GATE Chemistry

Sample Paper – 3

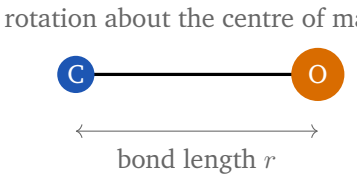
Duration: 128 Minutes **Maximum Marks: 72**

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. A carbon monoxide molecule is treated as a rigid rotor made of two nuclei joined by a rigid bond, as sketched below. Taking the atomic masses as $^{12}\mathrm{C} = 12$ and $^{16}\mathrm{O} = 16$, the reduced mass $\mu = \dfrac{m_1 m_2}{m_1 + m_2}$ of the molecule (in atomic mass units) is nearest to: **[1 mark]**



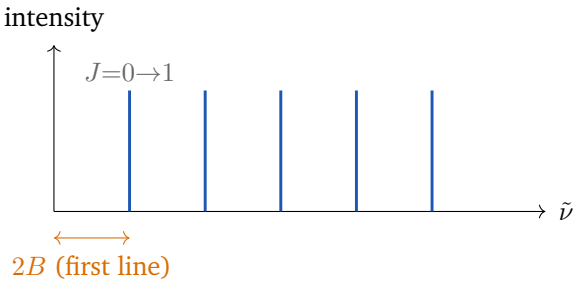
(A) 28

(B) 14

(C) 4

(D) 6.86

Q2. The pure rotational spectrum of a rigid diatomic rotor shows equally spaced lines, and the very first line (the $J = 0 \rightarrow 1$ transition) appears at a wavenumber of $2B$, as marked below. If the rotational constant of the molecule is $B = 10\ \text{cm}^{-1}$, the wavenumber of this first absorption line is: **[1 mark]**



(A) $10\ \text{cm}^{-1}$

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

(C) $40\ \text{cm}^{-1}$

(D) $5\ \text{cm}^{-1}$

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

(A) 0

(B) 1

(C) 2

(D) 3

Q4. The vibrational energy levels of a harmonic oscillator are $E_v = \left(v + \frac{1}{2}\right) h\nu$, with $v = 0, 1, 2, \ldots$ The spacing between two adjacent vibrational levels is: **[1 mark]**

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

(B) $2h\nu$

(C) $v\,h\nu$

(D) $h\nu$

Q5. A vibrational mode is infrared active only if it produces a change in the molecular dipole moment. Among the molecules $\mathrm{N_2}$, CO, $\mathrm{O_2}$ and $\mathrm{Cl_2}$, the one whose stretching vibration is infrared active is: **[1 mark]**

(A) $\mathrm{N_2}$

(B) CO

(C) $\mathrm{O_2}$

(D) $\mathrm{Cl_2}$

Q6. The energy of a single photon is $E = h\nu = \dfrac{hc}{\lambda}$, with $h = 6.626 \times 10^{-34}\ \mathrm{J\,s}$ and $c = 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$. For light of wavelength $\lambda = 500\ \mathrm{nm}$, the photon energy is nearest to: **[1 mark]**

(A) $2.0 \times 10^{-19}\ \mathrm{J}$

(B) $6.6 \times 10^{-34}\ \mathrm{J}$

(C) $4.0 \times 10^{-19}\ \mathrm{J}$

(D) $3.0 \times 10^{8}\ \mathrm{J}$

Physical Chemistry: Thermodynamics, Kinetics and Electrochemistry

Q7. For any spontaneous (irreversible) process taking place inside an isolated system, the second law of thermodynamics requires that the total entropy change of the system is: **[1 mark]**

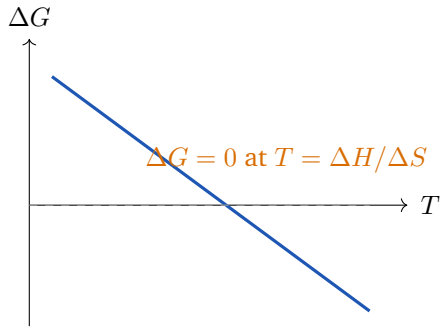
(A) positive ($\Delta S > 0$)

(B) zero ($\Delta S = 0$)

(C) negative ($\Delta S < 0$)

(D) undefined

Q8. An endothermic reaction has $\Delta H = +50\ \text{kJ mol}^{-1}$ and $\Delta S = +100\ \text{J mol}^{-1}\text{K}^{-1}$. From $\Delta G = \Delta H - T\Delta S$, the crossover temperature above which the reaction just becomes spontaneous ($\Delta G < 0$), read as the point where the line below cuts $\Delta G = 0$, is: **[1 mark]**



(A) $50\ \text{K}$

(B) $100\ \text{K}$

(C) $500\ \text{K}$

(D) $5000\ \text{K}$

Q9. At equilibrium the standard Gibbs free-energy change and the equilibrium constant are related by $\Delta G^\circ = -RT \ln K$. If a reaction has $\Delta G^\circ = 0$ at a given temperature, the value of its equilibrium constant K is: **[1 mark]**

(A) 0

(B) 1

(C) ∞

(D) negative

Q10. When a system absorbs $300\ \mathrm{J}$ of heat reversibly at a constant temperature of $300\ \mathrm{K}$, the entropy change of the system, $\Delta S = \dfrac{q_{\text{rev}}}{T}$, is: **[1 mark]**

(A) $300\ \mathrm{J\,K^{-1}}$

(B) $1.0\ \mathrm{J\,K^{-1}}$

(C) $0.5\ \mathrm{J\,K^{-1}}$

(D) $900\ \mathrm{J\,K^{-1}}$

Q11. For an elementary reaction, the units of the rate constant depend on the overall order. For a reaction that is *second order* overall, with the rate expressed in $\mathrm{mol\,L^{-1}\,s^{-1}}$ and concentration in $\mathrm{mol\,L^{-1}}$, the units of the rate constant are: **[1 mark]**

(A) $\mathrm{s^{-1}}$

(B) $\mathrm{mol\,L^{-1}\,s^{-1}}$

(C) $\mathrm{L\,mol^{-1}\,s^{-1}}$

(D) dimensionless

Q12. The temperature dependence of a rate constant follows the Arrhenius equation $k = A\,e^{-E_a/RT}$, where A is the pre-exponential (frequency) factor. In the limit $T \to \infty$, the exponential term tends to unity, so the rate constant k approaches: **[1 mark]**

(A) A

(B) 0

(C) ∞

(D) E_a

Q13. In the electrolytic refining of copper, deposition follows $\mathrm{Cu^{2+} + 2e^- \to Cu}$. Using Faraday's law $n_{\mathrm{Cu}} = \dfrac{Q}{zF}$, the number of moles of copper deposited by passing a charge of $96500\ \mathrm{C}$ is: **[1 mark]**

(A) 2

(B) 1

(C) 0.25

(D) 0.5

Q14. The Nernst equation at $298\ \text{K}$ is $E = E^\circ - \dfrac{0.059}{n}\log Q$. For a cell reaction with $n = 1$ and reaction quotient $Q = 10$, the electrode potential E becomes: **[1 mark]**

(A) $E^\circ + 0.059\ \text{V}$

(B) E°

(C) $E^\circ - 0.118\ \text{V}$

(D) $E^\circ - 0.059\ \text{V}$

Inorganic Chemistry: Main Group and Periodic Properties

Q15. Among the halogens F_2, Cl_2, Br_2 and I_2, the bond dissociation enthalpy does not fall smoothly down the group: the value for fluorine is anomalously low because of lone-pair repulsion in the small F_2 molecule. The halogen with the *highest* bond dissociation enthalpy is: **[1 mark]**

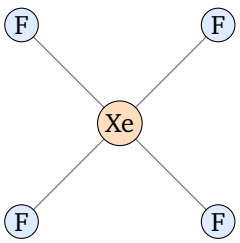
(A) F_2

(B) Cl_2

(C) Br_2

(D) I_2

Q16. The noble-gas compound xenon tetrafluoride, XeF_4, has a central xenon atom surrounded by four bonding pairs and two lone pairs. The two lone pairs occupy opposite axial positions, giving the geometry shown below. The molecular shape of XeF_4 is: **[1 mark]**



square-planar XeF_4

(A) tetrahedral

(B) octahedral

(C) square planar

(D) see-saw

Q17. In the iodate ion IO_3^-, each of the three oxygen atoms is assigned an oxidation number of -2 and the ion carries an overall charge of -1. The oxidation state of iodine in IO_3^- is: **[1 mark]**

(A) $+1$

(B) $+3$

(C) $+5$

(D) $+7$

Q18. The noble gases are extremely unreactive, but the heavier members can form compounds because their outer electrons are more easily removed. Among He, Xe, Ne and Ar, the noble gas with the *lowest* first ionization energy, and hence the one that most readily forms fluorides, is: **[1 mark]**

(A) He

(B) Xe

(C) Ne

(D) Ar

Q19. Electronegativity is highest for fluorine among all elements. On descending group 17 from F to Cl to Br to I, the electronegativity of the halogens generally: **[1 mark]**

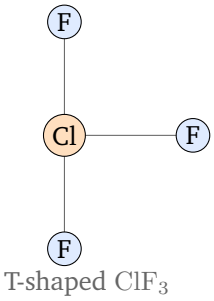
(A) increases

(B) decreases

(C) stays essentially constant

(D) becomes zero

Q20. In the interhalogen molecule chlorine trifluoride, ClF_3, the central chlorine atom is surrounded by three bonding pairs and two lone pairs (an sp^3d set). The two lone pairs take equatorial positions, leaving the shape drawn below. The molecular shape of ClF_3 is: **[1 mark]**



T-shaped ClF_3

(A) trigonal planar

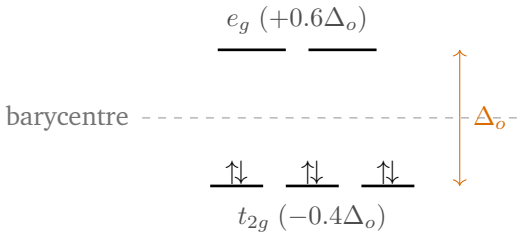
(B) pyramidal

(C) trigonal bipyramidal

(D) T-shaped

Inorganic Chemistry: Coordination Compounds and Organometallics

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



(A) $-1.6\,\Delta_o$

(B) $-0.4\,\Delta_o$

(C) $-2.4\,\Delta_o$

(D) 0

Q22. The magnitude of the crystal-field splitting Δ_o follows the spectrochemical series of the ligands, ammonia lying well above fluoride. Considering the two cobalt(III) complexes $[\mathrm{Co(NH_3)_6}]^{3+}$ and $[\mathrm{CoF_6}]^{3-}$, the complex with the *larger* value of Δ_o is: **[2 marks]**

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

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

(C) both are exactly equal

(D) cannot be decided

Q23. A high-spin octahedral nickel(II) complex has a d^8 configuration ($t_{2g}^6 e_g^2$) with two unpaired electrons. Using the spin-only formula $\mu = \sqrt{n(n+2)}\ \mathrm{BM}$, the magnetic moment of the complex is nearest to: **[2 marks]**

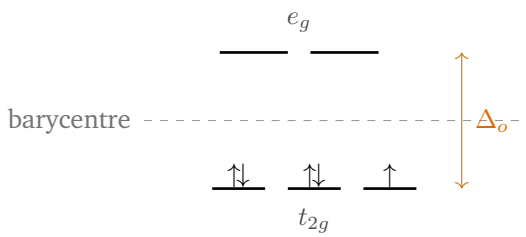
(A) 1.73 BM

(B) 5.92 BM

(C) 3.87 BM

(D) 2.83 BM

Q24. A d^5 octahedral complex is placed in a *strong* field where Δ_o exceeds the pairing energy P. The electrons then adopt the low-spin arrangement shown below, filling the t_{2g} set before the e_g set. The number of unpaired electrons in this low-spin d^5 ion is: **[2 marks]**



(A) 5

(B) 1

(C) 3

(D) 0

Q25. For an octahedral complex of the type $[MA_4B_2]$, the two B ligands can sit either adjacent or opposite to each other. The number of geometrical (cis/trans) isomers possible for $[MA_4B_2]$ is: **[2 marks]**

(A) 2

(B) 3

(C) 4

(D) 1

Q26. In the spectrochemical series the ligands are ranked by the field strength (and hence the crystal-field splitting) they produce. Among the ligands Br^-, CN^-, NH_3 and H_2O, the one that produces the *smallest* crystal-field splitting (weakest field) is: **[2 marks]**

(A) Br^-

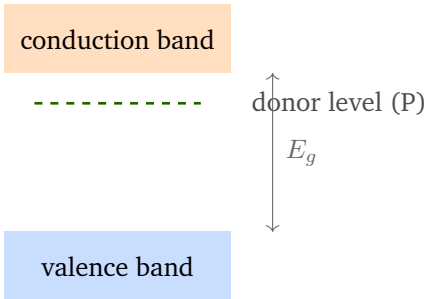
(B) CN^-

(C) NH_3

(D) H_2O

Inorganic Chemistry: Solid State and Bioinorganic

Q27. In band theory, an intrinsic semiconductor such as silicon has a small gap between its filled valence band and empty conduction band. When silicon is doped with phosphorus (a group-15 element), a filled donor level appears just below the conduction band, as sketched. The type of extrinsic semiconductor produced is: **[2 marks]**



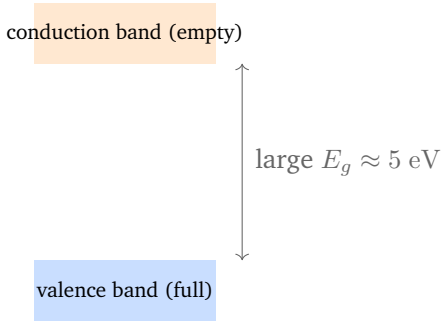
(A) p-type

(B) an insulator

(C) a superconductor

(D) n-type

Q28. The electrical behaviour of a solid depends on the gap E_g between its valence and conduction bands. A crystalline solid has a completely filled valence band, an empty conduction band, and a *large* band gap of about $5\ \text{eV}$, as drawn. On the basis of band theory this solid behaves as: **[2 marks]**



(A) a good conductor

(B) an intrinsic semiconductor

(C) an insulator

(D) a metal

Q29. Chlorophyll, the green pigment responsible for capturing light in photosynthesis, is built on a porphyrin-type ring holding a single metal ion at its centre. The metal ion present at the centre of the chlorophyll molecule is: **[2 marks]**

(A) Mg^{2+}

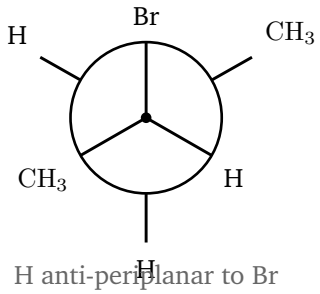
(B) Fe^{2+}

(C) Ca^{2+}

(D) Zn^{2+}

Organic Chemistry: Stereochemistry and Reaction Mechanisms

Q30. The $E2$ elimination is a single-step, concerted process in which the base removes a β-hydrogen that lies *anti-periplanar* to the leaving group, as shown in the Newman projection below. The rate law that governs an $E2$ reaction is: **[2 marks]**



H anti-periplanar to Br

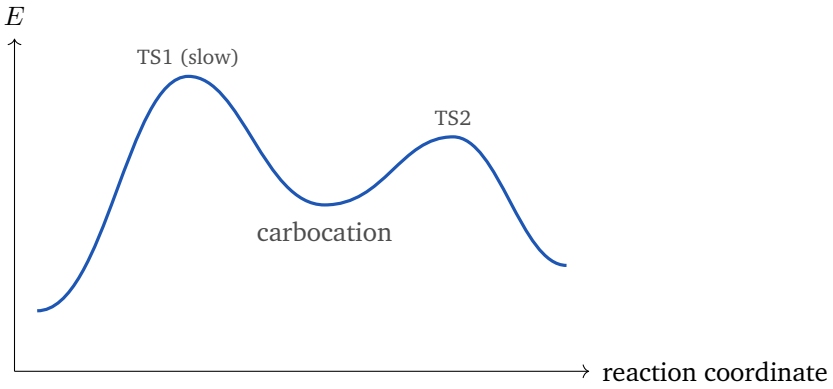
(A) first order, rate $= k$[substrate]

(B) second order, rate $= k$[substrate][base]

(C) zero order in both

(D) third order overall

Q31. The $E1$ elimination is a two-step reaction: the leaving group departs first to give a carbocation (the slow, rate-determining step), and the base then removes a proton. The reaction-coordinate diagram is sketched below. The rate law that governs an $E1$ reaction is: **[2 marks]**



(A) rate $= k$[substrate][base]

(B) zero order overall

(C) first order, rate $= k$[substrate]

(D) rate $= k$[base]

Q32. 2-Bromo-2-methylbutane is treated with the bulky base potassium *tert*-butoxide and undergoes elimination. Because the base is sterically hindered, the reaction follows the Hofmann orientation. The major alkene product is therefore the: **[2 marks]**

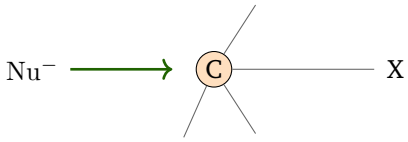
(A) more substituted (Saytzeff) alkene

(B) less substituted (Hofmann) alkene

(C) no elimination occurs

(D) substitution product instead

Q33. A single-step S_N2 substitution occurs when the nucleophile attacks the carbon from the side directly opposite the leaving group, as shown. This backside attack has a well-defined stereochemical consequence at the reacting carbon, namely: **[2 marks]**



backside attack at the sp^3 carbon

(A) inversion of configuration (Walden inversion)

(B) retention of configuration

(C) complete racemization

(D) no change at the carbon

Q34. $2,3$-Dibromobutane has two stereogenic centres that carry identical sets of substituents, so one of its stereoisomers is an achiral *meso* form. Counting the meso compound together with the pair of enantiomers, the number of distinct stereoisomers of $2,3$-dibromobutane is: **[2 marks]**

(A) 2

(B) 3

(C) 4

(D) 1

Q35. Configuration at a stereocentre is assigned by the Cahn–Ingold–Prelog rules: the four groups are ranked by priority, the lowest-priority group is pointed away from the viewer, and the sense of $1 \to 2 \to 3$ is read. If this sequence traces a *clockwise* path, the configuration is designated: [2 marks]

(A) S

(B) *meso*

(C) Z

(D) R

Q36. During an $E1$ (or S_N1) reaction the initially formed carbocation can rearrange when a neighbouring $\mathrm{C{-}H}$ bond migrates. A $1,2$-hydride shift that moves a hydrogen from an adjacent carbon onto a *secondary* carbocation converts it into the more stable: [2 marks]

(A) tertiary carbocation

(B) primary carbocation

(C) methyl cation

(D) carbanion

Organic Chemistry: Named Reactions and Synthesis

Q37. A Grignard reagent RMgX adds across the carbonyl group of an aldehyde (other than formaldehyde). After acidic work-up, the type of alcohol produced is a: [2 marks]

(A) secondary alcohol

(B) primary alcohol

(C) tertiary alcohol

(D) carboxylic acid

Q38. When a Grignard reagent RMgX reacts with a ketone $\mathrm{R'COR''}$ and the adduct is then hydrolysed with dilute acid, the alcohol obtained is a: **[2 marks]**

(A) primary alcohol

(B) aldehyde

(C) secondary alcohol

(D) tertiary alcohol

Q39. Formaldehyde (HCHO) is unique among aldehydes in having two hydrogen atoms on the carbonyl carbon. When a Grignard reagent RMgX reacts with formaldehyde and the mixture is worked up, the alcohol obtained (with one extra carbon) is a: **[2 marks]**

(A) secondary alcohol

(B) tertiary alcohol

(C) ketone

(D) primary alcohol

Q40. Grignard reagents are strongly basic carbanion-like species and react instantly with any source of an acidic proton. When a Grignard reagent RMgX is exposed to water (or any protic solvent), the organic product formed is: **[2 marks]**

(A) an alcohol ROH

(B) an alkane $\mathrm{R-H}$

(C) an alkene

(D) an ether

Q41. In the Reformatsky reaction, an α-halo ester is first converted into an organometallic reagent, which then adds to an aldehyde or ketone to give a β-hydroxy ester after work-up. The metal used to generate the organometallic reagent in this reaction is: **[2 marks]**

(A) magnesium

(B) lithium

(C) zinc

(D) sodium

Q42. The Wurtz reaction couples two molecules of an alkyl halide in dry ether to build a symmetrical alkane containing twice the number of carbon atoms. The metal that brings about this coupling is: [2 marks]

(A) zinc

(B) magnesium

(C) copper

(D) sodium

Q43. Gilman reagents are lithium dialkylcuprates ($\mathrm{R_2CuLi}$) prepared from an organolithium and a copper(I) halide; they couple efficiently with alkyl and aryl halides. The transition metal that characterises a Gilman reagent is: [2 marks]

(A) copper

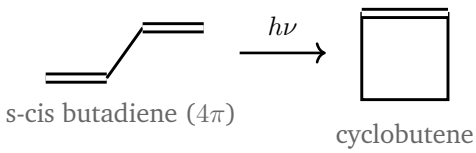
(B) zinc

(C) magnesium

(D) nickel

Organic Chemistry: Pericyclic, Photochemistry and Biomolecules

Q44. A substituted $1,3$-butadiene contains four π electrons ($4n$ with $n = 1$) and undergoes electrocyclic ring closure to a cyclobutene under *photochemical* conditions, as sketched. According to the Woodward–Hoffmann rules, the stereochemical mode of this photochemical $4n$ electrocyclization is: [2 marks]



s-cis butadiene (4π) cyclobutene

(A) disrotatory

(B) conrotatory

(C) forbidden (does not occur)

(D) suprafacial–antarafacial

Q45. The same substituted $1,3$-butadiene (4π electrons) can instead be heated, so that it undergoes a *thermal* electrocyclic ring closure to a cyclobutene. According to the Woodward–Hoffmann rules, the stereochemical mode of this thermal $4n$ electrocyclization is: **[2 marks]**

(A) disrotatory

(B) forbidden (does not occur)

(C) conrotatory

(D) antarafacial only

Q46. In the DNA double helix, the two complementary strands are held together by specific pairing between the bases adenine–thymine and guanine–cytosine. The interaction responsible for holding a base pair together is a set of: **[2 marks]**

(A) hydrogen bonds

(B) peptide bonds

(C) ionic bonds

(D) disulfide bonds

Detailed Solutions

Q1.

Solution

Concept – reduced mass of a two-body rotor: For a diatomic molecule the rotation is described by a single effective mass, the reduced mass $\mu = \dfrac{m_1 m_2}{m_1 + m_2}$.

Step 1 – list the two atomic masses: $m_1 = 12$ (carbon), $m_2 = 16$ (oxygen).

Step 2 – form the product in the numerator: $m_1 m_2 = 12 \times 16 = 192$.

Step 3 – form the sum in the denominator: $m_1 + m_2 = 12 + 16 = 28$.

Step 4 – divide: $\mu = \dfrac{192}{28}$

$\mu = 6.857 \approx 6.86$ atomic mass units.

Why the other options are wrong: 28 is the total mass, not the reduced mass, and 14 would be the simple average; both ignore the correct formula.

Final Answer: $\mu \approx 6.86$ amu $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

Concept – rotational line positions of a rigid rotor: The rotational term values are $F(J) = B\,J(J+1)$, and an absorption line for $J \to J+1$ appears at $\tilde{\nu}(J) = 2B(J+1)$.

Step 1 – take the first transition $J = 0 \to 1$: Put $J = 0$ in $\tilde{\nu}(J) = 2B(J+1)$.

Step 2 – evaluate the expression: $\tilde{\nu}(0) = 2B(0+1) = 2B$.

Step 3 – substitute $B = 10\ \text{cm}^{-1}$: $\tilde{\nu}(0) = 2 \times 10\ \text{cm}^{-1}$

$\tilde{\nu}(0) = 20\ \text{cm}^{-1}$.

Step 4 – cross-check with the spectrum: The first stick sits at $2B$ and successive lines are spaced by $2B$, exactly as drawn.

Final Answer: first line at $20\ \text{cm}^{-1} \Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q2

Q3.

Solution

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

Step 1 – read off the quantum numbers of $3s$: For $3s$, the principal quantum number $n = 3$ 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: $= 2$.

Step 4 – consistency check: The total number of nodes is $n - 1 = 2$; with no angular nodes ($l = 0$), all 2 are radial, which agrees.

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

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – evenly spaced harmonic-oscillator levels: For a harmonic oscillator $E_v = \left(v + \frac{1}{2}\right) h\nu$, and the levels are equally spaced.

Step 1 – write two neighbouring levels: $E_{v+1} = \left(v + \frac{3}{2}\right) h\nu$

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

Step 2 – subtract to get the spacing: $E_{v+1} - E_v = \left[\left(v + \frac{3}{2}\right) - \left(v + \frac{1}{2}\right)\right] h\nu$.

Step 3 – simplify the bracket: $\left(v + \frac{3}{2}\right) - \left(v + \frac{1}{2}\right) = 1$.

Step 4 – conclude: $E_{v+1} - E_v = h\nu$, the same for every pair of adjacent levels.

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

Answer: (D) Go Back to Q4

Q5.

Solution

Concept – infrared activity requires a changing dipole: A vibration absorbs infrared radiation only if the molecular dipole moment changes during the motion.

Step 1 – classify the molecules by symmetry: N_2, O_2 and Cl_2 are homonuclear diatomics; each has a permanent dipole of zero and stays zero when it stretches.

Step 2 – test each homonuclear case: Stretching a homonuclear bond keeps the

two identical atoms symmetric, so $\frac{d\mu}{dr} = 0$ and the vibration is IR inactive.

Step 3 – test CO**:** CO is heteronuclear and already polar; stretching the bond changes its dipole moment, so $\frac{d\mu}{dr} \neq 0$.

Step 4 – conclude: Only CO has an IR-active stretch.

Final Answer: CO is infrared active $\Rightarrow$ B

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – photon energy from wavelength: $E = \frac{hc}{\lambda}$.

Step 1 – convert the wavelength to metres: $\lambda = 500\ \text{nm} = 500 \times 10^{-9}\ \text{m} = 5.0 \times 10^{-7}\ \text{m}$.

Step 2 – multiply h **and** c**:** $hc = (6.626 \times 10^{-34})(3.0 \times 10^{8}) = 1.988 \times 10^{-25}\ \text{J m}$.

Step 3 – divide by λ**:** $E = \frac{1.988 \times 10^{-25}}{5.0 \times 10^{-7}}$.

Step 4 – evaluate: $E = 3.98 \times 10^{-19}\ \text{J} \approx 4.0 \times 10^{-19}\ \text{J}$.

Final Answer: $E \approx 4.0 \times 10^{-19}\ \text{J} \Rightarrow$ C

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – second law for an isolated system: For a spontaneous change in an isolated system the total entropy must increase.

Step 1 – state the criterion: $\Delta S_{\text{total}} > 0$ for any real (irreversible) spontaneous process.

Step 2 – note the boundary case: $\Delta S_{\text{total}} = 0$ only for a reversible (idealized, equilibrium) process.

Step 3 – rule out a decrease: $\Delta S_{\text{total}} < 0$ would violate the second law and cannot happen spontaneously in an isolated system.

Step 4 – conclude: A spontaneous process therefore has a positive total entropy change.

Final Answer: $\Delta S > 0$ (positive) $\Rightarrow$ A

Answer: (A) Go Back to Q7

Q8.

Solution

Concept – spontaneity crossover temperature: For $\Delta H > 0$ and $\Delta S > 0$, $\Delta G = \Delta H - T\Delta S$ turns negative once T is large enough; the crossover is at $\Delta G = 0$.

Step 1 – set $\Delta G = 0$: $0 = \Delta H - T\Delta S$.

Step 2 – solve for the temperature: $T = \dfrac{\Delta H}{\Delta S}$.

Step 3 – put both quantities in consistent units: $\Delta H = 50\ \text{kJ mol}^{-1} = 50000\ \text{J mol}^{-1}$; $\Delta S = 100\ \text{J mol}^{-1}\text{K}^{-1}$.

Step 4 – evaluate: $T = \dfrac{50000}{100} = 500\ \text{K}$.

Why the other options are wrong: Options that keep ΔH in kJ while ΔS is in J (giving 50 or 5000) come from a units mismatch.

Final Answer: crossover temperature $= 500\ \text{K} \Rightarrow$ C

Answer: (C) Go Back to Q8

Q9.

Solution

Concept – link between ΔG° and K: $\Delta G^\circ = -RT \ln K$.

Step 1 – insert $\Delta G^\circ = 0$: $0 = -RT \ln K$.

Step 2 – since $RT \neq 0$, isolate the log: $\ln K = 0$.

Step 3 – solve for K: $K = e^0$.

Step 4 – evaluate: $K = 1$, meaning the reaction is exactly balanced at standard conditions.

Final Answer: $K = 1 \Rightarrow$ B

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – entropy of reversible heat transfer: $\Delta S = \dfrac{q_{\text{rev}}}{T}$ at constant temperature.

Step 1 – list the data: $q_{\text{rev}} = 300\ \text{J}$ (absorbed), $T = 300\ \text{K}$.

Step 2 – substitute into the formula: $\Delta S = \dfrac{300\ \text{J}}{300\ \text{K}}$.

Step 3 – evaluate: $\Delta S = 1.0\ \text{J K}^{-1}$.

Step 4 – check the sign: Heat is absorbed, so $\Delta S > 0$, consistent with a positive value.

Final Answer: $\Delta S = 1.0\ \text{J K}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – units of a rate constant from the rate law: For an n-th order reaction, rate $= k[\text{A}]^n$, so k has units $(\text{concentration})^{1-n}(\text{time})^{-1}$.

Step 1 – write the second-order rate law: rate $= k[\text{A}]^2$ (overall order $n = 2$).

Step 2 – solve for k: $k = \dfrac{\text{rate}}{[\text{A}]^2}$.

Step 3 – substitute units: $k = \dfrac{\text{mol L}^{-1}\,\text{s}^{-1}}{(\text{mol L}^{-1})^2}$.

Step 4 – simplify: $k = \text{mol}^{-1}\,\text{L}\,\text{s}^{-1} = \text{L mol}^{-1}\,\text{s}^{-1}$.

Final Answer: k has units $\text{L mol}^{-1}\,\text{s}^{-1} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept – high-temperature limit of the Arrhenius equation: $k = A\,e^{-E_a/RT}$, in which A is the pre-exponential factor.

Step 1 – examine the exponent as $T \to \infty$: As $T \to \infty$, the ratio $\dfrac{E_a}{RT} \to 0$.

Step 2 – evaluate the exponential: $e^{-E_a/RT} \to e^0 = 1$.

Step 3 – substitute back: $k \to A \times 1 = A$.

Step 4 – interpret: A is the ceiling on k; every collision would be effective if the

energy barrier no longer mattered.

Final Answer: $k \to A \Rightarrow$ A

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – Faraday's law of electrolysis: Moles deposited $n = \dfrac{Q}{zF}$, where z is the number of electrons per ion.

Step 1 – identify the electron count: For $Cu^{2+} + 2e^- \to Cu$, $z = 2$.

Step 2 – substitute the data: $n = \dfrac{96500}{2 \times 96500}$.

Step 3 – simplify the denominator: $2 \times 96500 = 193000$.

Step 4 – evaluate: $n = \dfrac{96500}{193000} = 0.5$ mol.

Final Answer: 0.5 mol of copper $\Rightarrow$ D

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – Nernst equation correction term: $E = E^\circ - \dfrac{0.059}{n} \log Q$ at 298 K.

Step 1 – insert $n = 1$ and $Q = 10$: $E = E^\circ - \dfrac{0.059}{1} \log 10$.

Step 2 – evaluate the logarithm: $\log 10 = 1$.

Step 3 – compute the correction term: $\dfrac{0.059}{1} \times 1 = 0.059$ V.

Step 4 – write the result: $E = E^\circ - 0.059$ V.

Final Answer: $E = E^\circ - 0.059$ V $\Rightarrow$ D

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – anomalous $F-F$ bond strength: Bond dissociation enthalpy usually falls down a group, but F_2 breaks the trend.

Step 1 – explain the fluorine anomaly: The F_2 bond is very short, so the lone pairs on the two tiny fluorine atoms repel strongly and weaken the bond.

Step 2 – place chlorine: Cl_2 atoms are larger, lone-pair repulsion is much smaller, and the bond is the strongest of the group.

Step 3 – place the heavier halogens: From Cl_2 to Br_2 to I_2 the bond weakens because of poorer orbital overlap with increasing size.

Step 4 – rank: $Cl_2 > Br_2 > F_2 > I_2$, so Cl_2 has the highest bond dissociation enthalpy.

Final Answer: $Cl_2 \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – VSEPR for six electron domains: Four bond pairs plus two lone pairs give a total of six domains (octahedral electron geometry).

Step 1 – place the electron domains: Six domains point to the corners of an octahedron.

Step 2 – position the lone pairs: The two lone pairs take the two axial (trans) positions to be as far apart as possible.

Step 3 – read off the atom positions: The four fluorine atoms then lie in one plane at the equator.

Step 4 – name the shape: Four atoms in a plane around the centre give a square-planar molecule.

Final Answer: XeF_4 is square planar $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – oxidation-number balance in an oxoanion: The oxidation numbers must add up to the ion's overall charge.

Step 1 – let the iodine oxidation state be x: Each oxygen is -2, and there are three oxygens.

Step 2 – write the balance for IO_3^-: $x + 3(-2) = -1$.

Step 3 – simplify: $x - 6 = -1$.

Step 4 – solve for x: $x = -1 + 6 = +5$.

Final Answer: oxidation state of I $= +5 \Rightarrow$ C

Answer: (C) Go Back to Q17

Q18.

Solution

Concept – ionization energy trend down group 18: First ionization energy falls down a group as the outer electrons move farther from the nucleus.

Step 1 – order the noble gases by period: He (period 1), Ne (2), Ar (3), Xe (5).

Step 2 – apply the trend: Ionization energy decreases He $>$ Ne $>$ Ar $>$ Xe.

Step 3 – pick the lowest: Xe has the lowest first ionization energy of the four.

Step 4 – connect to reactivity: Because its electrons are held least tightly, Xe is the one that forms fluorides (XeF_2, XeF_4, XeF_6).

Final Answer: Xe $\Rightarrow$ B

Answer: (B) Go Back to Q18

Q19.

Solution

Concept – electronegativity trend down a group: Electronegativity decreases down a group because the bonding electrons are increasingly shielded and farther from the nucleus.

Step 1 – list the halogens top to bottom: F $\rightarrow$ Cl $\rightarrow$ Br $\rightarrow$ I.

Step 2 – note the atomic size change: Atomic radius grows down the group, so the nucleus attracts a shared pair less strongly.

Step 3 – apply to electronegativity: The pull on bonding electrons weakens, so

electronegativity falls.

Step 4 – conclude: From F to I the electronegativity decreases.

Final Answer: electronegativity decreases $\Rightarrow$ B

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – VSEPR for sp^3d with two lone pairs: Five electron domains give a trigonal-bipyramidal arrangement; lone pairs prefer the roomier equatorial sites.

Step 1 – count the domains on chlorine: Three $\mathrm{Cl-F}$ bonds plus two lone pairs give five domains.

Step 2 – place the lone pairs: Both lone pairs occupy equatorial positions to minimize repulsion.

Step 3 – locate the fluorine atoms: Two fluorines go to the axial positions and one to the remaining equatorial position.

Step 4 – name the resulting shape: The three fluorines describe a bent "T", so the molecule is T-shaped.

Final Answer: $\mathrm{ClF_3}$ is T-shaped $\Rightarrow$ D

Answer: (D) Go Back to Q20

Q21.

Solution

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

Step 1 – write the low-spin d^6 configuration: All six electrons pair up in t_{2g}: $t_{2g}^6 e_g^0$.

Step 2 – put the occupancies into the formula: $\mathrm{CFSE} = \big[-0.4(6) + 0.6(0)\big]\Delta_o$.

Step 3 – evaluate each term: $-0.4 \times 6 = -2.4$ and $0.6 \times 0 = 0$.

Step 4 – add: $\mathrm{CFSE} = -2.4\,\Delta_o$.

Why the other options are wrong: $-1.6\,\Delta_o$ corresponds to a high-spin d^6 ($t_{2g}^4 e_g^2$), not the low-spin case shown.

Final Answer: $\mathrm{CFSE} = -2.4\,\Delta_o \Rightarrow$ C

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – spectrochemical series sets Δ_o: Stronger-field ligands split the d orbitals more, giving a larger Δ_o.

Step 1 – rank the two ligands: In the spectrochemical series NH_3 lies well above F^- (ammonia is a stronger field ligand).

Step 2 – compare the complexes: Same metal and oxidation state (Co^{3+}), so the difference in Δ_o comes only from the ligand.

Step 3 – assign the larger split: The ammine complex $[Co(NH_3)_6]^{3+}$ therefore has the larger Δ_o (indeed it is low spin), while $[CoF_6]^{3-}$ is high spin.

Step 4 – conclude: $[Co(NH_3)_6]^{3+}$ has the greater crystal-field splitting.

Final Answer: $[Co(NH_3)_6]^{3+} \Rightarrow \boxed{A}$

Answer: (A) 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 high-spin d^8: The configuration $t_{2g}^6 e_g^2$ has two unpaired electrons, so $n = 2$.

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

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

Step 4 – evaluate: $\mu = 2.83$ BM.

Final Answer: $\mu \approx 2.83$ BM $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – low-spin filling of a d^5 ion: When $\Delta_o > P$, electrons pair in the lower t_{2g} set before entering e_g.

Step 1 – write the low-spin d^5 configuration: $t_{2g}^5 e_g^0$.

Step 2 – fill the three t_{2g} orbitals with five electrons: Two orbitals hold pairs ($\uparrow\downarrow$, $\uparrow\downarrow$) and the third holds a single electron ($\uparrow$).

Step 3 – count unpaired electrons: Only the single electron in the third t_{2g} orbital is unpaired, so $n = 1$.

Step 4 – contrast with high spin: A high-spin d^5 would have 5 unpaired electrons; the strong field collapses this to 1.

Final Answer: 1 unpaired electron $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – geometrical isomers of $[MA_4B_2]$: In an octahedron the two B ligands are either adjacent (cis) or opposite (trans).

Step 1 – try the cis arrangement: The two B ligands occupy adjacent corners (90° apart) $\rightarrow$ the cis isomer.

Step 2 – try the trans arrangement: The two B ligands occupy opposite corners (180° apart) $\rightarrow$ the trans isomer.

Step 3 – check for further isomers: All four A ligands are identical, so no additional distinct placements exist.

Step 4 – count: There are exactly 2 geometrical isomers.

Final Answer: 2 isomers (cis and trans) $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q25

Q26.

Solution

Concept – ordering ligands by field strength: The spectrochemical series runs (weak $\rightarrow$ strong): $I^- < Br^- < Cl^- < F^- < H_2O < NH_3 < CN^-$.

Step 1 – locate the four given ligands in the series: Br^- is near the weak-field

end; H_2O and NH_3 are intermediate; CN^- is the strongest.

Step 2 – pick out the weakest: Of Br^-, CN^-, NH_3 and H_2O, the leftmost (weakest) is Br^-.

Step 3 – connect to splitting: A weaker field produces the smallest Δ, so Br^- gives the least crystal-field splitting.

Step 4 – conclude: Br^- is the weakest-field ligand of the set.

Final Answer: $Br^- \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – n-type doping in band theory: Adding a group-15 dopant to silicon supplies extra electrons, creating a filled donor level just below the conduction band.

Step 1 – compare valence electrons: Silicon has 4 valence electrons; phosphorus has 5.

Step 2 – account for the extra electron: Four of phosphorus's electrons form bonds; the fifth is loosely held in a donor level near the conduction band.

Step 3 – identify the majority carrier: That extra electron is easily promoted into the conduction band, so *negative* electrons carry the current.

Step 4 – name the semiconductor: Because the majority carriers are negative electrons, the material is n-type.

Final Answer: n-type semiconductor $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q27

Q28.

Solution

Concept – band-gap size decides conductivity: A conductor has overlapping bands; a semiconductor has a small gap (~ 1 eV); an insulator has a large gap.

Step 1 – note the band picture given: The valence band is completely full and the conduction band is completely empty.

Step 2 – consider the gap size: The gap is about 5 eV, far larger than thermal energy at room temperature.

Step 3 – assess electron promotion: Almost no electrons can jump such a wide

gap, so the conduction band stays empty and no current flows.

Step 4 – classify: A completely filled valence band with a large (~ 5 eV) gap describes an insulator.

Final Answer: the solid is an insulator $\Rightarrow$ C

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – metal centre of chlorophyll: Chlorophyll uses a porphyrin-like (chlorin) ring to chelate a single central metal ion.

Step 1 – recall the biological role: Chlorophyll harvests light energy for photosynthesis in green plants.

Step 2 – identify the central ion: The chlorin ring holds a magnesium ion, Mg^{2+}, at its centre.

Step 3 – contrast with haem: Haemoglobin's porphyrin holds Fe^{2+} instead; the two systems must not be confused.

Step 4 – conclude: The metal at the centre of chlorophyll is Mg^{2+}.

Final Answer: $Mg^{2+} \Rightarrow$ A

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – kinetics of the concerted $E2$ reaction: $E2$ is a single, bimolecular step in which the base and the substrate come together in the rate-determining transition state.

Step 1 – identify the species in the transition state: Both the alkyl halide (substrate) and the base participate in the one and only step.

Step 2 – write the rate law: rate $= k$[substrate][base].

Step 3 – read off the molecularity: First order in substrate and first order in base gives an overall order of 2 (bimolecular).

Step 4 – link to the geometry shown: The anti-periplanar H/Br alignment in the Newman projection is exactly what this concerted second-order step requires.

Final Answer: second order, rate $= k$[substrate][base] $\Rightarrow$ B

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – kinetics of the two-step $E1$ reaction: $E1$ proceeds through a carbocation, and the slow step is the unimolecular ionization of the substrate.

Step 1 – identify the rate-determining step: The first (slow) step is the loss of the leaving group to form the carbocation; only the substrate is involved.

Step 2 – write the rate law for that step: rate $= k[\text{substrate}]$.

Step 3 – note the role of the base: The base removes the proton only in the fast second step, so it does not appear in the rate law.

Step 4 – read the energy diagram: Two humps with a carbocation well confirm two steps, the first (TS1) being higher and rate-determining.

Final Answer: first order, rate $= k[\text{substrate}] \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – Hofmann orientation with a bulky base: A sterically hindered base such as potassium *tert*-butoxide removes the more accessible proton, favouring the less substituted alkene.

Step 1 – identify the two possible β-hydrogens: Removing a proton from one side gives the more substituted (Saytzeff) alkene; from the other side, the less substituted (Hofmann) alkene.

Step 2 – apply the size of the base: The bulky *tert*-butoxide cannot easily reach the crowded internal β-hydrogens.

Step 3 – choose the accessible proton: It preferentially abstracts a proton from the less hindered terminal carbon.

Step 4 – name the major product: The result is the less substituted Hofmann alkene.

Final Answer: major product is the less substituted (Hofmann) alkene $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – stereochemistry of S_N2: The nucleophile attacks opposite the leaving group, so the three remaining bonds flip through like an umbrella in the wind.

Step 1 – describe the attack geometry: The nucleophile approaches 180° from the leaving group (backside attack).

Step 2 – follow the transition state: The carbon becomes trigonal-bipyramidal, with the three unchanged groups in a plane.

Step 3 – complete the substitution: As the leaving group departs, the three groups invert to the far side.

Step 4 – name the outcome: This umbrella flip is the Walden inversion of configuration.

Final Answer: inversion of configuration $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – meso compounds reduce the isomer count: A molecule with two identically substituted stereocentres has a meso form, so it has fewer than $2^n = 4$ stereoisomers.

Step 1 – start from the naive count: Two stereocentres would give $2^2 = 4$ configurations in general.

Step 2 – spot the internal symmetry: In $2,3$-dibromobutane the two centres carry identical substituents, so the (R, S) form has an internal mirror plane and is meso (achiral).

Step 3 – list the distinct isomers: The (R, R) and (S, S) forms are a pair of enantiomers, and the meso (R, S) form is a single compound.

Step 4 – count: (R, R), (S, S) and meso give 3 distinct stereoisomers.

Final Answer: 3 stereoisomers $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – CIP rule for R/S assignment: Rank the four groups, point the lowest away, and read the sense of $1 \to 2 \to 3$.

Step 1 – orient the molecule: The lowest-priority group is directed away from the viewer, as required.

Step 2 – trace the priority sequence: Follow $1 \to 2 \to 3$ around the stereocentre.

Step 3 – read the sense of rotation: The path is stated to be clockwise.

Step 4 – assign the descriptor: A clockwise $1 \to 2 \to 3$ (with the lowest group pointing away) is designated R (Latin *rectus*).

Final Answer: configuration is $R \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – carbocation stability and $1,2$-hydride shifts: Carbocation stability increases methyl $<$ primary $<$ secondary $<$ tertiary, so a shift that raises the substitution is favourable.

Step 1 – start from the secondary cation: A secondary carbocation is only moderately stabilized by two alkyl groups.

Step 2 – perform the $1,2$-hydride shift: A hydrogen on the neighbouring carbon migrates with its bonding pair to the cationic carbon.

Step 3 – locate the new positive centre: The positive charge moves to the carbon that now bears three alkyl groups.

Step 4 – identify the product cation: That three-alkyl carbon is a tertiary carbocation, which is more stable.

Final Answer: a more stable tertiary carbocation $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept – Grignard addition to a carbonyl: The class of alcohol formed depends on how many carbon groups sit on the carbinol carbon after addition.

Step 1 – write the aldehyde: A general aldehyde is $\mathrm{R'CHO}$; the carbonyl carbon already carries one $\mathrm{R'}$ group and one hydrogen.

Step 2 – add the Grignard carbon: $\mathrm{R^-}$ from RMgX adds to the carbonyl carbon, which now bears R, $\mathrm{R'}$ and H.

Step 3 – protonate on work-up: Acidic work-up gives $\mathrm{R\,R'\,CH-OH}$.

Step 4 – classify the alcohol: The carbinol carbon is bonded to two carbon groups, so it is a secondary alcohol.

Final Answer: a secondary alcohol $\Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – Grignard addition to a ketone: A ketone's carbonyl carbon already carries two carbon groups before addition.

Step 1 – write the ketone: $\mathrm{R'COR''}$ has the carbonyl carbon bonded to $\mathrm{R'}$ and $\mathrm{R''}$.

Step 2 – add the Grignard carbon: $\mathrm{R^-}$ adds, so the carbon now carries R, $\mathrm{R'}$ and $\mathrm{R''}$.

Step 3 – protonate on work-up: Hydrolysis gives $\mathrm{R\,R'\,R''\,C-OH}$.

Step 4 – classify the alcohol: The carbinol carbon bears three carbon groups, so it is a tertiary alcohol.

Final Answer: a tertiary alcohol $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – Grignard addition to formaldehyde: Formaldehyde's carbonyl carbon carries two hydrogens and no other carbon.

Step 1 – write formaldehyde: HCHO has the carbonyl carbon bonded to two

hydrogens.

Step 2 – add the Grignard carbon: R^- adds, giving a carbon that now carries R, H and H.

Step 3 – protonate on work-up: Hydrolysis gives $R-CH_2-OH$.

Step 4 – classify the alcohol: The carbinol carbon bears only one carbon group, so it is a primary alcohol (one carbon longer than R).

Final Answer: a primary alcohol $\Rightarrow$ D

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – Grignard reagents are strong bases: The R^- carbon of RMgX grabs any available proton before it can do anything else.

Step 1 – recognise the proton source: Water supplies an acidic $O-H$ proton.

Step 2 – transfer the proton: The carbanion-like carbon abstracts H^+ from water.

Step 3 – write the product: $R-H$ is formed together with $Mg(OH)X$.

Step 4 – name the product: $R-H$ is simply the corresponding alkane, which is why Grignard reagents must be kept strictly dry.

Final Answer: an alkane $R-H$ $\Rightarrow$ B

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – the organometallic of the Reformatsky reaction: An α-halo ester is activated by a metal to give an ester enolate equivalent that adds to carbonyls.

Step 1 – form the organometallic reagent: The α-halo ester reacts with the metal to give an organometallic (a zinc enolate).

Step 2 – name the metal: The metal used is zinc, giving the "Reformatsky reagent".

Step 3 – add to the carbonyl: This reagent adds to an aldehyde or ketone.

Step 4 – work up: Acidic work-up gives a β-hydroxy ester, the characteristic Reformatsky product.

Final Answer: the metal is zinc $\Rightarrow$ C

Answer: (C) Go Back to Q41

Q42.

Solution

Concept – the coupling metal of the Wurtz reaction: The Wurtz reaction couples two alkyl halides through a metal in dry ether.

Step 1 – write the coupling: $2\,\mathrm{R{-}X} + 2\,\mathrm{Na} \rightarrow \mathrm{R{-}R} + 2\,\mathrm{NaX}$.

Step 2 – identify the metal: The reaction is driven by sodium metal.

Step 3 – note the product: Two alkyl groups join to give a symmetrical alkane with twice the carbon count.

Step 4 – conclude: The metal responsible is sodium.

Final Answer: the metal is sodium $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – the metal in a Gilman reagent: Gilman reagents are lithium dialkylcuprates, $\mathrm{R_2CuLi}$.

Step 1 – recall the preparation: An organolithium RLi reacts with a copper(I) halide such as CuI.

Step 2 – write the reagent: Two equivalents of RLi give $\mathrm{R_2CuLi}$.

Step 3 – identify the characteristic metal: The defining transition metal in the cuprate is copper.

Step 4 – note the use: Such cuprates couple with alkyl and aryl halides to make new C–C bonds.

Final Answer: the metal is copper $\Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – Woodward–Hoffmann rule for a photochemical $4n$ system: For electrocyclic reactions, a $4n$ π-electron system reacts conrotatory when heated but disrotatory when photochemically excited.

Step 1 – count the π electrons: Butadiene has 4 π electrons, so $4n$ with $n = 1$.

Step 2 – note the conditions: The reaction is carried out photochemically ($h\nu$), which promotes an electron and flips the symmetry rule.

Step 3 – apply the rule: A photochemical $4n$ electrocyclization is allowed in the disrotatory mode.

Step 4 – conclude: The butadiene-to-cyclobutene closure under light is disrotatory.

Final Answer: photochemical 4π closure is disrotatory $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – Woodward–Hoffmann rule for a thermal $4n$ system: The thermal and photochemical modes are always opposite for a given electron count.

Step 1 – count the π electrons: The same butadiene has 4 π electrons ($4n$, $n = 1$).

Step 2 – note the conditions: This time the ring closure is thermal (Δ, heating in the ground state).

Step 3 – apply the rule: A thermal $4n$ electrocyclization is allowed in the conrotatory mode.

Step 4 – contrast with Q44: The photochemical version was disrotatory, so the thermal version is the opposite, namely conrotatory.

Final Answer: thermal 4π closure is conrotatory $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – forces holding a DNA base pair: Complementary bases pair through specific, directional non-covalent interactions.

Step 1 – recall the pairing scheme: Adenine pairs with thymine, and guanine pairs with cytosine.

Step 2 – identify the interaction: Each pair is held by hydrogen bonds between $\mathrm{N-H}$ donors and $\mathrm{O/N}$ acceptors (two for A–T, three for G–C).

Step 3 – rule out covalent options: Peptide and disulfide bonds belong to proteins, and the base pairing is not ionic.

Step 4 – conclude: Base pairs in the DNA double helix are held together by hydrogen bonds.

Final Answer: hydrogen bonds $\Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q46

Answer Key

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