GATE Chemistry

Sample Paper – 1

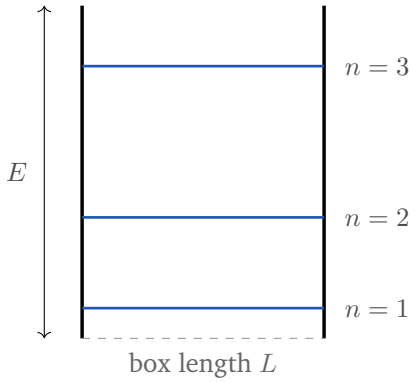
Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Chemistry (CY)** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Take $R = 8.314\ \mathrm{J\,mol^{-1}K^{-1}}$, $F = 96500\ \mathrm{C\,mol^{-1}}$ and $N_A = 6.022 \times 10^{23}\ \mathrm{mol^{-1}}$ unless stated otherwise.

Physical Chemistry: Quantum Chemistry and Spectroscopy

Q1. For a particle of mass m confined in a one-dimensional box of length L, the allowed energies are $E_n = \dfrac{n^2h^2}{8mL^2}$, with $n = 1, 2, 3, \ldots$ The energy-level ladder is sketched below. The ratio of the energy of the third level to that of the ground state, E_3/E_1, is: **[1 mark]**



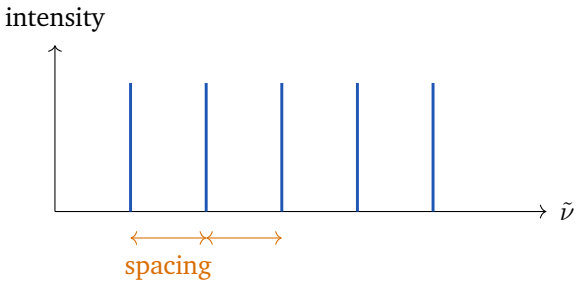
(A) 3

(B) 6

(C) 9

(D) $1/9$

Q2. The pure rotational (microwave) absorption spectrum of a rigid diatomic rotor consists of a series of equally spaced lines, as shown. If B is the rotational constant of the molecule, the spacing between two adjacent absorption lines is: **[1 mark]**



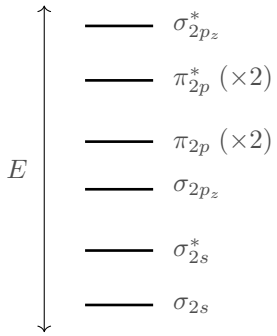
(A) B

(B) $4B$

(C) $2B$

(D) $B/2$

Q3. The molecular-orbital energy ordering for the second-period homonuclear diatomic O_2 is shown below. Using molecular-orbital theory (bonding electrons $= 10$, antibonding electrons $= 6$), the bond order of the O_2 molecule is: **[1 mark]**



(A) 2

(B) 3

(C) 1

(D) 2.5

Q4. The ground-state electronic configuration of the hydrogen atom is $1s^1$. The corresponding ground-state term symbol $^{2S+1}L_J$ of the hydrogen atom is: **[1 mark]**

(A) $^1S_0$

(B) $^2S_{1/2}$

(C) $^2P_{1/2}$

(D) $^2P_{3/2}$

Q5. The number of normal (fundamental) modes of vibration of a linear triatomic molecule such as CO_2 (with $N = 3$ atoms) is given by $3N - 5$. This number is: **[1 mark]**

(A) 3

(B) 5

(C) 4

(D) 9

Q6. The absorbance A of a coloured solution obeys the Beer–Lambert law $A = \varepsilon c l$. A solution shows an absorbance of 0.60 in a 1 cm cell. Keeping the concentration unchanged, the path length is increased to 2 cm. The new absorbance is: **[1 mark]**

(A) 0.30

(B) 0.60

(C) 0.90

(D) 1.20

Physical Chemistry: Thermodynamics, Kinetics and Electrochemistry

Q7. An ideal gas is taken through a reversible *isothermal* expansion. For this process, the change in internal energy of the gas, ΔU, is: **[1 mark]**

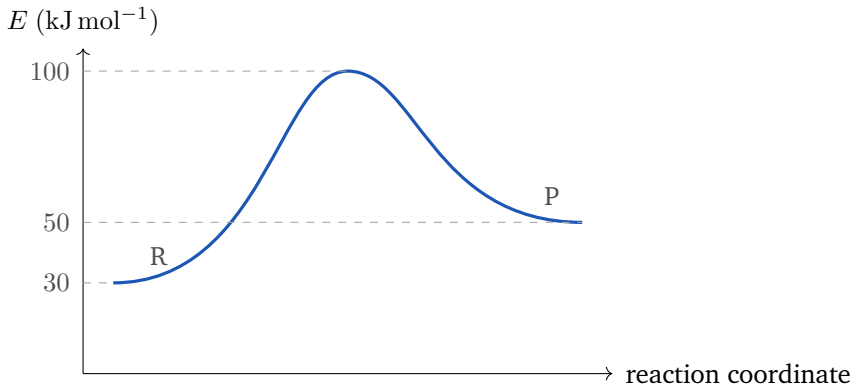
(A) zero

(B) equal to $-w$

(C) equal to $+w$

(D) equal to $nRT\ln(V_2/V_1)$

Q8. The reaction-coordinate (potential-energy) diagram for a one-step reaction is shown below. The reactants lie at $30\ \text{kJ mol}^{-1}$, the transition state at $100\ \text{kJ mol}^{-1}$ and the products at $50\ \text{kJ mol}^{-1}$. The activation energy of the *forward* reaction, $E_a(\text{forward})$, is: **[1 mark]**



(A) $50\ \text{kJ mol}^{-1}$

(B) $70\ \text{kJ mol}^{-1}$

(C) $20\ \text{kJ mol}^{-1}$

(D) $100\ \text{kJ mol}^{-1}$

Q9. A first-order reaction has a half-life of 20 minutes. The rate constant k of the reaction is nearest to: **[1 mark]**

(A) $0.693\ \text{min}^{-1}$

(B) $20\ \text{min}^{-1}$

(C) $0.050\ \text{min}^{-1}$

(D) $0.0347\ \text{min}^{-1}$

Q10. For the Daniell cell reaction $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$, the standard electrode potentials are $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34\ \text{V}$ and $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76\ \text{V}$. The standard cell potential E°_{cell} is: **[1 mark]**

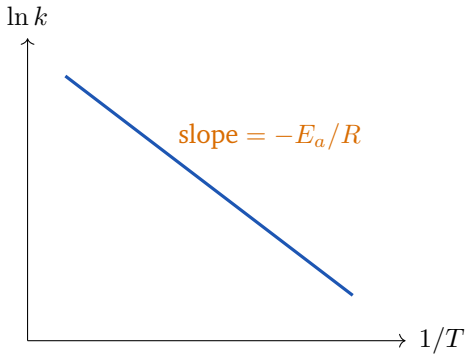
(A) $0.42\ \text{V}$

(B) $-1.10\ \text{V}$

(C) $0.34\ \text{V}$

(D) $1.10\ \text{V}$

Q11. The temperature dependence of a rate constant follows the Arrhenius equation $k = A\,e^{-E_a/RT}$. A plot of $\ln k$ against $1/T$ is a straight line, as shown. The slope of this line is: **[1 mark]**



(A) $-E_a/R$

(B) $+E_a/R$

(C) $-E_a/(2.303\,R)$

(D) $\ln A$

Q12. A reaction at $300\ \mathrm{K}$ has $\Delta H = -40\ \mathrm{kJ\,mol^{-1}}$ and $\Delta S = +50\ \mathrm{J\,mol^{-1}K^{-1}}$. The Gibbs free-energy change $\Delta G = \Delta H - T\Delta S$ for the reaction is: **[1 mark]**

(A) $-55\ \mathrm{kJ\,mol^{-1}}$

(B) $-25\ \mathrm{kJ\,mol^{-1}}$

(C) $+55\ \mathrm{kJ\,mol^{-1}}$

(D) $-40\ \mathrm{kJ\,mol^{-1}}$

Q13. In the electrolysis of molten NaCl, sodium is deposited by the reduction $\mathrm{Na^+} + e^- \rightarrow \mathrm{Na}$. The quantity of electric charge required to deposit exactly one mole of sodium is: **[1 mark]**

(A) $48250\ \mathrm{C}$

(B) $96500\ \mathrm{C}$

(C) $193000\ \mathrm{C}$

(D) $9650\ \mathrm{C}$

Q14. A zero-order reaction has a rate constant $k = 0.02\ \mathrm{mol\,L^{-1}s^{-1}}$ and an initial reactant concentration of $1.0\ \mathrm{mol\,L^{-1}}$. The time taken for the reaction to go to completion (that is, for the concentration to fall to zero) is: **[1 mark]**

(A) $20\ \mathrm{s}$

(B) $100\ \mathrm{s}$

(C) $0.02\ \mathrm{s}$

(D) $50\ \mathrm{s}$

Inorganic Chemistry: Main Group and Periodic Properties

Q15. Among the second-period elements N, O, F and Ne, the element having the *highest* first ionization energy is: **[1 mark]**

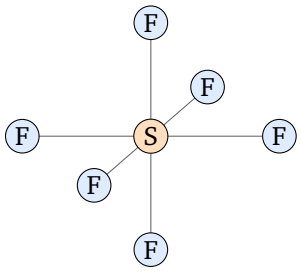
(A) N

(B) O

(C) Ne

(D) F

Q16. According to VSEPR theory, the central sulfur atom in SF_6 is surrounded by six bonding pairs and no lone pair, giving the geometry sketched below. The shape of the SF_6 molecule is: **[1 mark]**



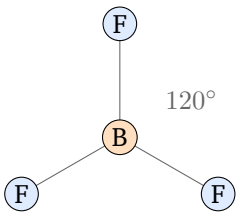
(A) tetrahedral

(B) octahedral

(C) trigonal bipyramidal

(D) square planar

Q17. The boron trifluoride molecule BF_3 is planar, with the three $B-F$ bonds separated by 120° as shown. The hybridization of the central boron atom is: **[1 mark]**



(A) sp

(B) sp^2

(C) sp^3

(D) sp^3d

Q18. In the perchlorate ion $\mathrm{ClO_4^-}$, the four oxygen atoms are each assigned an oxidation number of -2 and the ion bears a charge of -1. The oxidation state of chlorine in $\mathrm{ClO_4^-}$ is: **[1 mark]**

(A) $+1$

(B) $+3$

(C) $+5$

(D) $+7$

Q19. On moving across the second period from lithium (Li) to fluorine (F), the atomic radius of the elements generally: **[1 mark]**

(A) decreases

(B) increases

(C) stays essentially constant

(D) first increases and then decreases

Q20. The tendency of the heavier p-block elements such as Tl, Pb and Bi to exhibit an oxidation state two units lower than the group valency (for example $\mathrm{Tl^+}$ and $\mathrm{Pb^{2+}}$) is best explained by: **[1 mark]**

(A) the lanthanide contraction

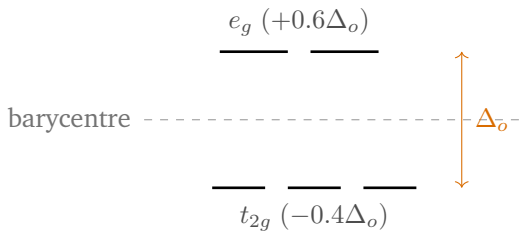
(B) the diagonal relationship

(C) hydrogen bonding

(D) the inert pair effect

Inorganic Chemistry: Coordination Compounds and Organometallics

Q21. In an octahedral crystal field the five d orbitals split into a lower t_{2g} set at $-0.4\Delta_o$ and an upper e_g set at $+0.6\Delta_o$ relative to the barycentre, as shown. For a d^3 ion (all three electrons in t_{2g}), the crystal-field stabilization energy (CFSE) is: **[2 marks]**



(A) $-0.8\,\Delta_o$

(B) $-1.2\,\Delta_o$

(C) $-0.6\,\Delta_o$

(D) 0

Q22. The tetracarbonylnickel(0) complex $[\mathrm{Ni(CO)_4}]$ obeys the effective-atomic-number (18-electron) rule. Taking nickel(0) to contribute 10 valence electrons and each CO ligand to donate 2 electrons, the total valence electron count of the complex is: **[2 marks]**

(A) 16

(B) 20

(C) 14

(D) 18

Q23. The high-spin octahedral complex $[\mathrm{Mn(H_2O)_6}]^{2+}$ contains a d^5 manganese(II) centre with five unpaired electrons. Using the spin-only formula $\mu = \sqrt{n(n+2)}$ BM, the magnetic moment of the complex is nearest to: **[2 marks]**

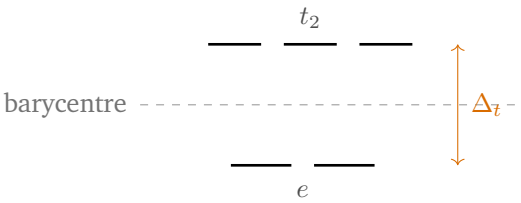
(A) 1.73 BM

(B) 3.87 BM

(C) 5.92 BM

(D) 4.90 BM

Q24. For a tetrahedral complex, the d orbitals split into a lower e set and an upper t_2 set, as shown. For the same metal ion and the same ligands, the tetrahedral crystal-field splitting Δ_t is related to the octahedral splitting Δ_o approximately by: **[2 marks]**



(A) $\Delta_t = \Delta_o$

(B) $\Delta_t \approx \dfrac{4}{9}\,\Delta_o$

(C) $\Delta_t \approx \dfrac{9}{4}\,\Delta_o$

(D) $\Delta_t = 2\,\Delta_o$

Q25. In the complex ion $[\mathrm{Co(en)_3}]^{3+}$, the ligand ethylenediamine (en) is bidentate, occupying two coordination sites per molecule. The coordination number of the central cobalt(III) ion is: **[2 marks]**

(A) 6

(B) 3

(C) 4

(D) 2

Q26. In the spectrochemical series, ligands are ordered by the magnitude of the crystal-field splitting they produce. Among the ligands $\mathrm{I^-}$, $\mathrm{H_2O}$, $\mathrm{CN^-}$ and $\mathrm{F^-}$, the one that produces the *largest* crystal-field splitting (strongest field) is: **[2 marks]**

(A) $\mathrm{I^-}$

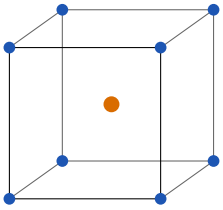
(B) $\mathrm{H_2O}$

(C) $\mathrm{CN^-}$

(D) $\mathrm{F^-}$

Inorganic Chemistry: Solid State and Bioinorganic

Q27. A body-centred cubic (BCC) unit cell is shown below, with atoms at the eight corners and one atom at the body centre. The number of atoms belonging to one BCC unit cell is: **[2 marks]**



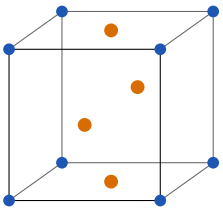
(A) 1

(B) 4

(C) 2

(D) 8

Q28. A face-centred cubic (FCC) unit cell is shown below, with atoms at the corners and at the centre of each face. For close-packed identical hard spheres in this arrangement, the atomic packing fraction is nearest to: **[2 marks]**



(A) 0.74

(B) 0.68

(C) 0.52

(D) 0.34

Q29. Haemoglobin transports molecular oxygen in blood by reversibly binding O_2 at the metal centre of its heme (porphyrin) prosthetic group. The metal ion present at the centre of the heme group is: **[2 marks]**

(A) Fe^{2+}

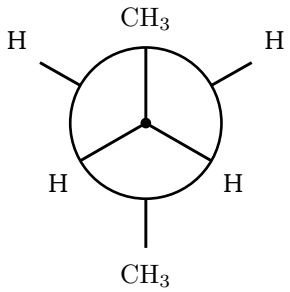
(B) Mg^{2+}

(C) Zn^{2+}

(D) Cu^{2+}

Organic Chemistry: Stereochemistry and Reaction Mechanisms

Q30. The Newman projection of n-butane, viewed along the $\mathrm{C2}-\mathrm{C3}$ bond, is shown below with the two methyl groups pointing to opposite ends. The lowest-energy (most stable) conformation of n-butane about this bond is the one in which the two methyl groups are: **[2 marks]**



(A) eclipsed (0° dihedral)

(B) gauche (60° dihedral)

(C) anti (180° dihedral)

(D) fully eclipsed with the two methyls together

Q31. A molecule contains two dissimilar (non-equivalent) stereogenic centres, so that the maximum number of stereoisomers is given by 2^n with n the number of such centres. The maximum number of stereoisomers possible for this molecule is: **[2 marks]**

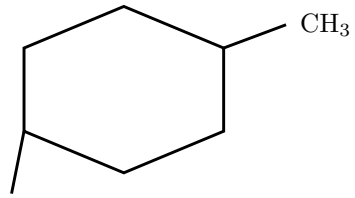
(A) 1

(B) 2

(C) 4

(D) 8

Q32. The most stable chair conformation of methylcyclohexane is shown below. The methyl substituent preferentially occupies which position on the ring so as to minimize $1,3$-diaxial strain? **[2 marks]**



chair conformation of methylcyclohexane

(A) axial

(B) eclipsed

(C) it makes no difference to the energy

(D) equatorial

Q33. A primary alkyl halide such as CH_3CH_2Br reacts with a strong, unhindered nucleophile in a polar aprotic solvent. Substitution proceeds predominantly by which mechanism? **[2 marks]**

(A) S_N1

(B) $E1$

(C) S_N2

(D) $E1cb$

Q34. Carbocations are stabilized by hyperconjugation and the inductive (electron-donating) effect of alkyl groups. Among a methyl, a primary, a secondary and a tertiary carbocation, the *most* stable is the: **[2 marks]**

(A) methyl carbocation

(B) primary carbocation

(C) secondary carbocation

(D) tertiary carbocation

Q35. *meso*-Tartaric acid contains two stereogenic centres yet shows no optical rotation. The reason it is optically inactive is that: **[2 marks]**

(A) it possesses an internal plane of symmetry, so the rotations of its two halves cancel

(B) it has no stereogenic (chiral) centre at all

(C) it is actually a $50:50$ racemic mixture of two enantiomers

(D) it exists as a single pure enantiomer

Q36. 2-Bromobutane is treated with a strong base (sodium ethoxide) and undergoes $E2$ elimination. According to Saytzeff's rule, the major alkene product is the more substituted one, namely: **[2 marks]**

(A) 1-butene

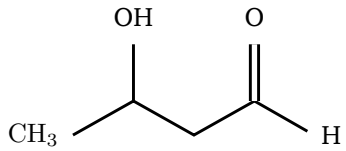
(B) 2-butene

(C) 1-butyne

(D) butane

Organic Chemistry: Named Reactions and Synthesis

Q37. Two molecules of acetaldehyde (CH_3CHO) undergo base-catalysed self-condensation to give 3-hydroxybutanal (the skeletal structure of the product is shown below). This carbon–carbon bond-forming reaction is known as the: **[2 marks]**



3-hydroxybutanal (aldol product)

(A) Cannizzaro reaction

(B) Aldol reaction

(C) Wittig reaction

(D) Claisen condensation

Q38. Formaldehyde ($HCHO$), which has no α-hydrogen, on treatment with concentrated sodium hydroxide disproportionates into methanol and sodium formate. This self oxidation–reduction of an aldehyde without an α-hydrogen is the: **[2 marks]**

(A) Cannizzaro reaction

(B) Aldol condensation

(C) Perkin reaction

(D) Reformatsky reaction

Q39. An aldehyde or ketone reacts with a phosphorus ylide ($R_3P{=}CR'_2$) to form a carbon–carbon double bond, converting the carbonyl into an alkene. This alkene-forming reaction is the: **[2 marks]**

(A) Wittig reaction

(B) Grignard reaction

(C) Clemmensen reduction

(D) Friedel–Crafts acylation

Q40. Benzene is nitrated using a mixture of concentrated nitric acid and concentrated sulfuric acid. The actual electrophile that attacks the aromatic ring in this reaction is the: **[2 marks]**

(A) nitrosonium ion, NO^+

(B) nitrite ion, NO_2^-

(C) nitronium ion, NO_2^+

(D) undissociated HNO_3

Q41. A Grignard reagent ($RMgX$) is added to dry carbon dioxide and the mixture is then worked up with dilute acid. The organic product of this sequence is: **[2 marks]**

(A) an aldehyde ($RCHO$)

(B) a carboxylic acid ($RCOOH$)

(C) a ketone ($RCOR'$)

(D) a primary alcohol (RCH_2OH)

Q42. The carbonyl group ($C{=}O$) of a ketone is reduced all the way to a methylene group (CH_2) by treatment with amalgamated zinc, $Zn(Hg)$, and

concentrated hydrochloric acid. This carbonyl-to-methylene reduction is the: [2 marks]

(A) Wolff–Kishner reduction

(B) Clemmensen reduction

(C) Rosenmund reduction

(D) Birch reduction

Q43. Propene ($CH_3CH{=}CH_2$) undergoes acid-catalysed hydration (addition of water). Following Markovnikov's rule, the $-OH$ adds to the more substituted carbon and the major product is: [2 marks]

(A) propan-1-ol

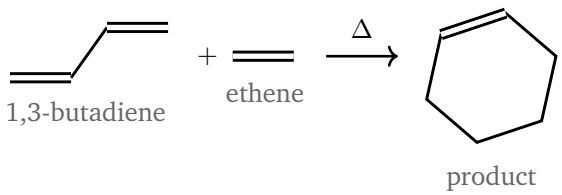
(B) propanal

(C) propanoic acid

(D) propan-2-ol

Organic Chemistry: Pericyclic, Photochemistry and Biomolecules

Q44. $1,3$-Butadiene (diene) reacts with ethene (dienophile) in a thermal $[4{+}2]$ cycloaddition, as sketched below. This Diels–Alder reaction gives a six-membered ring product, which is: [2 marks]



(A) cyclohexene

(B) benzene

(C) cyclobutane

(D) $1,3$-cyclohexadiene

Q45. A conjugated triene containing six π electrons undergoes a thermal electrocyclic ring closure. According to the Woodward–Hoffmann rules, the stereochemical mode of this $4n + 2$ (6π) thermal electrocyclization is: **[2 marks]**

(A) conrotatory

(B) disrotatory

(C) suprafacial–antarafacial

(D) forbidden (does not occur)

Q46. In a protein, two consecutive amino-acid residues are joined by a peptide bond formed between the carboxyl group of one residue and the amino group of the next. Chemically, this peptide linkage is a(n): **[2 marks]**

(A) ester bond

(B) ether linkage

(C) glycosidic bond

(D) amide linkage

Detailed Solutions

Q1.

Solution

Concept – particle-in-a-box energy scales as n^2: The allowed energies are $E_n = \dfrac{n^2h^2}{8mL^2}$, so every level is fixed by the quantum number n through n^2.

Step 1 – write the two energies of interest: $E_3 = \dfrac{3^2h^2}{8mL^2}$

$E_1 = \dfrac{1^2h^2}{8mL^2}$

Step 2 – form the ratio: $\dfrac{E_3}{E_1} = \dfrac{3^2}{1^2}$

Step 3 – evaluate the squares: $\dfrac{E_3}{E_1} = \dfrac{9}{1}$

$\dfrac{E_3}{E_1} = 9$

Final Answer: $E_3/E_1 = 9 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – rotational term values of a rigid rotor: The rotational energy levels are $F(J) = B\,J(J+1)$, with $J = 0, 1, 2, \ldots$ and B the rotational constant (in wavenumber units).

Step 1 – apply the selection rule $\Delta J = +1$: An absorption line for the transition $J \to J+1$ appears at $\tilde{\nu}(J) = F(J+1) - F(J)$.

Step 2 – substitute the term values: $\tilde{\nu}(J) = B(J+1)(J+2) - B\,J(J+1)$

Step 3 – factor out $B(J+1)$: $\tilde{\nu}(J) = B(J+1)\big[(J+2) - J\big] = 2B(J+1)$

Step 4 – take the spacing between adjacent lines: $\tilde{\nu}(J+1) - \tilde{\nu}(J) = 2B(J+2) - 2B(J+1) = 2B$

The lines are therefore equally spaced by $2B$, as the stick spectrum shows.

Final Answer: line spacing $= 2B \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – bond order from molecular-orbital populations: Bond order $= \dfrac{N_b - N_a}{2}$, where N_b and N_a are the numbers of electrons in bonding and antibonding MOs.

Step 1 – count the electrons in O_2: O_2 has 16 electrons; filling the MO ladder gives $N_b = 10$ bonding and $N_a = 6$ antibonding electrons.

Step 2 – substitute into the bond-order formula: Bond order $= \dfrac{10 - 6}{2}$

Step 3 – evaluate: Bond order $= \dfrac{4}{2} = 2$

Step 4 – cross-check: A bond order of 2 agrees with the O=O double bond, and the two unpaired electrons in the π^* orbitals correctly make O_2 paramagnetic.

Final Answer: bond order $= 2 \Rightarrow$ A

Answer: (A) Go Back to Q3

Q4.

Solution

Concept – building the atomic term symbol $^{2S+1}L_J$: For the ground state, read off the total spin S, the total orbital angular momentum L, and the total angular momentum J.

Step 1 – the single electron is in a $1s$ orbital: For s, the orbital quantum number is $l = 0$, so $L = 0$, which is labelled S.

Step 2 – find the spin multiplicity: One unpaired electron gives $S = \frac{1}{2}$, so the multiplicity is $2S + 1 = 2(\frac{1}{2}) + 1 = 2$.

Step 3 – find J: $J = |L + S| = |0 + \frac{1}{2}| = \frac{1}{2}$.

Step 4 – assemble the term symbol: $^2S_{1/2}$.

Final Answer: ground-state term symbol $= {}^2S_{1/2} \Rightarrow$ B

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – vibrational degrees of freedom of a molecule: A non-linear molecule has $3N - 6$ vibrational modes; a *linear* molecule has $3N - 5$ modes.

Step 1 – identify the geometry: CO_2 is linear, so the correct formula is $3N - 5$.

Step 2 – put in the number of atoms: $N = 3$, so number of modes $= 3(3) - 5$.

Step 3 – evaluate: $= 9 - 5 = 4$

Step 4 – name the four modes: symmetric stretch, asymmetric stretch, and a doubly degenerate bend (two components) $= 4$ in all, which matches.

Final Answer: number of vibrational modes $= 4 \Rightarrow$ C

Answer: (C) Go Back to Q5

Q6.

Solution

Concept – Beer–Lambert law: $A = \varepsilon c l$, so at fixed molar absorptivity ε and concentration c, absorbance is directly proportional to path length l.

Step 1 – write the proportionality: $\dfrac{A_2}{A_1} = \dfrac{l_2}{l_1}$

Step 2 – insert the values: $\dfrac{A_2}{0.60} = \dfrac{2}{1}$

Step 3 – solve for A_2: $A_2 = 0.60 \times 2$

$A_2 = 1.20$

Final Answer: $A_2 = 1.20 \Rightarrow$ D

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – internal energy of an ideal gas depends only on temperature: For an ideal gas, $U = U(T)$ only, so any process at constant temperature has $\Delta U = 0$.

Step 1 – note the process is isothermal: Temperature is constant, $\Delta T = 0$.

Step 2 – apply $\Delta U = nC_V\,\Delta T$: $\Delta U = nC_V(0) = 0$

Step 3 – interpret with the first law: Since $\Delta U = q + w = 0$, the heat absorbed equals the work done *by* the gas; but the internal-energy change itself is exactly zero.

Final Answer: $\Delta U = 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q7

Q8.

Solution

Concept – activation energy from a reaction-coordinate diagram: $E_a(\text{forward})$ is the height of the transition state *above* the reactant level.

Step 1 – read the energy levels: Reactants $= 30\ \text{kJ mol}^{-1}$, transition state $= 100\ \text{kJ mol}^{-1}$.

Step 2 – subtract to get the forward barrier: $E_a(\text{forward}) = 100 - 30$

Step 3 – evaluate: $E_a(\text{forward}) = 70\ \text{kJ mol}^{-1}$

Step 4 – cross-check the other quantities: $\Delta H = 50 - 30 = +20\ \text{kJ mol}^{-1}$ (endothermic) and $E_a(\text{reverse}) = 100 - 50 = 50\ \text{kJ mol}^{-1}$; these are consistent since $E_a(\text{forward}) - E_a(\text{reverse}) = 70 - 50 = 20 = \Delta H$.

Final Answer: $E_a(\text{forward}) = 70\ \text{kJ mol}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – half-life of a first-order reaction: $t_{1/2} = \dfrac{\ln 2}{k} = \dfrac{0.693}{k}$, which is independent of the initial concentration.

Step 1 – rearrange for k: $k = \dfrac{0.693}{t_{1/2}}$

Step 2 – substitute $t_{1/2} = 20$ min: $k = \dfrac{0.693}{20}$

Step 3 – evaluate: $k = 0.03465\ \text{min}^{-1}$

$k \approx 0.0347\ \text{min}^{-1}$

Final Answer: $k \approx 0.0347\ \text{min}^{-1} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – standard cell potential from electrode potentials: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, using reduction potentials.

Step 1 – identify cathode and anode: Cu^{2+} is reduced (cathode), Zn is oxidized (anode).

Step 2 – substitute the reduction potentials: $E^\circ_{\text{cell}} = (+0.34) - (-0.76)$

Step 3 – evaluate: $E^\circ_{\text{cell}} = 0.34 + 0.76$

$E^\circ_{\text{cell}} = 1.10\ \text{V}$

Step 4 – sanity check: $E^\circ_{\text{cell}} > 0$, so the reaction is spontaneous, as expected for a Daniell cell.

Final Answer: $E^\circ_{\text{cell}} = 1.10\ \text{V} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – linearized Arrhenius equation: Taking natural logs of $k = A\,e^{-E_a/RT}$ gives $\ln k = \ln A - \dfrac{E_a}{R} \cdot \dfrac{1}{T}$.

Step 1 – compare with the straight-line form $y = c + mx$: Here $y = \ln k$ and $x = \dfrac{1}{T}$.

Step 2 – read off the slope: The coefficient of $\dfrac{1}{T}$ is the slope, $m = -\dfrac{E_a}{R}$.

Step 3 – read off the intercept (for completeness): The intercept is $\ln A$.

Since $E_a > 0$, the slope is negative, matching the falling line in the plot.

Final Answer: slope $= -E_a/R \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – Gibbs free energy: $\Delta G = \Delta H - T\Delta S$, taking care to use consistent units (J).

Step 1 – convert quantities to joules: $\Delta H = -40\ \text{kJ mol}^{-1} = -40000\ \text{J mol}^{-1}$, $\Delta S = +50\ \text{J mol}^{-1}\text{K}^{-1}$, $T = 300\ \text{K}$.

Step 2 – compute the $T\Delta S$ term: $T\Delta S = 300 \times 50 = 15000\ \text{J mol}^{-1}$

Step 3 – substitute into $\Delta G = \Delta H - T\Delta S$: $\Delta G = -40000 - 15000$

Step 4 – evaluate: $\Delta G = -55000\ \text{J mol}^{-1}$

$\Delta G = -55\ \text{kJ mol}^{-1}$

The negative value confirms the reaction is spontaneous at 300 K.

Final Answer: $\Delta G = -55\ \text{kJ mol}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – Faraday's law of electrolysis: Depositing one mole of a species that needs n electrons requires n moles of electrons, i.e. $Q = nF$.

Step 1 – write the reduction: $\text{Na}^+ + e^- \rightarrow \text{Na}$, so $n = 1$ electron per sodium atom.

Step 2 – charge for one mole of electrons: One mole of electrons carries the Faraday charge $F = 96500$ C.

Step 3 – compute Q: $Q = nF = 1 \times 96500$

$Q = 96500$ C

Final Answer: $Q = 96500$ C $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – zero-order integrated rate law: $[A] = [A]_0 - kt$; the concentration falls linearly with time.

Step 1 – set the completion condition: Reaction is complete when $[A] = 0$.

Step 2 – put $[A] = 0$ into the rate law: $0 = [A]_0 - kt$

Step 3 – solve for the time t: $t = \dfrac{[A]_0}{k}$

Step 4 – substitute the numbers: $t = \dfrac{1.0}{0.02}$

$t = 50$ s

Final Answer: $t = 50$ s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – first ionization energy trend: Across a period, ionization energy generally rises with nuclear charge; the noble gas at the end has the highest value because of its stable, filled shell.

Step 1 – order the four elements: Going $\mathrm{N} \to \mathrm{O} \to \mathrm{F} \to \mathrm{Ne}$, the effective nuclear charge increases.

Step 2 – account for the noble-gas configuration: Ne has a completely filled $2s^2 2p^6$ shell, which is especially stable and hard to ionize.

Step 3 – conclude: Ne has the highest first ionization energy of the four (the small N-versus-O irregularity does not change the top value).

Final Answer: highest first ionization energy $= \mathrm{Ne} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – VSEPR geometry from steric number: The shape follows from the number of electron domains (bond pairs + lone pairs) around the central atom.

Step 1 – count the domains on sulfur in $\mathrm{SF_6}$: Six $\mathrm{S}-\mathrm{F}$ bonding pairs and zero lone pairs, so the steric number is 6.

Step 2 – map steric number to geometry: A steric number of 6 with no lone pair corresponds to an *octahedral* arrangement.

Step 3 – confirm with the figure: Four fluorines in a square plane plus one above and one below the central sulfur is exactly an octahedron.

Final Answer: shape of $\mathrm{SF_6}$ is octahedral $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – hybridization from the number of electron domains: Three domains give sp^2, four give sp^3, and so on.

Step 1 – count the domains on boron in BF_3: Three $B-F$ bonds and no lone pair, so three electron domains.

Step 2 – assign the hybridization: Three domains $\Rightarrow$ sp^2 hybridization.

Step 3 – confirm with the geometry: sp^2 gives a trigonal-planar shape with 120° bond angles, exactly as drawn.

Final Answer: boron is sp^2 hybridized $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – oxidation state from charge balance: The sum of the oxidation states in an ion equals the charge on the ion.

Step 1 – let the oxidation state of chlorine be x: Oxygen is -2 and there are four of them.

Step 2 – write the balance for ClO_4^-: $x + 4(-2) = -1$

Step 3 – simplify: $x - 8 = -1$

Step 4 – solve for x: $x = -1 + 8 = +7$

Final Answer: oxidation state of $Cl = +7 \Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – atomic-radius trend across a period: Moving left to right, protons are added to the same principal shell, so effective nuclear charge rises while the electrons feel a stronger pull.

Step 1 – track the nuclear charge: From Li ($Z = 3$) to F ($Z = 9$), nuclear charge steadily increases.

Step 2 – track the shielding: The added electrons enter the same period ($n = 2$) and shield poorly, so the net attraction on the outer electrons grows.

Step 3 – conclude the size change: Stronger pull draws the electron cloud inward, so the atomic radius *decreases* across the period.

Final Answer: atomic radius decreases $\Rightarrow$ A

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – the inert pair effect: In heavy p-block elements the ns^2 electrons are reluctant to take part in bonding, so a lower oxidation state (two below the group value) becomes more stable going down the group.

Step 1 – identify the observation: Tl^{+}, Pb^{2+} and Bi^{3+} are favoured over Tl^{3+}, Pb^{4+}, Bi^{5+}.

Step 2 – attribute the cause: Poor shielding by the intervening d and f electrons makes the $6s$ pair penetrate close to the nucleus and become tightly held ("inert").

Step 3 – name the effect: This is the inert pair effect; the other options describe unrelated phenomena.

Final Answer: the inert pair effect $\Rightarrow$ D

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – CFSE in an octahedral field: CFSE $= \big[-0.4\,n(t_{2g}) + 0.6\,n(e_g)\big]\Delta_o$, where n are the electron occupancies.

Step 1 – place the d^3 electrons: All three electrons go into the lower t_{2g} set, so $n(t_{2g}) = 3$ and $n(e_g) = 0$.

Step 2 – substitute into the CFSE expression: CFSE $= \big[-0.4(3) + 0.6(0)\big]\Delta_o$

Step 3 – evaluate the bracket: $= (-1.2 + 0)\Delta_o$

Step 4 – write the result: CFSE $= -1.2\,\Delta_o$ (there is no pairing energy term for d^3, which stays high spin either way).

Final Answer: CFSE $= -1.2\,\Delta_o \Rightarrow$ B

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – the 18-electron (EAN) rule: Total valence electron count = metal d-electrons + electrons donated by the ligands.

Step 1 – count the metal contribution: Ni is in group 10; as Ni(0) it contributes 10 valence electrons.

Step 2 – count the ligand contribution: Each CO donates 2 electrons; four CO give $4 \times 2 = 8$.

Step 3 – add: Total $= 10 + 8 = 18$

Step 4 – interpret: An 18-electron count is a filled, noble-gas-like valence shell, which is why $[Ni(CO)_4]$ is stable.

Final Answer: valence electron count $= 18 \Rightarrow$ D

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – spin-only magnetic moment: $\mu = \sqrt{n(n+2)}$ BM, with n the number of unpaired electrons.

Step 1 – find n for high-spin d^5: Mn^{2+} is d^5; in a high-spin octahedral field each d orbital is singly filled, giving $n = 5$.

Step 2 – substitute into the formula: $\mu = \sqrt{5(5+2)}$

Step 3 – evaluate inside the root: $\mu = \sqrt{5 \times 7} = \sqrt{35}$

Step 4 – take the square root: $\mu = 5.916$

$\mu \approx 5.92$ BM

Final Answer: $\mu \approx 5.92$ BM $\Rightarrow$ C

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – relative size of tetrahedral and octahedral splitting: For the same metal and ligands, the tetrahedral field has only four ligands and a less direct orientation toward the d orbitals, so it is much smaller.

Step 1 – recall the standard result: $\Delta_t = \frac{4}{9}\Delta_o$.

Step 2 – reason about the factors: The factor $\frac{4}{9}$ arises from four ligands (rather than six) that also point between, not at, the d orbitals.

Step 3 – draw the consequence: Because Δ_t is only about $0.44\,\Delta_o$, it is almost always smaller than the pairing energy, so tetrahedral complexes are essentially always high spin.

Final Answer: $\Delta_t \approx \frac{4}{9}\Delta_o \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – coordination number counts donor atoms, not ligand molecules: A bidentate ligand occupies two coordination sites.

Step 1 – identify the ligand denticity: Ethylenediamine (en) is bidentate, contributing 2 donor nitrogen atoms per molecule.

Step 2 – multiply by the number of ligands: Three en ligands give $3 \times 2 = 6$ donor atoms.

Step 3 – state the coordination number: Coordination number of $Co^{3+} = 6$ (an octahedral complex).

Final Answer: coordination number $= 6 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q25

Q26.

Solution

Concept – spectrochemical series: Ligands are ranked by the splitting they produce; a partial order is $I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 < en < CN^- \approx CO$.

Step 1 – locate the four candidates in the series: I^- is weakest, then F^-, then H_2O, and CN^- is the strongest of the four.

Step 2 – pick the strongest field: CN^- produces the largest Δ_o (it is a strong σ-donor and π-acceptor).

Final Answer: strongest-field ligand $= CN^- \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q26

Q27.

Solution

Concept – counting atoms in a cubic unit cell: A corner atom is shared by 8 cells (counts as $\frac{1}{8}$); a body-centre atom belongs entirely to one cell (counts as 1).

Step 1 – corner contribution: 8 corners $\times \dfrac{1}{8} = 1$ atom.

Step 2 – body-centre contribution: $1 \times 1 = 1$ atom.

Step 3 – add the contributions: Total per BCC cell $= 1 + 1 = 2$ atoms.

Final Answer: atoms per BCC unit cell $= 2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept – atomic packing fraction (APF) of FCC: APF $= \dfrac{\text{volume of atoms in the cell}}{\text{cell volume}}$, using the FCC relation between the sphere radius r and edge a.

Step 1 – number of atoms per FCC cell: $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$ atoms.

Step 2 – geometric relation for FCC: Atoms touch along the face diagonal, so $4r = \sqrt{2}\,a$, giving $a = 2\sqrt{2}\,r$.

Step 3 – form the packing fraction: $\text{APF} = \dfrac{4 \times \frac{4}{3}\pi r^3}{a^3} = \dfrac{\frac{16}{3}\pi r^3}{(2\sqrt{2}\,r)^3}$

Step 4 – simplify the denominator: $(2\sqrt{2})^3 = 16\sqrt{2}$, so $\text{APF} = \dfrac{\frac{16}{3}\pi}{16\sqrt{2}} = \dfrac{\pi}{3\sqrt{2}}$

Step 5 – evaluate: $\text{APF} = \dfrac{3.1416}{4.2426} = 0.740$

Final Answer: APF of FCC $\approx 0.74 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – metal centre of the heme group: Haemoglobin binds O_2 reversibly at an iron centre held in a porphyrin ring.

Step 1 – identify the prosthetic group: The heme is an iron–porphyrin complex.

Step 2 – identify the metal and its state: The metal is iron in the $+2$ state, Fe^{2+}, which coordinates O_2 at the sixth site.

Step 3 – reject the distractors: Mg^{2+} sits in chlorophyll, Zn^{2+} in carbonic anhydrase, and Cu^{2+} in haemocyanin, not in haemoglobin.

Final Answer: metal in heme $= Fe^{2+} \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – conformational energies of n-butane about $C2-C3$: Energy falls in the order fully eclipsed $>$ eclipsed $>$ gauche $>$ anti; the anti (methyls 180° apart) is the global minimum.

Step 1 – compare staggered forms: Both anti and gauche are staggered, but the gauche form suffers methyl–methyl steric strain.

Step 2 – pick the lowest-energy arrangement: In the anti conformation the two bulky methyl groups are as far apart as possible (180° dihedral), minimizing steric strain.

Step 3 – match the drawing: The Newman projection shows one methyl up on the front carbon and the other methyl down on the back carbon, i.e. the anti conformation.

Final Answer: most stable is the anti (180°) conformation $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q30

Q31.

Solution

Concept – counting stereoisomers: For n non-equivalent stereogenic centres with no symmetry, the maximum number of stereoisomers is 2^n.

Step 1 – set the number of centres: $n = 2$ dissimilar stereocentres.

Step 2 – apply the 2^n rule: Maximum stereoisomers $= 2^2$

Step 3 – evaluate: $= 4$

These four are two pairs of enantiomers (or diastereomers between the pairs); since the centres are dissimilar, no meso reduction applies.

Final Answer: maximum number of stereoisomers $= 4 \Rightarrow \boxed{C}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – axial versus equatorial preference in a chair ring: A substituent prefers the equatorial position to avoid $1,3$-diaxial steric repulsions.

Step 1 – consider the axial placement: An axial methyl points into the ring and clashes with the two axial hydrogens three carbons away ($1,3$-diaxial strain).

Step 2 – consider the equatorial placement: An equatorial methyl points outward, away from the ring, with no such clash.

Step 3 – pick the lower-energy chair: The equatorial conformer is more stable and therefore predominates at equilibrium.

Final Answer: methyl occupies the equatorial position $\Rightarrow$ D

Answer: (D) Go Back to Q32

Q33.

Solution

Concept – mechanism selection for a primary substrate: Primary carbocations are too unstable for $S_N1/E1$; a strong nucleophile in a polar aprotic solvent favours the concerted backside attack of S_N2.

Step 1 – rule out S_N1 and $E1$: Both need a carbocation intermediate, which a primary carbon does not form readily.

Step 2 – assess the conditions: A strong, unhindered nucleophile and a polar aprotic solvent (which leaves the nucleophile "naked" and reactive) strongly favour S_N2.

Step 3 – conclude: Substitution occurs by the concerted, single-step S_N2 mechanism with inversion of configuration.

Final Answer: mechanism is $S_N2 \Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – carbocation stability order: Stability increases with the number of attached alkyl groups because of hyperconjugation and the $+I$ (inductive) donation: tertiary $>$ secondary $>$ primary $>$ methyl.

Step 1 – compare the four cations: The tertiary cation has three alkyl groups

donating electron density into the empty p orbital.

Step 2 – identify the most stable: Maximum hyperconjugation and inductive stabilization make the tertiary carbocation the most stable.

Final Answer: most stable is the tertiary carbocation $\Rightarrow$ D

Answer: (D) Go Back to Q34

Q35.

Solution

Concept – meso compounds: A meso compound has stereocentres but also an internal mirror plane, so it is superimposable on its mirror image and hence achiral.

Step 1 – note the two stereocentres: Tartaric acid has two adjacent $\mathrm{CH(OH)COOH}$ stereocentres.

Step 2 – identify the symmetry of the meso form: In the meso diastereomer the two halves are mirror images of each other, giving an internal plane of symmetry.

Step 3 – explain the zero rotation: The optical rotation contributed by one half exactly cancels that of the other, so the molecule as a whole is optically inactive.

Final Answer: it has an internal plane of symmetry $\Rightarrow$ A

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – Saytzeff (Zaitsev) orientation in $E2$: With a small strong base, elimination gives predominantly the more substituted, more stable alkene.

Step 1 – identify the β-hydrogens in 2-bromobutane: Loss of HBr can involve the terminal $\mathrm{C1}$ (giving 1-butene) or the internal $\mathrm{C3}$ (giving 2-butene).

Step 2 – compare the two alkenes: 2-butene is disubstituted and more stable than the monosubstituted 1-butene.

Step 3 – apply Saytzeff's rule: The thermodynamically favoured, more substituted 2-butene is the major product.

Final Answer: major alkene $=$ 2-butene $\Rightarrow$ B

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – the aldol reaction: A base removes an α-hydrogen from one carbonyl compound to give an enolate, which adds to the carbonyl carbon of a second molecule, forming a β-hydroxy carbonyl compound.

Step 1 – form the enolate: Hydroxide removes an α-hydrogen of acetaldehyde to give the enolate of CH_3CHO.

Step 2 – nucleophilic addition: The enolate adds to the carbonyl carbon of a second acetaldehyde molecule.

Step 3 – identify the product: Protonation gives 3-hydroxybutanal, the β-hydroxy aldehyde shown, the hallmark "aldol".

Step 4 – name the reaction: This C–C bond-forming step is the aldol reaction (heating drives it on to the aldol *condensation* product).

Final Answer: the reaction is the Aldol reaction $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – the Cannizzaro reaction: An aldehyde with *no* α-hydrogen, treated with concentrated base, disproportionates: one molecule is oxidized to a carboxylate and another reduced to an alcohol.

Step 1 – check the substrate: Formaldehyde $HCHO$ has no α-hydrogen, so it cannot undergo an aldol reaction.

Step 2 – follow the disproportionation: One $HCHO$ is reduced to CH_3OH and another is oxidized to $HCOO^-Na^+$.

Step 3 – name it: This self oxidation–reduction is the Cannizzaro reaction.

Final Answer: the reaction is the Cannizzaro reaction $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q38

Q39.

Solution

Concept – the Wittig reaction: A phosphorus ylide reacts with a carbonyl compound to give an alkene plus a phosphine oxide.

Step 1 – identify the reagents: An aldehyde/ketone $\mathrm{C{=}O}$ and an ylide $\mathrm{R_3P{=}CR'_2}$.

Step 2 – follow the outcome: The carbonyl oxygen is replaced by the ylide carbon, forming a new $\mathrm{C{=}C}$ double bond; $\mathrm{R_3P{=}O}$ is the by-product.

Step 3 – name it: Converting a carbonyl into an alkene with an ylide is the Wittig reaction.

Final Answer: the reaction is the Wittig reaction $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – electrophile in aromatic nitration: Nitric acid is protonated by sulfuric acid and loses water to generate the nitronium ion, which is the attacking electrophile.

Step 1 – generate the electrophile: $\mathrm{HNO_3 + 2\,H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2\,HSO_4^-}$

Step 2 – identify the active species: The nitronium ion $\mathrm{NO_2^+}$ is the electrophile that attacks the benzene ring.

Step 3 – complete the mechanism (conceptually): The ring π-electrons attack $\mathrm{NO_2^+}$ to give an arenium ion, which loses a proton to restore aromaticity, yielding nitrobenzene.

Final Answer: the electrophile is the nitronium ion $\mathrm{NO_2^+}$ $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q40

Q41.

Solution

Concept – Grignard reagent plus carbon dioxide: The carbanionic carbon of RMgX adds to the electrophilic carbon of $\mathrm{CO_2}$, and acidic work-up releases a carboxylic acid.

Step 1 – nucleophilic addition: $\mathrm{R{-}MgX}$ adds to $\mathrm{O{=}C{=}O}$ to give a magnesium carboxylate, $\mathrm{RCOO{-}MgX}$.

Step 2 – acidic work-up: $\mathrm{RCOO{-}MgX + H^+ \rightarrow RCOOH}$.

Step 3 – identify the product: The product has one more carbon than R and is a carboxylic acid, RCOOH.

Final Answer: product is a carboxylic acid $\Rightarrow$ $\boxed{\mathrm{B}}$

Answer: (B) Go Back to Q41

Q42.

Solution

Concept – the Clemmensen reduction: Amalgamated zinc and concentrated HCl reduce a ketone (or aldehyde) carbonyl fully to a methylene group under acidic conditions.

Step 1 – write the transformation: $\mathrm{R{-}CO{-}R' \xrightarrow{Zn(Hg),\ conc.\ HCl} R{-}CH_2{-}R'}$

Step 2 – distinguish from Wolff–Kishner: Wolff–Kishner ($\mathrm{NH_2NH_2}$, base) achieves the same $\mathrm{C{=}O \rightarrow CH_2}$ result but under *basic* conditions; here the conditions are acidic.

Step 3 – name it: Acidic $\mathrm{Zn(Hg)/HCl}$ reduction of a carbonyl to methylene is the Clemmensen reduction.

Final Answer: the reaction is the Clemmensen reduction $\Rightarrow$ $\boxed{\mathrm{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – Markovnikov addition of water: In acid-catalysed hydration the proton adds first to give the more stable carbocation, so OH ends up on the more substituted carbon.

Step 1 – protonate the alkene: $\mathrm{H^+}$ adds to the terminal $\mathrm{CH_2}$ of propene, giving the secondary cation $\mathrm{CH_3{-}\overset{+}{C}H{-}CH_3}$ (more stable than the primary one).

Step 2 – water attacks the carbocation: Water adds to the positively charged secondary carbon.

Step 3 – lose a proton: Deprotonation gives $\mathrm{CH_3{-}CH(OH){-}CH_3}$.

Step 4 – name the product: The product is propan-2-ol (isopropanol), the Markovnikov alcohol.

Final Answer: major product $=$ propan-2-ol $\Rightarrow$ $\boxed{\mathrm{D}}$

Answer: (D) Go Back to Q43

Q44.

Solution

Concept – the Diels–Alder $[4+2]$ cycloaddition: A conjugated diene (4π) and a dienophile (2π) combine to form a cyclohexene ring, converting two π bonds and forming two new σ bonds plus one new π bond.

Step 1 – count the electrons: $1,3$-butadiene supplies 4π electrons, ethene supplies 2π electrons, a thermally allowed $[4+2]$ process.

Step 2 – form the ring: Two new σ bonds close a six-membered ring; one π bond survives inside the ring.

Step 3 – identify the product: The six-membered ring with one double bond is cyclohexene.

Final Answer: product is cyclohexene $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – Woodward–Hoffmann rules for electrocyclic reactions: For a thermal electrocyclization, a $4n$ π-electron system reacts conrotatory, while a $4n+2$ π-electron system reacts disrotatory.

Step 1 – count the π electrons: A conjugated triene has 6 π electrons, so $4n+2$ with $n=1$.

Step 2 – apply the thermal rule: For a thermal $4n+2$ system, the allowed mode is disrotatory.

Step 3 – conclude: The 6π triene therefore closes to a cyclohexadiene in a disrotatory fashion under thermal conditions.

Final Answer: thermal 6π closure is disrotatory $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – the peptide bond: A peptide bond forms when the carboxyl group of one amino acid condenses with the amino group of another, releasing water.

Step 1 – identify the functional groups joined: $-\text{COOH}$ of one residue reacts with $-\text{NH}_2$ of the next.

Step 2 – classify the resulting linkage: A $\mathrm{C}(=\mathrm{O})-\mathrm{NH}$ bond between a carbonyl and a nitrogen is, by definition, an amide.

Step 3 – conclude: The peptide bond is therefore an amide linkage (a substituted amide).

Final Answer: the peptide bond is an amide linkage $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q46

Answer Key

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