This antiparallel arrangement is essential for proper H-bond geometry between base pairs.

Step 3 — Sugar: DNA contains *deoxyribose* (lacks the 2'-OH). RNA contains *ribose* (has 2'-OH). This is why DNA is more stable (the 2'-OH in RNA makes it susceptible to base-catalysed hydrolysis).

Evaluate options: Option A: reverses the pairings (A-C and G-T) — wrong. Option B: wrong — strands are antiparallel, not parallel. Option D: wrong — DNA has deoxyribose, RNA has ribose (not reversed).

Final Answer: A-T (2 H-bonds), G-C (3 H-bonds), antiparallel $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept — Enzymes as biological catalysts: Enzymes are proteins (or RNA = ribozymes) that accelerate biochemical reactions by lowering the activation energy. Key properties:

Step 1 — Correct properties of enzymes:

- Enzymes lower E_a by providing an alternative reaction pathway — **true** (option A).
- The active site has a specific 3D shape complementary to the substrate (lock-and-key or induced-fit model) — **true** (option C).
- Enzyme activity is inhibited by heavy metal ions (which can bind to and denature the enzyme) — **true** (option D).
- Enzymes are **NOT** consumed in the reaction — they are regenerated unchanged after each catalytic cycle. A single enzyme molecule can catalyse thousands to millions of reactions per second.

Step 2 — Incorrect statement: Option B: "Enzymes are consumed and must be replenished" — this is **incorrect** and defines the incorrect statement we must identify.

Real limitation: Enzymes can be inactivated by extreme pH, high temperature (denaturation), heavy metals, or irreversible inhibitors (e.g. nerve agents block acetylcholinesterase). But under normal conditions they are catalytic and not consumed.

Final Answer: Enzymes are NOT consumed in the reaction $\Rightarrow \boxed{\text{B}}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Q28**

Q29.

Solution

Concept — Cross-linked thermosetting polymers: Thermosetting polymers form irreversible three-dimensional networks upon curing. Once set, they cannot be remelted (unlike thermoplastics).

Step 1 — Formation of Bakelite: Phenol (C_6H_5OH) has three reactive positions: two ortho and one para. Formaldehyde ($HCHO$) reacts under acid/base conditions.

Step 1 (linear novolak): Initial condensation gives hydroxymethyl phenol intermediates. *Step 2 (cross-linking):* Heating causes methylene ($-CH_2-$) bridges to form between phenol rings at the 2, 4, and 6 positions (ortho and para to OH), creating a rigid 3D network.

Step 2 — Why it is thermosetting: The extensive cross-linking locks the structure in place. Once cured, the polymer does not soften on heating; it chars instead.

Step 3 — Applications: Bakelite is used for electrical fittings, radio casings, billiard balls, and laboratory equipment owing to its rigidity, electrical insulation, and heat resistance.

Final Answer: Cross-linked 3D network via $-CH_2-$ bridges at ortho and para positions $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept — Bredig's arc method and lyophobic sols: The Bredig's arc method (also called electrical dispersion) is used to prepare metal sols, particularly of noble metals (Au, Ag, Pt).

Step 1 — Procedure: Two electrodes made of the metal to be dispersed are submerged in the dispersion medium (usually cold water). A high-voltage electric arc is struck between them. The intense heat vaporises metal atoms, which then condense in the cold water as colloidal particles (size 1-100 nm).

Step 2 — Nature of the sol: The metal particles are the disperse phase (solid); water is the dispersion medium (liquid). This is a **sol** (solid dispersed in liquid). Since the metal does not interact strongly with water (no affinity), it is a **lyophobic** (solvent-hating) sol.

Step 3 — Distinguish from other colloids:

- *Emulsion* = liquid in liquid
- *Lyophilic sol* = solvent-loving; formed spontaneously (e.g., starch, gelatin in water)
- *Lyophobic sol* = requires stabilisation; coagulates readily on adding electrolyte (Hardy-Schulze rule applies)

Final Answer: Lyophobic metal sol (metal particles dispersed in water) $\Rightarrow \boxed{\text{C}}$

$\boxed{\text{Answer: (C)}}$ **Go Back to Q30**

Answer Key

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