GATE Chemistry

Sample Paper – 10

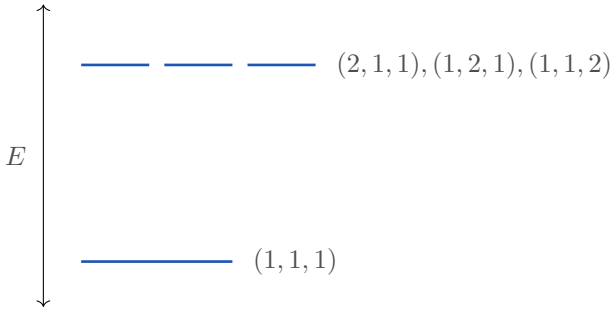
Duration: 128 Minutes **Maximum Marks: 72**

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 in a three-dimensional cubic box the energy is $E_{n_x n_y n_z} = \dfrac{h^2}{8mL^2}\left(n_x^2 + n_y^2 + n_z^2\right)$. The non-degenerate ground state is $(1,1,1)$; the first excited level, shown below, is reached by promoting one quantum number to 2. The degeneracy (number of distinct states) of this first excited level is: **[1 mark]**



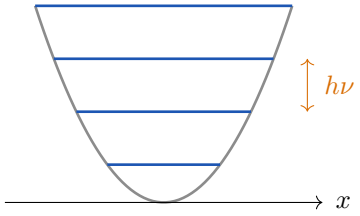
(A) 1

(B) 3

(C) 6

(D) 9

Q2. The vibrational energy levels of a harmonic oscillator of frequency ν are $E_v = \left(v + \frac{1}{2}\right) h\nu$, with $v = 0, 1, 2, \ldots$, sketched as equally spaced rungs inside the parabolic potential below. The spacing between two adjacent vibrational levels is: **[1 mark]**



(A) $2h\nu$

(B) $h\nu$

(C) $\frac{1}{2}h\nu$

(D) it grows with v

Q3. The number of radial nodes in an atomic orbital is given by $n - l - 1$, where n is the principal and l the azimuthal quantum number. For the $3s$ orbital of the hydrogen atom, the number of radial nodes is: **[1 mark]**

(A) 0

(B) 1

(C) 3

(D) 2

Q4. The maximum number of electrons that can be accommodated in a principal shell with principal quantum number n is $2n^2$. For the shell $n = 3$, this maximum number of electrons is: **[1 mark]**

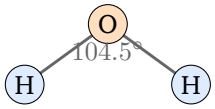
(A) 8

(B) 9

(C) 6

(D) 18

Q5. A non-linear molecule with N atoms has $3N - 6$ normal modes of vibration. For the bent water molecule H_2O ($N = 3$), shown below, the number of normal vibrational modes is: **[1 mark]**



(A) 3

(B) 6

(C) 4

(D) 9

Q6. A coloured solution obeys the Beer–Lambert law $A = \varepsilon c l$. It shows an absorbance of $A = 0.60$ when a $c = 0.02\ \text{mol}\,\text{L}^{-1}$ solution is measured in a $l = 1\ \text{cm}$ cell. The molar absorptivity ε of the species is: **[1 mark]**

(A) $0.012\ \text{L}\,\text{mol}^{-1}\text{cm}^{-1}$

(B) $60\ \text{L}\,\text{mol}^{-1}\text{cm}^{-1}$

(C) $30\ \text{L}\,\text{mol}^{-1}\text{cm}^{-1}$

(D) $1.2\ \text{L}\,\text{mol}^{-1}\text{cm}^{-1}$

Physical Chemistry: Thermodynamics, Kinetics and Electrochemistry

Q7. By the equipartition theorem, an ideal monatomic gas has three translational degrees of freedom, each contributing $\frac{1}{2}RT$ to the molar internal energy. The average molar translational energy $\overline{U}_{\text{trans}} = \frac{3}{2}RT$ of the gas at $T = 300\ \text{K}$ is nearest to: **[1 mark]**

(A) $2.49\ \text{kJ mol}^{-1}$

(B) $7.48\ \text{kJ mol}^{-1}$

(C) $3.74\ \text{kJ mol}^{-1}$

(D) $1.25\ \text{kJ mol}^{-1}$

Q8. An acetic-acid/acetate buffer is prepared so that the acetate ion is ten times as concentrated as the undissociated acid, i.e. $[\text{A}^-]/[\text{HA}] = 10$. Using the Henderson–Hasselbalch equation $\text{pH} = \text{p}K_a + \log_{10}\dfrac{[\text{A}^-]}{[\text{HA}]}$ with $\text{p}K_a = 4.74$, the pH of the buffer is: **[1 mark]**

(A) 4.74

(B) 5.74

(C) 3.74

(D) 6.74

Q9. For the sparingly soluble salt silver chloride, $\text{AgCl} \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$, the solubility product is $K_{sp} = s^2$, where s is the molar solubility. Taking $K_{sp} = 1.6 \times 10^{-10}$ at $25\ ^\circ\text{C}$, the molar solubility s of AgCl in pure water is nearest to: **[1 mark]**

(A) $1.6 \times 10^{-10}\ \text{mol L}^{-1}$

(B) $1.6 \times 10^{-5}\ \text{mol L}^{-1}$

(C) $4.0 \times 10^{-5}\ \text{mol L}^{-1}$

(D) $1.26 \times 10^{-5}\ \text{mol L}^{-1}$

Q10. In the electrolytic extraction of aluminium the reduction at the cathode is $\text{Al}^{3+} + 3e^- \rightarrow \text{Al}$. The electric charge required to deposit exactly one mole of aluminium metal is: **[1 mark]**

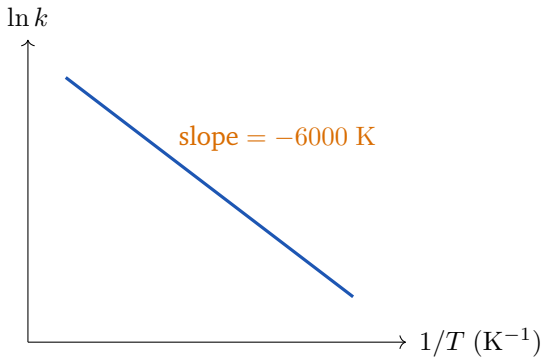
(A) 96500 C

(B) 193000 C

(C) 289500 C

(D) 48250 C

Q11. The Arrhenius plot of $\ln k$ against $1/T$ for a reaction is a straight line of slope -6000 K, as shown. Using slope $= -E_a/R$ with $R = 8.314\ \text{J mol}^{-1}\text{K}^{-1}$, the activation energy E_a of the reaction is nearest to: **[1 mark]**



(A) $49.9\ \text{kJ mol}^{-1}$

(B) $6000\ \text{kJ mol}^{-1}$

(C) $0.72\ \text{kJ mol}^{-1}$

(D) $12.5\ \text{kJ mol}^{-1}$

Q12. The Boltzmann relation connects the entropy of a macrostate to the number of accessible microstates W through $S = k_B \ln W$. For a perfectly ordered pure crystal at absolute zero there is only one accessible microstate, $W = 1$. The entropy of this crystal is: **[1 mark]**

(A) 0

(B) k_B

(C) $k_B \ln 2$

(D) R

Q13. A charge of $96500\ \mathrm{C}$ is passed through a solution of copper(II) sulfate, depositing copper by $\mathrm{Cu}^{2+} + 2e^- \rightarrow \mathrm{Cu}$. Taking the molar mass of copper as $63.5\ \mathrm{g\,mol^{-1}}$, the mass of copper deposited is: **[1 mark]**

(A) $63.5\ \mathrm{g}$

(B) $31.75\ \mathrm{g}$

(C) $127\ \mathrm{g}$

(D) $15.9\ \mathrm{g}$

Q14. A zero-order reaction has rate constant $k = 0.02\ \mathrm{mol\,L^{-1}s^{-1}}$ and an initial reactant concentration $[\mathrm{A}]_0 = 0.80\ \mathrm{mol\,L^{-1}}$. Using the zero-order half-life $t_{1/2} = \dfrac{[\mathrm{A}]_0}{2k}$, the time for the concentration to fall to half its initial value is: **[1 mark]**

(A) $40\ \mathrm{s}$

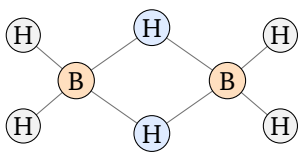
(B) $80\ \mathrm{s}$

(C) $10\ \mathrm{s}$

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

Inorganic Chemistry: Main Group and Periodic Properties

Q15. Diborane $\mathrm{B_2H_6}$ has an electron-deficient bridged structure: each boron carries two terminal hydrogens, and the two borons are joined by two three-centre two-electron $\mathrm{B{-}H{-}B}$ bridges, as sketched below. The number of *bridging* hydrogen atoms in $\mathrm{B_2H_6}$ is: **[1 mark]**



two $\mathrm{B{-}H{-}B}$ bridges

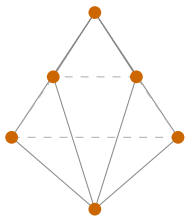
(A) 0

(B) 4

(C) 2

(D) 6

Q16. By Wade's rules a closo borane cluster $[B_nH_n]^{2-}$ has $(n+1)$ skeletal electron pairs and adopts a closed deltahedron. For the octahedral closo cluster $[B_6H_6]^{2-}$ shown below, the number of skeletal electron pairs is: **[1 mark]**



closo $[B_6H_6]^{2-}$ octahedron

(A) 7

(B) 6

(C) 8

(D) 5

Q17. Electronegativity increases across a period and decreases down a group, so it peaks at the top right of the periodic table (excluding the noble gases). Among the elements N, O, F and Cl, the one with the *highest* electronegativity is: **[1 mark]**

(A) F

(B) O

(C) Cl

(D) N

Q18. In the neutral fluoride XeF_6, each fluorine atom is assigned an oxidation number of -1 and the molecule is electrically neutral. The oxidation state of xenon in XeF_6 is: **[1 mark]**

(A) $+2$

(B) $+8$

(C) $+4$

(D) $+6$

Q19. Atomic radius increases on descending a group of the periodic table as successive shells are added. Among the alkali metals Li, Na, K and Rb, the element with the *largest* atomic radius is: **[1 mark]**

(A) Li

(B) Na

(C) Rb

(D) K

Q20. An amphoteric oxide dissolves in both acids and bases, reacting as a base with acids and as an acid with alkalis. Among the following main-group oxides, the one that is *amphoteric* is: **[1 mark]**

(A) $\mathrm{Na_2O}$

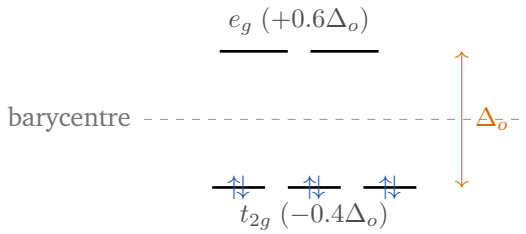
(B) MgO

(C) $\mathrm{SO_3}$

(D) $\mathrm{Al_2O_3}$

Inorganic Chemistry: Coordination Compounds and Organometallics

Q21. In a strong octahedral field the d orbitals split into t_{2g} $(-0.4\Delta_o)$ and e_g $(+0.6\Delta_o)$. A low-spin d^6 ion places all six electrons in the t_{2g} set, as shown. Its crystal-field stabilization energy (CFSE), neglecting the pairing-energy term, is: **[2 marks]**



(A) $-1.6\,\Delta_o$

(B) $-2.4\,\Delta_o$

(C) $-0.4\,\Delta_o$

(D) $-1.2\,\Delta_o$

Q22. Ferrocene $[\mathrm{Fe}(\eta^5\text{-}\mathrm{C_5H_5})_2]$ is a sandwich complex that obeys the 18-electron rule. Taking iron(II) (d^6) to supply 6 electrons and each cyclopentadienyl anion ($\mathrm{C_5H_5^-}$) to donate 6 electrons, the total valence-electron count of ferrocene is: **[2 marks]**

(A) 16

(B) 20

(C) 18

(D) 14

Q23. The octahedral complex $[\mathrm{Ni(H_2O)_6}]^{2+}$ has a d^8 nickel(II) centre; in an octahedral field the e_g orbitals hold two unpaired electrons. Using the spin-only formula $\mu = \sqrt{n(n+2)}$ BM with $n = 2$, the magnetic moment is nearest to: **[2 marks]**

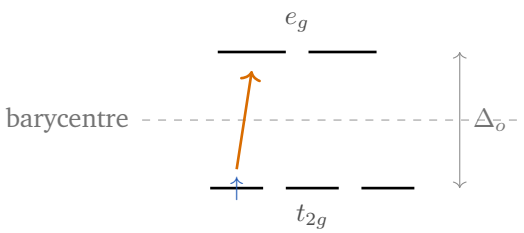
(A) 2.83 BM

(B) 1.73 BM

(C) 3.87 BM

(D) 0 BM

Q24. The hexaaquatitanium(III) ion $[\mathrm{Ti(H_2O)_6}]^{3+}$ is a d^1 system. Its single d electron can be promoted from the t_{2g} set to the e_g set, as the diagram shows. The number of spin-allowed d–d electronic absorption bands expected in its visible spectrum is: **[2 marks]**



(A) 1

(B) 2

(C) 3

(D) 0

Q25. In the octahedral complex ion $[Co(NH_3)_4Cl_2]^+$, two of the six sites are occupied by chloride and four by ammonia. Counting only geometric (cis/trans) isomers, the number of such isomers of this complex is: [2 marks]

(A) 6

(B) 4

(C) 3

(D) 2

Q26. Fluoride is a weak-field ligand, so with cobalt(III) it fails to force electron pairing and gives a high-spin complex. Among the cobalt(III) complexes below, the one that is *high-spin* (paramagnetic with four unpaired electrons) is: [2 marks]

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

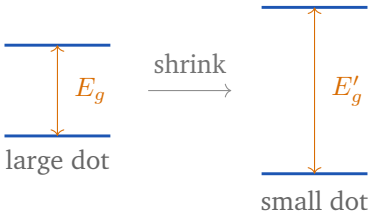
(B) $[CoF_6]^{3-}$

(C) $[Co(CN)_6]^{3-}$

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

Inorganic Chemistry: Solid State and Bioinorganic

Q27. In a semiconductor quantum dot the charge carriers are confined to a region comparable to the exciton radius. As the dot is made smaller, quantum confinement pushes the energy levels apart, as sketched, so the band gap E_g widens and the emission blue-shifts. Therefore, decreasing the quantum-dot size makes the band gap: [2 marks]



(A) increase

(B) decrease

(C) remain unchanged

(D) become zero

Q28. In a face-centred cubic (cubic close-packed) lattice the number of octahedral voids per unit cell equals the number of lattice atoms in the cell. Since the FCC cell contains four atoms, the number of octahedral voids per FCC unit cell is: **[2 marks]**

(A) 8

(B) 2

(C) 1

(D) 4

Q29. Vitamin B_{12} (cobalamin) is a naturally occurring corrin-ring coordination complex in which a single metal ion sits at the centre of the macrocycle. The metal ion at the centre of vitamin B_{12} is: **[2 marks]**

(A) Fe

(B) Zn

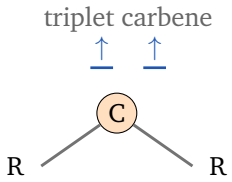
(C) Mg

(D) Co

Organic Chemistry: Stereochemistry and Reaction Mechanisms

Q30. A carbene is a neutral divalent carbon species with only six valence electrons; in its *triplet* ground state the two non-bonding electrons occupy

two different orbitals with parallel spins, as drawn below. The number of *unpaired* electrons in a triplet carbene is: **[2 marks]**



(A) 2

(B) 0

(C) 1

(D) 4

Q31. Free radicals are stabilized by hyperconjugation and the electron-releasing inductive effect of attached alkyl groups, so the stability order is $3^\circ > 2^\circ > 1^\circ >$ methyl. Among the following carbon radicals, the *most* stable is the: **[2 marks]**

(A) methyl radical

(B) primary radical

(C) tertiary radical

(D) secondary radical

Q32. The maximum number of stereoisomers of a molecule that contains n dissimilar stereogenic centres and no internal symmetry is 2^n. For a molecule with three such non-equivalent stereocentres, the maximum number of stereoisomers is: **[2 marks]**

(A) 8

(B) 4

(C) 6

(D) 2

Q33. A tertiary alkyl halide is solvolysed by a weak nucleophile in a polar protic solvent; the reaction proceeds through a rate-determining ionization to a carbocation (S_N1). The kinetic order of an S_N1 reaction is: **[2 marks]**

(A) zero order

(B) first order

(C) second order

(D) third order

Q34. A racemic mixture contains equal amounts of two enantiomers whose specific rotations are equal in magnitude but opposite in sign, so their contributions to optical rotation cancel exactly. The observed optical rotation of a racemic mixture is therefore: **[2 marks]**

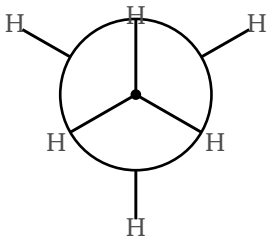
(A) zero

(B) strongly dextrorotatory $(+)$

(C) strongly laevorotatory $(-)$

(D) at its maximum possible value

Q35. In ethane the two methyl groups can rotate about the $\mathrm{C}-\mathrm{C}$ bond. The conformation drawn in the Newman projection below, with the front and back $\mathrm{C}-\mathrm{H}$ bonds 60° apart, minimizes torsional strain. The lowest-energy conformation of ethane is the: **[2 marks]**



staggered ethane

(A) eclipsed

(B) gauche

(C) staggered

(D) fully eclipsed

Q36. When a secondary carbocation is generated next to a carbon bearing a methyl group, a $1,2$-shift can occur that converts it into a more stable

tertiary carbocation. The rearrangement responsible for this increase in stability is a: [2 marks]

(A) simple loss of a proton with no rearrangement

(B) hydride shift that produces a primary carbocation

(C) $1,2$-methyl shift that produces a tertiary carbocation

(D) ring-expansion of an unstrained acyclic chain

Organic Chemistry: Named Reactions and Synthesis

Q37. An aromatic aldehyde is heated with an aliphatic acid anhydride in the presence of the corresponding sodium carboxylate salt to give an α,β-unsaturated (cinnamic-type) acid. This classical route to cinnamic acids is the: [2 marks]

(A) Aldol reaction

(B) Cannizzaro reaction

(C) Claisen condensation

(D) Perkin reaction

Q38. Two molecules of an ester bearing α-hydrogens condense in the presence of a strong alkoxide base, with one ester enolate attacking the carbonyl of the second, to give a β-keto ester. This carbon–carbon bond-forming reaction is the: [2 marks]

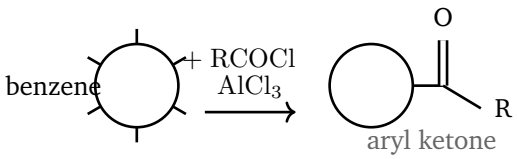
(A) Aldol reaction

(B) Claisen condensation

(C) Perkin reaction

(D) Wittig reaction

Q39. Benzene reacts with an acyl chloride in the presence of anhydrous aluminium chloride ($AlCl_3$) to give an aryl ketone, as shown. This electrophilic aromatic substitution is the: [2 marks]



(A) Wittig reaction

(B) Cannizzaro reaction

(C) Friedel–Crafts acylation

(D) Reimer–Tiemann reaction

Q40. Phenol is warmed with chloroform and aqueous sodium hydroxide, and after acidification the product is salicylaldehyde (2-hydroxybenzaldehyde); the reactive intermediate is dichlorocarbene, which attacks the ortho position of the phenoxide ring. This ortho-formylation of phenol is the: **[2 marks]**

(A) Reimer–Tiemann reaction

(B) Kolbe–Schmitt reaction

(C) Sandmeyer reaction

(D) Gattermann reaction

Q41. A Grignard reagent RMgX is added to formaldehyde (HCHO) and the alkoxide adduct is then hydrolysed with dilute acid. In a retrosynthetic sense the carbonyl carbon becomes a new $\mathrm{CH_2}$ centre, so the organic product of this sequence is: **[2 marks]**

(A) a carboxylic acid (RCOOH)

(B) a primary alcohol ($\mathrm{RCH_2OH}$)

(C) a ketone ($\mathrm{RCOR'}$)

(D) a tertiary alcohol ($\mathrm{R_3COH}$)

Q42. Aniline is treated with sodium nitrite and hydrochloric acid at 0–$5\ ^\circ\mathrm{C}$. This diazotization converts the aryl amine into a key synthetic intermediate that on further reaction gives phenols, aryl halides and azo dyes. The product formed directly from aniline in this step is: **[2 marks]**

(A) nitrobenzene

(B) phenol

(C) benzenediazonium chloride

(D) aniline hydrochloride only

Q43. A primary alcohol is treated with pyridinium chlorochromate (PCC) in dichloromethane, a mild oxidant that stops the oxidation at the first stage. The organic product of this controlled oxidation of a primary alcohol is: **[2 marks]**

(A) a carboxylic acid

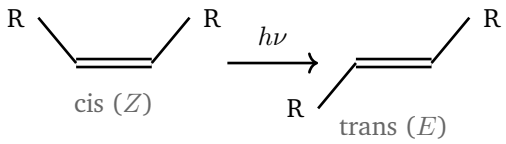
(B) an aldehyde

(C) a ketone

(D) no reaction (PCC does not oxidize alcohols)

Organic Chemistry: Pericyclic, Photochemistry and Biomolecules

Q44. Absorption of ultraviolet light promotes a π electron of an alkene to the π^* orbital; in this excited state the π bond order drops and rotation about the former double bond becomes possible, as sketched. When a pure *cis* (Z) alkene absorbs UV light, it is converted into: **[2 marks]**



(A) the corresponding alkane

(B) the corresponding alcohol

(C) a vicinal diol

(D) the *trans* (E) isomer

Q45. Two alkene molecules combine face to face to form a cyclobutane ring in a $[2+2]$ cycloaddition. By the Woodward–Hoffmann rules a suprafacial–suprafacial $[2+2]$ cycloaddition ($4n$ π electrons) is thermally forbidden

but allowed on photochemical excitation. The $[2 + 2]$ cycloaddition of two alkenes is therefore allowed under: **[2 marks]**

(A) thermal conditions

(B) photochemical conditions

(C) both thermal and photochemical conditions

(D) neither thermal nor photochemical conditions

Q46. In a polysaccharide such as starch or cellulose, successive monosaccharide units are joined through an oxygen bridge formed between the anomeric carbon of one sugar and a hydroxyl of the next, with loss of water. Chemically, this sugar–sugar linkage is a(n): **[2 marks]**

(A) peptide bond

(B) glycosidic bond

(C) phosphodiester bond

(D) ordinary ester bond

Detailed Solutions

Q1.

Solution

Concept – degeneracy in a 3D cubic box: The energy depends only on the sum $n_x^2 + n_y^2 + n_z^2$, so any set of quantum numbers giving the same sum belongs to the same energy level.

Step 1 – fix the ground state: The lowest state is $(1, 1, 1)$ with sum $1 + 1 + 1 = 3$; there is only one way to write it, so it is non-degenerate.

Step 2 – build the first excited level: The next-higher sum is obtained by raising exactly one quantum number to 2, giving sum $4 + 1 + 1 = 6$.

Step 3 – list the distinct states with sum 6: $(2, 1, 1)$, $(1, 2, 1)$ and $(1, 1, 2)$.

Step 4 – count them: There are 3 distinct states of equal energy, so the degeneracy is 3.

Final Answer: degeneracy of the first excited level $= 3 \Rightarrow$ B

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – energy ladder of a harmonic oscillator: The allowed energies are $E_v = \left(v + \frac{1}{2}\right) h\nu$, which are equally spaced rungs.

Step 1 – write two adjacent levels: $E_{v+1} = \left(v + 1 + \frac{1}{2}\right) h\nu$

$E_v = \left(v + \frac{1}{2}\right) h\nu$

Step 2 – subtract to get the spacing: $\Delta E = E_{v+1} - E_v = \left[\left(v + 1 + \frac{1}{2}\right) - \left(v + \frac{1}{2}\right)\right] h\nu$

Step 3 – simplify: $\Delta E = (1)\, h\nu = h\nu$

Step 4 – note the key feature: The spacing $h\nu$ is the same between every pair of adjacent levels, which is why the rungs in the sketch are evenly spaced.

Final Answer: level spacing $= h\nu \Rightarrow$ B

Answer: (B) Go Back to Q2

Q3.

Solution

Concept – radial nodes of an atomic orbital: The number of radial (spherical) nodes is $n - l - 1$.

Step 1 – identify n and l for a $3s$ orbital: For $3s$: $n = 3$ and, since it is an s orbital, $l = 0$.

Step 2 – substitute into the formula: radial nodes $= n - l - 1 = 3 - 0 - 1$

Step 3 – evaluate: radial nodes $= 2$

Step 4 – cross-check with total nodes: Total nodes $= n - 1 = 2$; angular nodes $= l = 0$; so radial nodes $= 2 - 0 = 2$, which agrees.

Final Answer: number of radial nodes $= 2 \Rightarrow$ D

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – capacity of a principal shell: A shell with principal quantum number n holds at most $2n^2$ electrons.

Step 1 – put $n = 3$: maximum electrons $= 2 \times 3^2$

Step 2 – evaluate the square: $= 2 \times 9$

Step 3 – multiply: $= 18$

Step 4 – verify by summing subshells: $3s$ holds 2, $3p$ holds 6, $3d$ holds 10; $2 + 6 + 10 = 18$, confirming the result.

Final Answer: maximum electrons in $n = 3 = 18 \Rightarrow$ D

Answer: (D) Go Back to Q4

Q5.

Solution

Concept – vibrational modes of a non-linear molecule: A non-linear molecule has $3N - 6$ normal modes of vibration.

Step 1 – confirm the geometry: H_2O is bent (non-linear), so the correct formula is $3N - 6$.

Step 2 – put in the number of atoms: $N = 3$, so number of modes $= 3(3) - 6$

Step 3 – evaluate: $= 9 - 6 = 3$

Step 4 – name the three modes: symmetric stretch, asymmetric stretch and bending; that is 3 modes in all, matching the count.

Final Answer: number of vibrational modes $= 3 \Rightarrow$ A

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – Beer–Lambert law solved for ε: $A = \varepsilon c l$, so $\varepsilon = \dfrac{A}{c\,l}$.

Step 1 – list the data: $A = 0.60$, $c = 0.02\ \text{mol L}^{-1}$, $l = 1\ \text{cm}$.

Step 2 – substitute into $\varepsilon = A/(cl)$: $\varepsilon = \dfrac{0.60}{0.02 \times 1}$

Step 3 – evaluate the denominator: $0.02 \times 1 = 0.02$

Step 4 – divide: $\varepsilon = \dfrac{0.60}{0.02} = 30\ \text{L mol}^{-1}\text{cm}^{-1}$

Final Answer: $\varepsilon = 30\ \text{L mol}^{-1}\text{cm}^{-1} \Rightarrow$ C

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – equipartition and translational energy: Each of the three translational degrees of freedom contributes $\frac{1}{2}RT$ per mole, so $\overline{U}_{\text{trans}} = \frac{3}{2}RT$.

Step 1 – write the expression: $\overline{U}_{\text{trans}} = \dfrac{3}{2}RT$

Step 2 – insert the values: $= \dfrac{3}{2} \times 8.314 \times 300$

Step 3 – multiply R and T: $8.314 \times 300 = 2494.2\ \text{J mol}^{-1}$

Step 4 – multiply by $\frac{3}{2}$: $\overline{U}_{\text{trans}} = 1.5 \times 2494.2 = 3741.3\ \text{J mol}^{-1}$

$\overline{U}_{\text{trans}} \approx 3.74\ \text{kJ mol}^{-1}$

Final Answer: $\overline{U}_{\text{trans}} \approx 3.74\ \text{kJ mol}^{-1} \Rightarrow$ C

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – Henderson–Hasselbalch equation for a buffer: $\mathrm{pH} = \mathrm{p}K_a + \log_{10}\dfrac{[\mathrm{A}^-]}{[\mathrm{HA}]}$.

Step 1 – insert the ratio: $\dfrac{[\mathrm{A}^-]}{[\mathrm{HA}]} = 10$, so $\log_{10}(10) = 1$.

Step 2 – substitute the pKa: $\mathrm{pH} = 4.74 + 1$

Step 3 – add: $\mathrm{pH} = 5.74$

Step 4 – sanity check: More conjugate base than acid should push the pH above $\mathrm{p}K_a$, and $5.74 > 4.74$, which is consistent.

Final Answer: $\mathrm{pH} = 5.74 \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – solubility from K_{sp} for a 1:1 salt: For $\mathrm{AgCl} \rightleftharpoons \mathrm{Ag}^+ + \mathrm{Cl}^-$, if s is the molar solubility then $[\mathrm{Ag}^+] = [\mathrm{Cl}^-] = s$ and $K_{sp} = s^2$.

Step 1 – write the relation: $K_{sp} = s^2$

Step 2 – solve for s: $s = \sqrt{K_{sp}} = \sqrt{1.6 \times 10^{-10}}$

Step 3 – take the square root of the mantissa and exponent: $\sqrt{1.6} = 1.264$ and $\sqrt{10^{-10}} = 10^{-5}$

Step 4 – combine: $s = 1.264 \times 10^{-5}\ \mathrm{mol\,L^{-1}} \approx 1.26 \times 10^{-5}\ \mathrm{mol\,L^{-1}}$

Final Answer: $s \approx 1.26 \times 10^{-5}\ \mathrm{mol\,L^{-1}} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – Faraday's law and charge per mole: Depositing one mole of a metal ion of charge $+z$ requires z moles of electrons, i.e. $z \times F$ coulombs.

Step 1 – identify z for aluminium: $\mathrm{Al}^{3+} + 3e^- \rightarrow \mathrm{Al}$, so $z = 3$.

Step 2 – write the required charge: $Q = z \times F = 3 \times 96500\ \mathrm{C}$

Step 3 – evaluate: $Q = 289500\ \mathrm{C}$

Final Answer: charge required $= 289500$ C $\Rightarrow$ C

Answer: (C) Go Back to Q10

Q11.

Solution

Concept – activation energy from an Arrhenius slope: The linearized Arrhenius equation $\ln k = \ln A - \dfrac{E_a}{R} \cdot \dfrac{1}{T}$ has slope $-\dfrac{E_a}{R}$.

Step 1 – equate the given slope: $-\dfrac{E_a}{R} = -6000$ K

Step 2 – solve for E_a: $E_a = 6000 \times R = 6000 \times 8.314$

Step 3 – multiply: $E_a = 49884$ J mol^{-1}

Step 4 – convert to kilojoules: $E_a = 49.9$ kJ mol^{-1}

Final Answer: $E_a \approx 49.9$ kJ mol^{-1} $\Rightarrow$ A

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – Boltzmann's entropy formula: $S = k_B \ln W$, where W is the number of accessible microstates.

Step 1 – set the microstate count: A perfectly ordered pure crystal at 0 K has a single arrangement, so $W = 1$.

Step 2 – substitute: $S = k_B \ln(1)$

Step 3 – evaluate the logarithm: $\ln(1) = 0$

Step 4 – conclude: $S = k_B \times 0 = 0$

This is the statistical statement of the third law of thermodynamics.

Final Answer: $S = 0 \Rightarrow$ A

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – Faraday's laws of electrolysis: Moles of metal deposited $= \dfrac{Q}{zF}$, and mass $=$ moles $\times\, M$.

Step 1 – find moles of electrons passed: moles of $e^- = \dfrac{Q}{F} = \dfrac{96500}{96500} = 1$ mol

Step 2 – convert to moles of copper ($z = 2$): moles of $\mathrm{Cu} = \dfrac{1}{2} = 0.5$ mol

Step 3 – convert to mass: mass $= 0.5 \times 63.5$

Step 4 – evaluate: mass $= 31.75$ g

Final Answer: mass of copper $= 31.75$ g $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – half-life of a zero-order reaction: For a zero-order reaction $[\mathrm{A}] = [\mathrm{A}]_0 - kt$, so the concentration halves after $t_{1/2} = \dfrac{[\mathrm{A}]_0}{2k}$.

Step 1 – list the data: $[\mathrm{A}]_0 = 0.80\ \mathrm{mol\,L^{-1}}$, $k = 0.02\ \mathrm{mol\,L^{-1}s^{-1}}$.

Step 2 – substitute: $t_{1/2} = \dfrac{0.80}{2 \times 0.02}$

Step 3 – evaluate the denominator: $2 \times 0.02 = 0.04$

Step 4 – divide: $t_{1/2} = \dfrac{0.80}{0.04} = 20$ s

Final Answer: $t_{1/2} = 20$ s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – bridged structure of diborane: $\mathrm{B_2H_6}$ is electron-deficient; four hydrogens are terminal (ordinary $2c$-$2e$ bonds) and the remaining two are bridging.

Step 1 – count all hydrogens: There are 6 hydrogens in total.

Step 2 – count the terminal hydrogens: Each boron carries two terminal $\mathrm{B-H}$ bonds: $2 \times 2 = 4$ terminal hydrogens.

Step 3 – find the bridging hydrogens: Bridging $= 6 - 4 = 2$; these form the two $\mathrm{B-H-B}$ three-centre two-electron bridges shown.

Final Answer: number of bridging hydrogens $= 2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – Wade's rules for a closo borane: A closo cluster $[B_nH_n]^{2-}$ has $(n+1)$ skeletal electron pairs and adopts a closed deltahedron with n vertices.

Step 1 – identify n: For $[B_6H_6]^{2-}$, $n = 6$ boron vertices, giving the octahedron drawn.

Step 2 – apply the closo rule: skeletal electron pairs $= n + 1 = 6 + 1$

Step 3 – evaluate: $= 7$ skeletal electron pairs

Step 4 – cross-check by counting electrons: Each $B-H$ unit gives 2 skeletal electrons: $6 \times 2 = 12$; add the $2-$ charge: $12 + 2 = 14$ electrons $= 7$ pairs, which agrees.

Final Answer: skeletal electron pairs $= 7 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – periodic trend in electronegativity: Electronegativity rises across a period (left to right) and falls down a group, peaking near fluorine.

Step 1 – compare within period 2: Across $N < O < F$, electronegativity increases, so F exceeds both N and O.

Step 2 – compare F with Cl: F sits above Cl in group 17, and electronegativity decreases down the group, so $F > Cl$.

Step 3 – conclude: Fluorine is the most electronegative of the four (indeed the most electronegative element of all).

Final Answer: highest electronegativity $= F \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – oxidation state from a neutral molecule: The sum of oxidation numbers in a neutral molecule is zero, and each F is -1.

Step 1 – let the oxidation state of Xe be x: $x + 6(-1) = 0$

Step 2 – simplify: $x - 6 = 0$

Step 3 – solve: $x = +6$

Final Answer: oxidation state of Xe in $XeF_6 = +6 \Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – atomic radius down a group: Descending a group adds electron shells, so the atomic radius increases from top to bottom.

Step 1 – order the alkali metals by period: Li (period 2) $<$ Na (3) $<$ K (4) $<$ Rb (5) in shell count.

Step 2 – apply the trend: Because radius grows down the group, the lowest listed element has the largest radius.

Step 3 – identify it: Rb lies lowest among Li, Na, K, Rb, so it has the largest atomic radius.

Final Answer: largest atomic radius $=$ Rb $\Rightarrow$ C

Answer: (C) Go Back to Q19

Q20.

Solution

Concept – acidic, basic and amphoteric oxides: Metal oxides of very electropositive metals are basic, non-metal oxides are acidic, and certain intermediate oxides are amphoteric (react with both acids and bases).

Step 1 – classify each option: Na_2O and MgO are basic metal oxides; SO_3 is an acidic non-metal oxide.

Step 2 – test Al_2O_3: Aluminium oxide dissolves in acids (forming Al^{3+}) and in alkalis (forming aluminate, $[Al(OH)_4]^-$), so it reacts both ways.

Step 3 – conclude: Al_2O_3 is the amphoteric oxide.

Final Answer: amphoteric oxide $= Al_2O_3 \Rightarrow$ D

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – CFSE of an octahedral configuration: CFSE $= \big[n(t_{2g})(-0.4) + n(e_g)(+0.6)\big]\Delta_o$, neglecting the pairing-energy term.

Step 1 – assign the electrons for low-spin d^6: All six electrons are in t_{2g}: $n(t_{2g}) = 6$, $n(e_g) = 0$.

Step 2 – substitute: CFSE $= \big[6(-0.4) + 0(+0.6)\big]\Delta_o$

Step 3 – evaluate the t_{2g} term: $6 \times (-0.4) = -2.4$

Step 4 – combine: CFSE $= -2.4\,\Delta_o$

Final Answer: CFSE $= -2.4\,\Delta_o \Rightarrow$ B

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – 18-electron count of ferrocene: Add the metal d-electron count to the electrons donated by each ligand.

Step 1 – count the metal electrons: Iron is in the $+2$ state (d^6), contributing 6 electrons.

Step 2 – count the ligand electrons: Each η^5-cyclopentadienyl anion $C_5H_5^-$ donates 6 electrons; there are two of them: $2 \times 6 = 12$.

Step 3 – add: total $= 6 + 12 = 18$ valence electrons.

Step 4 – interpret: The 18-electron count matches the noble-gas configuration and explains ferrocene's high stability.

Final Answer: valence-electron count $= 18 \Rightarrow$ C

Answer: (C) Go Back to Q22

Q23.

Solution

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

Step 1 – find n for octahedral d^8: Ni^{2+} is d^8; in an octahedral field the configuration is $t_{2g}^6 e_g^2$ with $n = 2$ unpaired electrons.

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

Step 3 – simplify inside the root: $= \sqrt{2 \times 4} = \sqrt{8}$

Step 4 – evaluate: $\mu = 2.83$ BM

Final Answer: $\mu \approx 2.83$ BM $\Rightarrow$ A

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – d–d bands of a d^1 ion: The number of spin-allowed d–d transitions depends on how many ways the electron configuration can be rearranged between the split levels.

Step 1 – set up the d^1 case: The one electron sits in t_{2g} in the ground state ($^2T_{2g}$).

Step 2 – identify the only excited configuration: Promotion places the electron in e_g (^2E_g); there is exactly one such excited state.

Step 3 – count the transitions: Only the single $t_{2g} \rightarrow e_g$ excitation is possible, giving one absorption band.

Step 4 – connect to observation: This is why $[Ti(H_2O)_6]^{3+}$ shows a single broad visible band (near 20000 cm^{-1}) and appears purple.

Final Answer: number of d–d bands $= 1 \Rightarrow$ A

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – geometric isomerism in MA_4B_2 octahedral complexes: An octahedral $[MA_4B_2]$ complex can place the two B ligands either adjacent or opposite.

Step 1 – place the two chlorides adjacent: The two Cl at 90° give the cis isomer.

Step 2 – place the two chlorides opposite: The two Cl at 180° give the trans

isomer.

Step 3 – count the distinct arrangements: Only cis and trans are possible, so there are 2 geometric isomers.

Step 4 – note on optical isomerism: Neither cis nor trans $[\mathrm{Co(NH_3)_4Cl_2}]^+$ is chiral, so no extra optical isomers arise.

Final Answer: number of geometric isomers $= 2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – ligand field strength and spin state: Strong-field ligands (large Δ_o) force low-spin; weak-field ligands (small Δ_o) leave the complex high-spin.

Step 1 – rank the ligands by the spectrochemical series: $\mathrm{F^-}$ is a weak-field ligand, whereas $\mathrm{NH_3}$, en and especially $\mathrm{CN^-}$ are strong-field.

Step 2 – apply to cobalt(III), d^6: With strong-field ligands ($\mathrm{NH_3}$, en, $\mathrm{CN^-}$) the d^6 ion is low-spin (t_{2g}^6, diamagnetic). With weak-field $\mathrm{F^-}$ it stays high-spin ($t_{2g}^4 e_g^2$, four unpaired electrons).

Step 3 – pick the high-spin complex: Only $[\mathrm{CoF_6}]^{3-}$ is high-spin and paramagnetic.

Final Answer: high-spin complex $= [\mathrm{CoF_6}]^{3-} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – quantum confinement in nanocrystals: When a semiconductor crystal shrinks to the nanometre scale, the electron and hole are squeezed into a smaller box, and the particle-in-a-box levels move apart as $1/L^2$.

Step 1 – relate size to level spacing: Smaller confinement length L means larger energy separations between the occupied and empty levels.

Step 2 – connect to the band gap: The lowest optical transition (the effective band gap E_g) therefore widens as the dot gets smaller.

Step 3 – state the optical consequence: A wider gap means higher-energy (shorter-wavelength) emission, i.e. a blue shift, exactly as used to tune quantum-dot colours.

Final Answer: decreasing the dot size makes the band gap increase $\Rightarrow$ A

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – voids in a close-packed lattice: In any close-packed arrangement the number of octahedral voids equals the number of packing atoms, and the number of tetrahedral voids is twice that.

Step 1 – count atoms in an FCC cell: Corners: $8 \times \frac{1}{8} = 1$; faces: $6 \times \frac{1}{2} = 3$; total $= 1 + 3 = 4$ atoms.

Step 2 – apply the octahedral-void rule: Number of octahedral voids $=$ number of atoms $= 4$.

Step 3 – cross-check (tetrahedral voids): Tetrahedral voids $= 2 \times 4 = 8$, consistent with the standard result, confirming the octahedral count of 4.

Final Answer: number of octahedral voids per FCC cell $= 4 \Rightarrow$ D

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – metal centre of vitamin B_{12}: Vitamin B_{12} (cobalamin) is built around a corrin macrocycle that chelates a central metal ion.

Step 1 – recall the biological cofactor: Cobalamin is the cobalt-containing vitamin; the metal at the corrin centre is cobalt.

Step 2 – rule out the distractors: Iron sits in haem, magnesium in chlorophyll and zinc in carbonic anhydrase, none of which is the B_{12} centre.

Step 3 – conclude: The metal ion at the centre of vitamin B_{12} is cobalt.

Final Answer: metal in vitamin $B_{12} = Co \Rightarrow$ D

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – singlet versus triplet carbenes: A carbene has two non-bonding electrons. In a singlet they are paired in one orbital; in a triplet they occupy two different orbitals with parallel spins.

Step 1 – identify the triplet arrangement: The two non-bonding electrons are in separate orbitals, each singly occupied.

Step 2 – count the unpaired electrons: Two singly occupied orbitals give 2 unpaired electrons (a spin state $S = 1$, hence "triplet").

Step 3 – confirm the multiplicity: Multiplicity $= 2S+1 = 2(1)+1 = 3$, consistent with the name triplet and the two parallel arrows drawn.

Final Answer: number of unpaired electrons in a triplet carbene $= 2 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q30

Q31.

Solution

Concept – stability order of alkyl radicals: Alkyl groups donate electron density and provide hyperconjugation, stabilizing an adjacent radical; more alkyl substituents means a more stable radical.

Step 1 – write the stability order: $3^\circ > 2^\circ > 1^\circ >$ methyl.

Step 2 – match to the options: The tertiary radical carries the most alkyl groups and the greatest number of hyperconjugative $\mathrm{C}-\mathrm{H}$ bonds.

Step 3 – conclude: The tertiary radical is the most stable of those listed.

Final Answer: most stable radical $=$ tertiary radical $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – counting stereoisomers with the 2^n rule: For n dissimilar stereogenic centres and no internal symmetry, the maximum number of stereoisomers is 2^n.

Step 1 – identify n: The molecule has three non-equivalent stereocentres, so $n = 3$.

Step 2 – substitute: maximum stereoisomers $= 2^3$

Step 3 – evaluate: $= 8$

Final Answer: maximum number of stereoisomers $= 8 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – kinetics of the S_N1 mechanism: S_N1 proceeds in two steps; the slow, rate-determining step is ionization of the substrate to a carbocation, which does not involve the nucleophile.

Step 1 – write the rate law: rate $= k$[substrate], depending only on the alkyl halide concentration.

Step 2 – read off the order: The exponent on the substrate is 1, and the nucleophile does not appear, so the reaction is first order overall.

Step 3 – contrast with S_N2: S_N2 would be second order (rate $= k$[substrate][Nu]); the tertiary substrate and weak nucleophile here favour S_N1, hence first order.

Final Answer: S_N1 is a first-order reaction $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – optical activity of a racemate: A racemic mixture is an equimolar blend of two enantiomers with equal and opposite specific rotations.

Step 1 – add the two contributions: One enantiomer rotates by $+\alpha$, the other by $-\alpha$, in equal amount.

Step 2 – combine: net rotation $= (+\alpha) + (-\alpha) = 0$

Step 3 – interpret: The rotations cancel exactly, so the racemate is optically inactive "by external compensation".

Final Answer: observed rotation of a racemate $=$ zero $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – conformations of ethane: Rotation about the $C-C$ bond interconverts staggered and eclipsed forms; torsional (eclipsing) strain is minimized when bonds are as far apart as possible.

Step 1 – compare the two extremes: In the eclipsed form front and back $C-H$ bonds overlap (0° dihedral); in the staggered form they are 60° apart.

Step 2 – assess the strain: The staggered form has no eclipsing interactions and lies about $12\ \text{kJ mol}^{-1}$ below the eclipsed form.

Step 3 – conclude: The staggered conformation is the lowest-energy (most stable) form of ethane, as drawn.

Final Answer: lowest-energy conformation $=$ staggered $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – carbocation rearrangement by a $1,2$-shift: A less stable carbocation can rearrange when a group on the adjacent carbon migrates with its bonding pair to the cationic centre, provided this yields a more stable cation.

Step 1 – identify the starting cation: A secondary carbocation sits next to a carbon bearing a methyl group.

Step 2 – carry out the migration: The methyl group migrates ($1,2$-methyl shift) to the positive carbon, moving the positive charge to the now more substituted carbon.

Step 3 – assess the product: The new cation is tertiary and therefore more stable, so the shift is favourable.

Step 4 – reject the wrong options: A hydride shift here would give a primary cation (less stable), and there is no ring to expand, so those are not the driving rearrangement.

Final Answer: a $1,2$-methyl shift converts the 2° cation into a 3° cation $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q36

Q37.

Solution

Concept – the Perkin reaction: An aromatic aldehyde condenses with an aliphatic acid anhydride in the presence of the corresponding carboxylate salt to give an α,β-unsaturated aromatic acid.

Step 1 – identify the reactants: Aromatic aldehyde + anhydride + sodium salt of the acid, on heating.

Step 2 – identify the product type: A cinnamic-type α,β-unsaturated acid is formed.

Step 3 – name the reaction and reject distractors: This is the Perkin reaction. The aldol needs an aldehyde/ketone enolate, Cannizzaro needs an aldehyde without α-H under strong base, and Claisen condenses esters; none matches.

Final Answer: the reaction is the Perkin reaction $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – the Claisen condensation: Two ester molecules with α-hydrogens condense under a strong alkoxide base to give a β-keto ester.

Step 1 – generate the enolate: The base removes an α-hydrogen from one ester to form an ester enolate.

Step 2 – carbon–carbon bond formation: The enolate attacks the carbonyl carbon of the second ester, expelling an alkoxide leaving group.

Step 3 – identify the product and name it: The product is a β-keto ester (e.g. ethyl acetoacetate from ethyl acetate); this is the Claisen condensation.

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

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – Friedel–Crafts acylation: An acyl chloride and a Lewis acid ($AlCl_3$) generate an acylium ion that substitutes onto the aromatic ring to give an aryl ketone.

Step 1 – form the electrophile: $RCOCl + AlCl_3 \rightarrow RCO^+ + AlCl_4^-$ (acylium ion).

Step 2 – electrophilic aromatic substitution: Benzene's π electrons attack the acylium carbon, and loss of a proton restores aromaticity.

Step 3 – identify the product and name the reaction: The product is an aryl ketone $\mathrm{Ar-CO-R}$; this is the Friedel–Crafts acylation.

Final Answer: the reaction is Friedel–Crafts acylation $\Rightarrow$ C

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – the Reimer–Tiemann reaction: Phenol, chloroform and aqueous base give ortho-hydroxybenzaldehyde (salicylaldehyde) via a dichlorocarbene intermediate.

Step 1 – generate the carbene: $\mathrm{CHCl_3}$ with NaOH loses HCl to form dichlorocarbene $:\mathrm{CCl_2}$.

Step 2 – attack the phenoxide ring: The electrophilic carbene adds at the ortho position of the activated phenoxide, and hydrolysis of the resulting $\mathrm{CHCl_2}$ group gives a $-\mathrm{CHO}$ group.

Step 3 – identify the product and name the reaction: The product is salicylaldehyde; this ortho-formylation is the Reimer–Tiemann reaction (Kolbe–Schmitt gives salicylic acid using $\mathrm{CO_2}$, not chloroform).

Final Answer: the reaction is the Reimer–Tiemann reaction $\Rightarrow$ A

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – Grignard addition to formaldehyde: A Grignard reagent adds to a carbonyl; with formaldehyde the carbonyl carbon becomes a $\mathrm{CH_2}$ group bearing the new R and an OH.

Step 1 – nucleophilic addition: $\mathrm{R-MgX}$ adds to $\mathrm{H_2C{=}O}$ to give $\mathrm{R-CH_2-O-MgX}$.

Step 2 – acidic work-up: $\mathrm{R-CH_2-O-MgX + H^+ \rightarrow R-CH_2-OH}$.

Step 3 – classify the product: The carbon bearing OH carries only one carbon substituent (R) and two hydrogens, so it is a primary alcohol. (Formaldehyde always gives 1° alcohols; higher aldehydes give 2° and ketones give 3°.)

Final Answer: product is a primary alcohol $\mathrm{RCH_2OH} \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q41

Q42.

Solution

Concept – diazotization of aniline: A primary aromatic amine reacts with nitrous acid (from $\mathrm{NaNO_2 + HCl}$) at low temperature to form an aryl diazonium salt.

Step 1 – generate nitrous acid: $\mathrm{NaNO_2 + HCl \rightarrow HNO_2 + NaCl}$.

Step 2 – form the diazonium ion: $\mathrm{C_6H_5NH_2 + HNO_2 + HCl \rightarrow C_6H_5N_2^+Cl^- + 2\,H_2O}$, kept at 0–$5\ ^\circ\mathrm{C}$ to stop decomposition.

Step 3 – identify the product: The direct product is benzenediazonium chloride, the key intermediate for phenols, aryl halides and azo dyes.

Final Answer: product is benzenediazonium chloride $\Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – controlled oxidation with PCC: Pyridinium chlorochromate in dichloromethane is a mild, anhydrous oxidant that stops the oxidation of a primary alcohol at the aldehyde stage.

Step 1 – oxidize the primary alcohol: $\mathrm{R-CH_2OH \xrightarrow{PCC,\ CH_2Cl_2} R-CHO}$.

Step 2 – explain why it stops there: Without water present, no hydrate forms, so the aldehyde is not further oxidized to the carboxylic acid (unlike aqueous $\mathrm{KMnO_4}$ or $\mathrm{CrO_3/H^+}$).

Step 3 – identify the product: The product is the aldehyde.

Final Answer: product is an aldehyde $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – photochemical cis–trans isomerization of alkenes: Absorption of UV light excites a π electron to π^*; the excited state has essentially no π bond, so the two ends can rotate about the former double bond.

Step 1 – excite the alkene: $h\nu$ promotes $\pi \rightarrow \pi^*$, weakening the double bond.

Step 2 – allow rotation: Free rotation in the excited state lets the geometry change; relaxation gives back a ground-state alkene of either geometry.

Step 3 – identify the product from a cis start: Starting from the pure cis (Z) alkene, the photostationary process delivers the trans (E) isomer (no atoms are added, so it stays an alkene, not an alcohol or diol).

Final Answer: the cis alkene is converted to the trans (E) isomer $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – Woodward–Hoffmann rules for cycloadditions: For a suprafacial–suprafacial cycloaddition, a $4n+2$ π-electron process (like $[4+2]$) is thermally allowed, while a $4n$ π-electron process (like $[2+2]$) is thermally forbidden but photochemically allowed.

Step 1 – count the π electrons: A $[2+2]$ cycloaddition of two alkenes involves $2+2=4$ π electrons, i.e. $4n$ with $n=1$.

Step 2 – apply the selection rule: A $4n$ suprafacial–suprafacial cycloaddition is thermally forbidden and photochemically allowed.

Step 3 – conclude: The $[2+2]$ dimerization of alkenes to cyclobutanes proceeds under photochemical conditions.

Final Answer: $[2+2]$ cycloaddition is allowed photochemically $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – the glycosidic bond: Monosaccharides are joined through an acetal (or ketal) oxygen bridge formed between the anomeric carbon of one sugar and a hydroxyl of another, releasing water.

Step 1 – identify the groups joined: The anomeric $-\mathrm{OH}$ (hemiacetal) of one sugar condenses with an $-\mathrm{OH}$ of the next.

Step 2 – classify the linkage: The resulting $\mathrm{C}-\mathrm{O}-\mathrm{C}$ acetal bridge between two sugar units is called a glycosidic bond.

Step 3 – reject the distractors: Peptide bonds join amino acids, phosphodiester bonds join nucleotides, and a plain ester needs a carboxylic acid; none of these describes a sugar–sugar link.

Final Answer: the sugar–sugar linkage is a glycosidic bond $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q46

Answer Key

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