GATE Chemistry

Sample Paper – 9

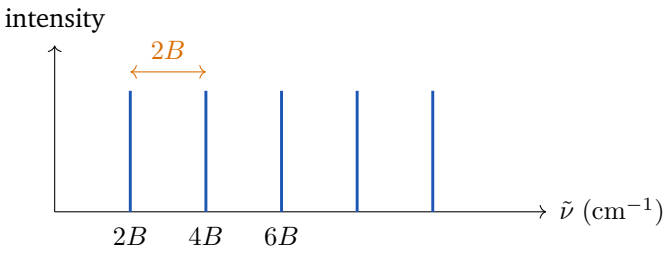
Duration: 128 Minutes **Maximum Marks: 72**

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 rigid diatomic molecule has a rotational constant $B = 2\ \mathrm{cm^{-1}}$. Its pure rotational (microwave) absorption spectrum consists of equally spaced lines, as sketched below, with the transition energies given by $\tilde{\nu}(J) = 2B(J+1)$. The wavenumber of the *first* line, corresponding to the transition $J = 0 \to 1$, is: [1 mark]



(A) $2\ \text{cm}^{-1}$

(B) $8\ \text{cm}^{-1}$

(C) $6\ \text{cm}^{-1}$

(D) $4\ \text{cm}^{-1}$

Q2. The vibrational frequency of a diatomic molecule treated as a harmonic oscillator is $\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$, where k is the force constant and μ the reduced mass. If the force constant of a bond is increased fourfold ($k \to 4k$) while the reduced mass is unchanged, the vibrational frequency changes by a factor of: **[1 mark]**

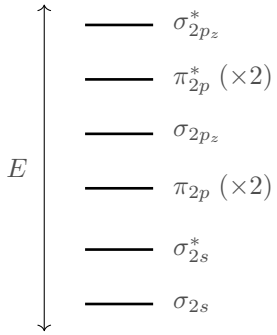
(A) 4

(B) $1/2$

(C) 2

(D) 16

Q3. The molecular-orbital energy ordering for the second-period homonuclear diatomic N_2 is shown below (the σ_{2p_z} level lies *above* the π_{2p} level for N_2). Filling the 14 electrons of N_2 gives 10 bonding and 4 antibonding electrons. The bond order of N_2 is: **[1 mark]**



(A) 3

(B) 2

(C) 2.5

(D) 1

Q4. For a hydrogen-like atom, an orbital of azimuthal (orbital angular momentum) quantum number l has exactly l angular nodes. The number of angular nodes in a $3d$ orbital is: **[1 mark]**

(A) 0

(B) 1

(C) 2

(D) 3

Q5. A non-linear molecule containing N atoms has $3N - 6$ normal (fundamental) modes of vibration. For the non-linear molecule ammonia, NH_3 (with $N = 4$ atoms), the number of vibrational modes is: **[1 mark]**

(A) 12

(B) 9

(C) 3

(D) 6

Q6. A molecule shows a pure rotational (microwave) absorption spectrum only if it possesses a permanent electric dipole moment. Among the following gas-phase molecules, the one that is microwave (rotationally) active is: **[1 mark]**

(A) HCl

(B) N_2

(C) O_2

(D) CO_2

Physical Chemistry: Thermodynamics, Kinetics and Electrochemistry

Q7. One mole of an ideal gas expands *isothermally and reversibly* from a volume V_1 to $V_2 = 2V_1$. For such a process the entropy change of the gas is $\Delta S = nR\ln(V_2/V_1)$. Taking $\ln 2 = 0.693$, the entropy change of the gas is nearest to: **[1 mark]**

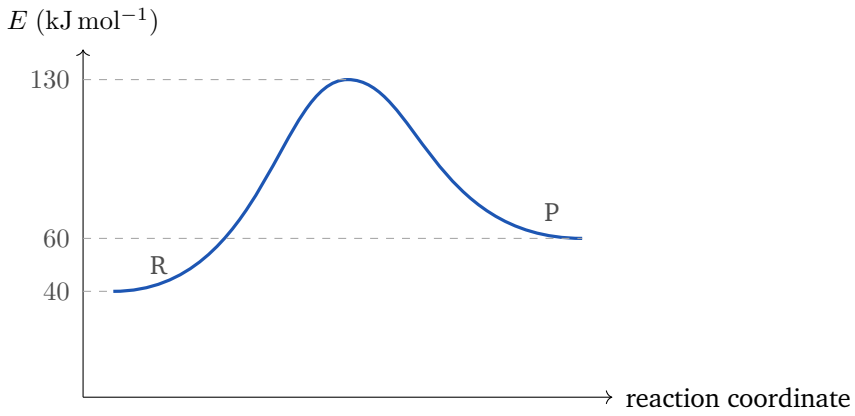
(A) $-5.76\ \text{J mol}^{-1}\text{K}^{-1}$

(B) $+11.5\ \text{J mol}^{-1}\text{K}^{-1}$

(C) 0

(D) $+5.76\ \text{J mol}^{-1}\text{K}^{-1}$

Q8. The reaction-coordinate (potential-energy) diagram for a one-step reaction is shown below. The reactants lie at $40\ \text{kJ mol}^{-1}$, the transition state at $130\ \text{kJ mol}^{-1}$ and the products at $60\ \text{kJ mol}^{-1}$. The activation energy of the *forward* reaction, $E_a(\text{forward})$, is: **[1 mark]**



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

(B) $90\ \text{kJ mol}^{-1}$

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

(D) $130\ \text{kJ mol}^{-1}$

Q9. A certain first-order reaction is found to be 75% complete in 60 minutes. Since a first-order half-life is constant, the time taken for the reaction to become 75% complete equals two successive half-lives. The half-life $t_{1/2}$ of the reaction is: **[1 mark]**

(A) $60\ \text{min}$

(B) 30 min

(C) 15 min

(D) 45 min

Q10. For a galvanic cell the standard potential is $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$ (both as reduction potentials). Given $E^\circ(\text{Ag}^+/\text{Ag}) = +0.80$ V (cathode) and $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34$ V (anode), the standard cell potential is: **[1 mark]**

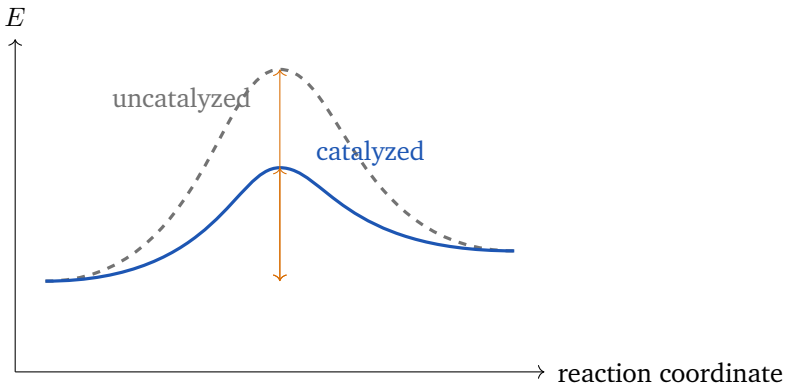
(A) 0.46 V

(B) 1.14 V

(C) 0.34 V

(D) -0.46 V

Q11. The energy profile below compares an *uncatalyzed* reaction (upper curve) with the same reaction in the presence of a heterogeneous *catalyst* (lower curve). The essential role of the catalyst is to: **[1 mark]**



(A) lower the activation energy by providing an alternative reaction pathway

(B) increase the enthalpy change ΔH of the reaction

(C) shift the position of equilibrium toward the products

(D) raise the overall temperature of the reacting system

Q12. For a phase change (such as melting) carried out at its equilibrium transition temperature, the Gibbs free-energy change is zero, so $\Delta G = \Delta H -$

$T\Delta S = 0$, giving $T = \Delta H/\Delta S$. For a process with $\Delta H = +30\ \text{kJ mol}^{-1}$ and $\Delta S = +100\ \text{J mol}^{-1}\text{K}^{-1}$, the equilibrium temperature is: **[1 mark]**

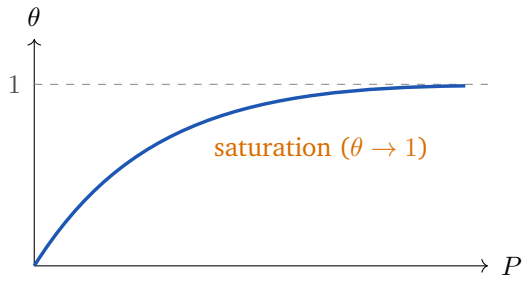
(A) 30 K

(B) 3000 K

(C) 100 K

(D) 300 K

Q13. The Langmuir adsorption isotherm for a gas adsorbing on a solid surface is $\theta = \dfrac{KP}{1+KP}$, where θ is the fractional surface coverage and P the pressure. The isotherm is sketched below. In the limit of very high pressure ($KP \gg 1$), the fractional coverage θ tends to: **[1 mark]**



(A) 0

(B) KP

(C) $1/2$

(D) 1

Q14. In the electrolytic refining of copper the cathode reaction is $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$. By Faraday's law, the charge required to deposit exactly one mole of copper metal is: **[1 mark]**

(A) 96500 C

(B) 48250 C

(C) 193000 C

(D) 9650 C

Inorganic Chemistry: Main Group and Periodic Properties

Q15. Across a period the atomic radius decreases, so among the third-period elements the leftmost (least nuclear pull on the valence shell) is the largest. Among Na, Mg, Al and Si, the element with the *largest* atomic radius is: **[1 mark]**

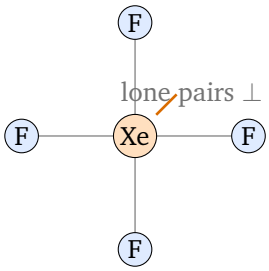
(A) Si

(B) Al

(C) Na

(D) Mg

Q16. According to VSEPR theory, the central xenon atom in $\mathrm{XeF_4}$ is surrounded by four bonding pairs and two lone pairs (steric number 6). The two lone pairs occupy opposite (axial) positions of the octahedron, leaving the four fluorines in a plane, as shown. The molecular shape of $\mathrm{XeF_4}$ is: **[1 mark]**



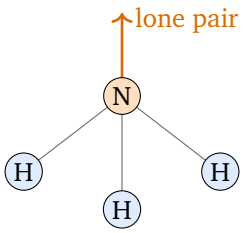
(A) tetrahedral

(B) square planar

(C) octahedral

(D) see-saw

Q17. The ammonia molecule $\mathrm{NH_3}$ has a central nitrogen bearing three $\mathrm{N-H}$ bonds and one lone pair (steric number 4), as shown. Because the lone pair pushes the three bonds down, the molecular shape (counting only the atoms) is: **[1 mark]**



(A) trigonal pyramidal

(B) trigonal planar

(C) tetrahedral

(D) T-shaped

Q18. In potassium dichromate, $K_2Cr_2O_7$, each potassium is $+1$ and each oxygen is -2, and the compound is neutral overall. The oxidation state of chromium in $K_2Cr_2O_7$ is: **[1 mark]**

(A) $+2$

(B) $+3$

(C) $+7$

(D) $+6$

Q19. On moving *down* group 17 (the halogens) from fluorine to iodine, the valence electrons lie in shells further from the nucleus and are more shielded. As a result, the electronegativity of the halogens down the group generally: **[1 mark]**

(A) decreases

(B) increases

(C) stays essentially constant

(D) first increases and then decreases

Q20. Certain diagonally placed pairs of elements in periods 2 and 3 show similar chemistry because of comparable charge-to-size ratios. The pair that best illustrates such a diagonal relationship is: **[1 mark]**

(A) Na and Mg

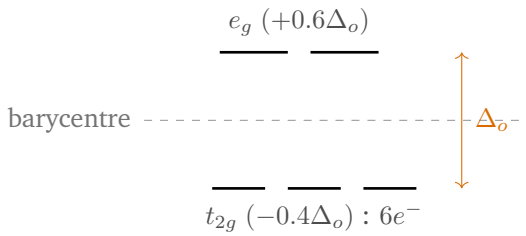
(B) B and C

(C) Be and Al

(D) Li and Na

Inorganic Chemistry: Coordination Compounds and Organometallics

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



(A) $-2.4\,\Delta_o$

(B) $-0.4\,\Delta_o$

(C) $-1.6\,\Delta_o$

(D) 0

Q22. The hexacarbonylchromium(0) complex $[\mathrm{Cr(CO)_6}]$ obeys the effective-atomic-number (18-electron) rule. Taking chromium(0) (group 6) to contribute 6 valence electrons and each CO ligand to donate 2 electrons, the total valence electron count of the complex is: **[2 marks]**

(A) 16

(B) 20

(C) 14

(D) 18

Q23. The high-spin octahedral complex $[\mathrm{Fe(H_2O)_6}]^{2+}$ contains a d^6 iron(II) centre. In a high-spin d^6 configuration ($t_{2g}^4 e_g^2$) there are four unpaired electrons. Using the spin-only formula $\mu = \sqrt{n(n+2)}$ BM, the magnetic moment is nearest to: **[2 marks]**

(A) 1.73 BM

(B) 5.92 BM

(C) 3.87 BM

(D) 4.90 BM

Q24. The tetracyanonickelate(II) ion $[\mathrm{Ni(CN)_4}]^{2-}$ is diamagnetic and square planar. The hybridization of the nickel(II) centre in this square-planar complex is: **[2 marks]**

(A) dsp^2

(B) sp^3

(C) d^2sp^3

(D) sp^3d^2

Q25. In the coordination compound potassium hexacyanoferrate(II), $\mathrm{K_4[Fe(CN)_6]}$, each potassium is $+1$ and each cyanide ligand is -1, and the complex is neutral overall. The oxidation state of iron in this complex is: **[2 marks]**

(A) $+3$

(B) $+2$

(C) 0

(D) $+6$

Q26. In the industrially important hydroformylation (oxo) process, an alkene is treated with carbon monoxide and hydrogen in the presence of a cobalt- or rhodium-carbonyl catalyst. The organic functional group produced in the primary product of hydroformylation is: **[2 marks]**

(A) a carboxylic acid

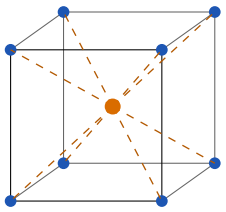
(B) an aldehyde

(C) an alcohol

(D) a ketone

Inorganic Chemistry: Solid State and Bioinorganic

Q27. A body-centred cubic (BCC) lattice is shown below, with the central body atom highlighted. Each atom in a BCC lattice is surrounded by a definite number of nearest-neighbour atoms located at the corners of its cube. The coordination number of an atom in a BCC lattice is: **[2 marks]**



8 nearest neighbours

(A) 8

(B) 6

(C) 12

(D) 4

Q28. In an ionic crystal, a point defect in which a cation leaves its normal lattice site and lodges in an interstitial position (creating a cation vacancy plus an interstitial cation, with no change in the overall density) is called a: **[2 marks]**

(A) Schottky defect

(B) Frenkel defect

(C) substitutional impurity defect

(D) colour (F) centre

Q29. Chlorophyll, the green pigment that harvests light in photosynthesis, is built around a substituted porphyrin (chlorin) ring holding a single central metal ion. The metal ion present at the centre of chlorophyll is: **[2 marks]**

(A) Fe^{2+}

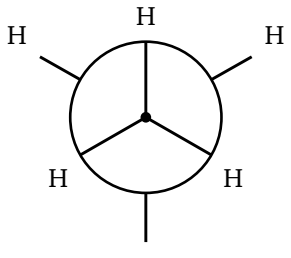
(B) Ca^{2+}

(C) Mg^{2+}

(D) Zn^{2+}

Organic Chemistry: Stereochemistry and Reaction Mechanisms

Q30. The Newman projection of ethane, viewed along the $\mathrm{C}-\mathrm{C}$ bond, is shown below in its lowest-energy form, in which the front and back $\mathrm{C}-\mathrm{H}$ bonds are as far apart as possible. The dihedral (torsion) angle between a front $\mathrm{C}-\mathrm{H}$ bond and the nearest back $\mathrm{C}-\mathrm{H}$ bond in this most stable, staggered conformation is: **[2 marks]**



staggered ethane

(A) 0°

(B) 60°

(C) 120°

(D) 180°

Q31. A molecule has three dissimilar (non-equivalent) stereogenic centres and no internal symmetry. The maximum number of stereoisomers of such a molecule is given by 2^n, with n the number of stereocentres. This maximum number is: **[2 marks]**

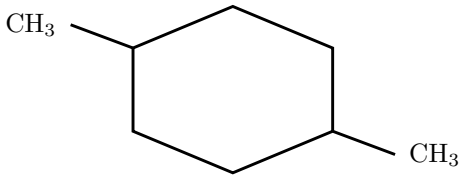
(A) 3

(B) 6

(C) 8

(D) 4

Q32. The most stable chair conformation of *trans*-$1,4$-dimethylcyclohexane is shown below. To minimize $1,3$-diaxial strain, the two methyl groups on this *trans* isomer both occupy which type of position? **[2 marks]**



chair of *trans*-1,4-dimethylcyclohexane

(A) both axial

(B) both equatorial

(C) one axial and one equatorial

(D) it makes no difference to the energy

Q33. A tertiary alkyl halide such as $(CH_3)_3CBr$ is solvolysed in a polar *protic* solvent (aqueous ethanol) with no strong nucleophile present. Substitution proceeds predominantly by which mechanism? **[2 marks]**

(A) S_N2

(B) S_N1

(C) $E2$

(D) $E1cb$

Q34. Carbocations are stabilized by resonance (delocalization) as well as by hyperconjugation. Among the methyl, primary, vinyl and allyl carbocations, the *most* stable is the: **[2 marks]**

(A) allyl carbocation

(B) methyl carbocation

(C) vinyl carbocation

(D) primary carbocation

Q35. An equimolar $(50:50)$ mixture of the (R) and (S) enantiomers of a chiral compound (a racemic mixture) shows no net optical rotation. The reason this racemate is optically inactive is that: **[2 marks]**

(A) it is a meso compound with an internal plane of symmetry

(B) neither of the two enantiomers rotates plane-polarized light

(C) each molecule contains no stereogenic centre

(D) the equal and opposite rotations of the two enantiomers cancel (external compensation)

Q36. 2-Bromobutane is treated with a *bulky* strong base, potassium *tert*-butoxide, and undergoes $E2$ elimination. With such a hindered base the reaction follows Hofmann orientation, giving predominantly the *less* substituted alkene, namely: **[2 marks]**

(A) 2-butene

(B) butane

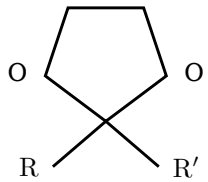
(C) 1-butene

(D) 1-butyne

Organic Chemistry: Named Reactions and Synthesis

Q37. During a multistep synthesis a ketone carbonyl is temporarily masked by treating it with ethylene glycol (ethane-1, 2-diol) under acid catalysis, giving the five-membered cyclic structure shown below (a 1, 3-dioxolane). This protecting group is best described as a: **[2 marks]**

1,3-dioxolane (cyclic protecting group)



(A) cyclic acetal (1,3-dioxolane)

(B) hemiketal

(C) enamine

(D) imine (Schiff base)

Q38. In a synthetic sequence an acyl chloride, RCOCl, must be converted *selectively* to the corresponding aldehyde, RCHO, without over-reduction to the alcohol. The reagent system that accomplishes this selective reduction (the Rosenmund reduction) is: **[2 marks]**

(A) $\mathrm{LiAlH_4}$ in dry ether

(B) $\mathrm{NaBH_4}$ in methanol

(C) concentrated $\mathrm{HNO_3}$

(D) $\mathrm{H_2}$ over $\mathrm{Pd–BaSO_4}$ (poisoned)

Q39. Benzene is treated with acetyl chloride ($\mathrm{CH_3COCl}$) in the presence of anhydrous aluminium chloride ($\mathrm{AlCl_3}$). This Friedel–Crafts acylation introduces an acetyl group onto the ring, and the organic product is: **[2 marks]**

(A) toluene

(B) benzaldehyde

(C) acetophenone

(D) benzoic acid

Q40. In the Friedel–Crafts alkylation of benzene with chloromethane ($\mathrm{CH_3Cl}$) and anhydrous $\mathrm{AlCl_3}$, the Lewis acid abstracts chloride to generate the actual attacking electrophile. This electrophile is: **[2 marks]**

(A) the methyl carbanion, $\mathrm{CH_3^-}$

(B) the methyl carbocation, $\mathrm{CH_3^+}$

(C) molecular $\mathrm{AlCl_3}$

(D) hydrogen chloride, HCl

Q41. A Grignard reagent (RMgX) is added to formaldehyde (HCHO) and the adduct is then hydrolysed with dilute acid. The class of organic product formed by this sequence is: **[2 marks]**

(A) a primary alcohol, $\mathrm{RCH_2OH}$

(B) a carboxylic acid, RCOOH

(C) a tertiary alcohol

(D) a ketone, $\mathrm{RCOR'}$

Q42. The carbonyl group of a ketone is reduced all the way to a methylene ($\mathrm{CH_2}$) group by heating with hydrazine ($\mathrm{NH_2NH_2}$) followed by a strong base (KOH) at high temperature. This carbonyl-to-methylene reduction, carried out under *basic* conditions, is the: **[2 marks]**

(A) Clemmensen reduction

(B) Rosenmund reduction

(C) Wolff–Kishner reduction

(D) Birch reduction

Q43. Propene ($\mathrm{CH_3CH{=}CH_2}$) is treated with hydrogen bromide (HBr) in the presence of an organic peroxide. Under these radical (peroxide) conditions the addition follows anti-Markovnikov (Kharasch) orientation, and the major product is: **[2 marks]**

(A) 2-bromopropane

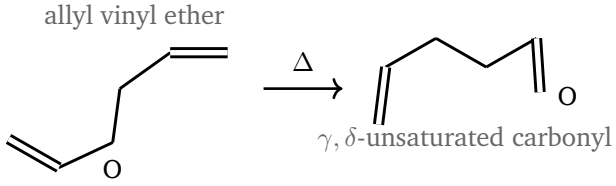
(B) 1-bromopropane

(C) propan-2-ol

(D) $2,2$-dibromopropane

Organic Chemistry: Pericyclic, Photochemistry and Biomolecules

Q44. An allyl vinyl ether, on heating, undergoes a concerted $[3,3]$-sigmatropic rearrangement to give a γ,δ-unsaturated carbonyl compound, as sketched below. This thermal $[3,3]$-sigmatropic reaction of an allyl vinyl ether is the: **[2 marks]**



(A) Diels–Alder reaction

(B) Cope rearrangement

(C) ene reaction

(D) Claisen rearrangement

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

(A) disrotatory

(B) suprafacial only

(C) conrotatory

(D) forbidden (does not occur)

Q46. In double-stranded DNA the two strands are held together by complementary base pairing through hydrogen bonds. The purine base adenine (A) pairs specifically, through two hydrogen bonds, with the pyrimidine base: **[2 marks]**

(A) guanine

(B) thymine

(C) cytosine

(D) uracil

Detailed Solutions

Q1.

Solution

Concept – position of the first rotational line: For a rigid rotor the absorption lines occur at $\tilde{\nu}(J) = 2B(J+1)$, so the lines sit at $2B, 4B, 6B, \ldots$

Step 1 – set the transition: The first line is the transition $J = 0 \rightarrow J = 1$, so put $J = 0$.

Step 2 – substitute into $\tilde{\nu}(J) = 2B(J+1)$: $\tilde{\nu}(0) = 2B(0+1)$

Step 3 – simplify: $\tilde{\nu}(0) = 2B$

Step 4 – put in the numerical value of B: $\tilde{\nu}(0) = 2 \times 2 \text{ cm}^{-1}$

$\tilde{\nu}(0) = 4 \text{ cm}^{-1}$

Final Answer: first line at $4 \text{ cm}^{-1} \Rightarrow$ D

Answer: (D) Go Back to Q1

Q2.

Solution

Concept – how vibrational frequency scales with force constant: For a harmonic oscillator $\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$, so at fixed μ the frequency is proportional to $\sqrt{k}$.

Step 1 – write the proportionality: $\nu \propto \sqrt{k}$

Step 2 – form the ratio of new to old frequency: $\frac{\nu_2}{\nu_1} = \sqrt{\frac{k_2}{k_1}}$

Step 3 – put in $k_2 = 4k_1$: $\frac{\nu_2}{\nu_1} = \sqrt{\frac{4k_1}{k_1}} = \sqrt{4}$

Step 4 – evaluate the root: $\frac{\nu_2}{\nu_1} = 2$

So the frequency doubles.

Final Answer: frequency changes by a factor of $2 \Rightarrow$ C

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – bond order from molecular-orbital populations: Bond order $= \dfrac{N_b - N_a}{2}$, where N_b and N_a are bonding and antibonding electron counts.

Step 1 – count the electrons in N_2: N_2 has 14 electrons in total.

Step 2 – read the populations from the MO diagram: Filling the ladder gives $N_b = 10$ bonding electrons and $N_a = 4$ antibonding electrons.

Step 3 – substitute into the bond-order formula: Bond order $= \dfrac{10 - 4}{2}$

Step 4 – evaluate: Bond order $= \dfrac{6}{2} = 3$

Step 5 – cross-check: A bond order of 3 matches the very strong N≡N triple bond; all electrons are paired, so N_2 is diamagnetic.

Final Answer: bond order $= 3 \Rightarrow$ A

Answer: (A) Go Back to Q3

Q4.

Solution

Concept – angular nodes of an atomic orbital: The number of angular (nodal-plane) nodes equals the azimuthal quantum number l.

Step 1 – identify l for a d orbital: For any d orbital, $l = 2$.

Step 2 – read the rule for angular nodes: Number of angular nodes $= l$.

Step 3 – substitute: Angular nodes $= 2$.

Step 4 – cross-check the total nodes: Total nodes $= n - 1 = 3 - 1 = 2$, and radial nodes $= n - l - 1 = 3 - 2 - 1 = 0$, so all 2 nodes are angular, consistent with the answer.

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

Answer: (C) Go Back to Q4

Q5.

Solution

Concept – vibrational degrees of freedom: A non-linear molecule has $3N - 6$ vibrational modes (N = number of atoms).

Step 1 – confirm the geometry: NH_3 is pyramidal, hence non-linear, so use $3N - 6$.

Step 2 – count the atoms: $N = 4$ (one N and three H).

Step 3 – substitute into $3N - 6$**:** Number of modes $= 3(4) - 6$

Step 4 – evaluate: $= 12 - 6 = 6$

Final Answer: number of vibrational modes $= 6 \Rightarrow$ D

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – gross selection rule for pure rotational spectra: A molecule can absorb microwave radiation and show a pure rotational spectrum only if it has a permanent electric dipole moment.

Step 1 – test each molecule for a permanent dipole: HCl is heteronuclear and polar, so it has a permanent dipole.

Step 2 – reject the non-polar molecules: $\mathrm{N_2}$ and $\mathrm{O_2}$ are homonuclear (zero dipole); linear symmetric $\mathrm{CO_2}$ also has zero net dipole.

Step 3 – conclude: Only HCl satisfies the selection rule, so it alone is microwave (rotationally) active.

Final Answer: rotationally active molecule $= \mathrm{HCl} \Rightarrow$ A

Answer: (A) Go Back to Q6

Q7.

Solution

Concept – entropy change of isothermal reversible expansion: For an ideal gas at constant temperature, $\Delta S = nR \ln\left(\dfrac{V_2}{V_1}\right)$.

Step 1 – list the data: $n = 1$ mol, $R = 8.314\ \mathrm{J\,mol^{-1}K^{-1}}$, $V_2/V_1 = 2$.

Step 2 – substitute into the formula: $\Delta S = (1)(8.314)\ln 2$

Step 3 – use $\ln 2 = 0.693$**:** $\Delta S = 8.314 \times 0.693$

Step 4 – evaluate: $\Delta S = 5.76\ \mathrm{J\,mol^{-1}K^{-1}}$

The gas expands (volume increases), so ΔS is positive, as expected.

Final Answer: $\Delta S = +5.76\ \mathrm{J\,mol^{-1}K^{-1}} \Rightarrow$ D

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – forward activation energy from an energy profile: $E_a(\text{forward})$ is the height of the transition state above the reactant level.

Step 1 – read the levels from the diagram: Reactants $= 40\ \text{kJ mol}^{-1}$, transition state $= 130\ \text{kJ mol}^{-1}$.

Step 2 – subtract to obtain the forward barrier: $E_a(\text{forward}) = 130 - 40$

Step 3 – evaluate: $E_a(\text{forward}) = 90\ \text{kJ mol}^{-1}$

Step 4 – consistency check: $\Delta H = 60 - 40 = +20\ \text{kJ mol}^{-1}$ (endothermic) and $E_a(\text{reverse}) = 130 - 60 = 70\ \text{kJ mol}^{-1}$; indeed $E_a(\text{fwd}) - E_a(\text{rev}) = 90 - 70 = 20 = \Delta H$.

Final Answer: $E_a(\text{forward}) = 90\ \text{kJ mol}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – first-order fractions and half-lives: Each half-life halves the amount remaining, independent of concentration.

Step 1 – translate 75% complete into fraction remaining: If 75% has reacted, 25% (that is $\frac{1}{4}$) of the reactant remains.

Step 2 – count the half-lives to reach $\frac{1}{4}$: $1 \to \frac{1}{2}$ (one half-life) $\to \frac{1}{4}$ (two half-lives), so $\frac{1}{4}$ remaining corresponds to $2\,t_{1/2}$.

Step 3 – set $2\,t_{1/2}$ equal to the given time: $2\,t_{1/2} = 60\ \text{min}$

Step 4 – solve for $t_{1/2}$: $t_{1/2} = \dfrac{60}{2} = 30\ \text{min}$

Final Answer: $t_{1/2} = 30\ \text{min} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

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

Step 1 – identify the electrodes: Ag^+/Ag (higher potential) is the cathode; Cu^{2+}/Cu is the anode.

Step 2 – substitute the reduction potentials: $E^\circ_{\text{cell}} = (+0.80) - (+0.34)$

Step 3 – evaluate: $E^\circ_{\text{cell}} = 0.46\ \text{V}$

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

Final Answer: $E^\circ_{\text{cell}} = 0.46\ \text{V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – how a catalyst speeds a reaction: A catalyst supplies a different reaction pathway whose transition state lies lower in energy, so the activation energy is reduced.

Step 1 – read the diagram: The catalyzed (lower) curve has a smaller barrier than the uncatalyzed (upper) curve, while reactant and product levels are unchanged.

Step 2 – interpret the unchanged end points: Because $\Delta H = E(\text{products}) - E(\text{reactants})$ and both ends are the same, the catalyst does *not* change ΔH, ΔG, or the equilibrium position.

Step 3 – attribute the rate increase: A lower E_a means a larger rate constant $k = Ae^{-E_a/RT}$, so the reaction (both forward and reverse) is accelerated equally.

Step 4 – reject the distractors: It does not alter ΔH, does not shift equilibrium, and does not heat the system; it only lowers E_a.

Final Answer: the catalyst lowers E_a via an alternative path $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – equilibrium (transition) temperature: At the equilibrium temperature of a phase change, $\Delta G = 0$, so $\Delta H = T\Delta S$ and $T = \dfrac{\Delta H}{\Delta S}$.

Step 1 – put both quantities in consistent units (J): $\Delta H = +30\ \text{kJ mol}^{-1} = 30000\ \text{J mol}^{-1}$, $\Delta S = +100\ \text{J mol}^{-1}\text{K}^{-1}$.

Step 2 – substitute into $T = \Delta H/\Delta S$: $T = \dfrac{30000}{100}$

Step 3 – evaluate: $T = 300\ \text{K}$

Final Answer: equilibrium temperature $= 300\ \text{K} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q12

Q13.

Solution

Concept – Langmuir isotherm at high pressure: $\theta = \dfrac{KP}{1+KP}$ describes monolayer coverage that saturates as P grows.

Step 1 – take the high-pressure limit: When $KP \gg 1$, the "1" in the denominator becomes negligible next to KP.

Step 2 – simplify the expression: $\theta \approx \dfrac{KP}{KP}$

Step 3 – evaluate: $\theta \approx 1$

Step 4 – interpret physically: $\theta \to 1$ means the surface is fully covered by a complete monolayer, exactly the saturation plateau shown in the sketch.

Final Answer: $\theta \to 1$ at high pressure $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – Faraday's law for a multi-electron deposition: Depositing one mole of a species needing n electrons requires $Q = nF$.

Step 1 – read the electrode reaction: $\text{Cu}^{2+} + 2e^- \to \text{Cu}$, so $n = 2$ electrons per copper atom.

Step 2 – write the charge needed: $Q = nF = 2 \times 96500$

Step 3 – evaluate: $Q = 193000\ \text{C}$

Step 4 – reason: Two moles of electrons ($2F$) are needed because each Cu^{2+} ion gains two electrons.

Final Answer: $Q = 193000\ \text{C} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – atomic-radius trend across a period: Radius decreases left to right as nuclear charge rises, so the leftmost element of a period is the largest.

Step 1 – order the four elements by position: $\mathrm{Na} \to \mathrm{Mg} \to \mathrm{Al} \to \mathrm{Si}$ runs left to right in period 3.

Step 2 – apply the trend: Effective nuclear charge increases in that direction, pulling the valence shell inward, so radius decreases $\mathrm{Na} > \mathrm{Mg} > \mathrm{Al} > \mathrm{Si}$.

Step 3 – pick the largest: Na, being furthest left, has the largest atomic radius.

Final Answer: largest atomic radius $= \mathrm{Na} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – VSEPR shape with lone pairs: The shape (of the atoms) depends on how bonding pairs and lone pairs arrange around the central atom.

Step 1 – find the steric number of Xe in $\mathrm{XeF_4}$: Four $\mathrm{Xe-F}$ bonds plus two lone pairs give a steric number of 6 (octahedral electron geometry).

Step 2 – place the lone pairs: The two lone pairs take the trans (opposite axial) positions to minimize their mutual repulsion.

Step 3 – read off the shape of the atoms: The four fluorines then lie in a single plane around xenon, giving a *square planar* molecular shape.

Final Answer: shape of $\mathrm{XeF_4}$ is square planar $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – shape from bonding pairs plus a lone pair: When one of four electron domains is a lone pair, the molecular shape is derived from the tetrahedral electron geometry but named from the atom positions only.

Step 1 – find the steric number of N in $\mathrm{NH_3}$: Three $\mathrm{N-H}$ bonds plus one lone pair give a steric number of 4 (tetrahedral electron geometry).

Step 2 – account for the lone pair: The lone pair occupies one tetrahedral position and pushes the three $\mathrm{N-H}$ bonds together.

Step 3 – name the shape of the atoms: Three bonded H atoms below the nitrogen make a *trigonal pyramidal* shape (bond angle $\approx 107°$).

Final Answer: shape of NH_3 is trigonal pyramidal $\Rightarrow$ A

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – oxidation state by charge balance: The sum of oxidation states of all atoms equals the overall charge (zero for a neutral compound).

Step 1 – assign the known oxidation states: Each K is $+1$ (two of them) and each O is -2 (seven of them). Let $Cr = x$ (two of them).

Step 2 – write the balance for $K_2Cr_2O_7$: $2(+1) + 2x + 7(-2) = 0$

Step 3 – simplify: $2 + 2x - 14 = 0$

Step 4 – solve for x: $2x = 12$

$x = +6$

Final Answer: oxidation state of $Cr = +6 \Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – electronegativity trend down a group: Going down a group, the valence shell is further from the nucleus and better shielded, so the pull on bonding electrons weakens.

Step 1 – track the change down group 17: From F to Cl to Br to I, the atomic size increases.

Step 2 – relate size to electronegativity: A larger atom holds shared electrons less tightly, so electronegativity falls.

Step 3 – conclude: The electronegativity of the halogens *decreases* down the group (F is the most electronegative element).

Final Answer: electronegativity decreases $\Rightarrow$ A

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – the diagonal relationship: An element of period 2 often resembles the element one place to its lower-right in period 3, because their charge-to-size (polarizing-power) ratios are similar.

Step 1 – recall the classic diagonal pairs: Li–Mg, Be–Al, and B–Si.

Step 2 – test the options: Be and Al form a genuine diagonal pair (both give amphoteric oxides and covalent halides).

Step 3 – reject the others: Na–Mg and Li–Na are same-period/same-group neighbours, and B–C is a period-2 pair, none of which is the diagonal relationship.

Final Answer: diagonal pair = Be and Al $\Rightarrow$ C

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – CFSE for a low-spin d^6 octahedral ion: CFSE $= \big[-0.4\,n(t_{2g}) + 0.6\,n(e_g)\big]\Delta_o$, evaluated from the orbital occupancies.

Step 1 – place the six electrons (low spin): In the strong field all six electrons pair up in the lower set, so $n(t_{2g}) = 6$ and $n(e_g) = 0$.

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

Step 3 – evaluate the bracket: $= (-2.4 + 0)\Delta_o$

Step 4 – write the result: CFSE $= -2.4\,\Delta_o$ (the pairing-energy term is not included, as stated).

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

Answer: (A) Go Back to Q21

Q22.

Solution

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

Step 1 – count the metal contribution: Cr is in group 6; as Cr(0) it supplies 6 valence electrons.

Step 2 – count the ligand contribution: Each CO donates 2 electrons; six CO

give $6 \times 2 = 12$.

Step 3 – add the two contributions: Total $= 6 + 12 = 18$

Step 4 – interpret: An 18-electron count is a stable, noble-gas-like valence configuration, consistent with the robustness of $[\mathrm{Cr(CO)_6}]$.

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

Answer: (D) Go Back to Q22

Q23.

Solution

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

Step 1 – find n for high-spin d^6: $\mathrm{Fe^{2+}}$ is d^6; in the high-spin arrangement $t_{2g}^4 e_g^2$ there are 4 unpaired electrons, so $n = 4$.

Step 2 – substitute into the formula: $\mu = \sqrt{4(4+2)}$

Step 3 – evaluate inside the root: $\mu = \sqrt{4 \times 6} = \sqrt{24}$

Step 4 – take the square root: $\mu = 4.899$

$\mu \approx 4.90$ BM

Final Answer: $\mu \approx 4.90$ BM $\Rightarrow$ D

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – hybridization of a square-planar complex: A square-planar geometry uses one $(n-1)d$ orbital together with the ns and two np orbitals, i.e. dsp^2 hybridization.

Step 1 – identify the metal configuration: $\mathrm{Ni^{2+}}$ is d^8; with the strong-field $\mathrm{CN^-}$ ligands the electrons pair up, freeing one $3d$ orbital.

Step 2 – form the hybrid set: The empty $3d$ orbital combines with $4s$ and two $4p$ orbitals to give four dsp^2 hybrids pointing to the corners of a square.

Step 3 – match with the observed properties: All electrons are paired, so the complex is diamagnetic and square planar, exactly as stated.

Final Answer: hybridization $= dsp^2 \Rightarrow$ A

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – oxidation state of the metal in a complex: The charge on the metal plus the charges of the ligands equals the overall charge of the neutral compound (through the counter-ions).

Step 1 – assign the outer ions and ligands: Four K are $+1$ each ($+4$ total); six $\mathrm{CN^-}$ are -1 each (-6 total). Let $\mathrm{Fe} = x$.

Step 2 – write the neutrality condition: $4(+1) + x + 6(-1) = 0$

Step 3 – simplify: $4 + x - 6 = 0$

Step 4 – solve for x: $x = +2$

Final Answer: oxidation state of $\mathrm{Fe} = +2 \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – the hydroformylation (oxo) reaction: An alkene reacts with synthesis gas ($\mathrm{CO}+\mathrm{H_2}$) over a Co or Rh carbonyl catalyst, adding one H and one CHO group across the double bond.

Step 1 – write the net transformation: $\mathrm{RCH{=}CH_2 + CO + H_2 \rightarrow RCH_2CH_2CHO}$ (plus the branched isomer).

Step 2 – identify the new functional group: A carbonyl carbon bearing a hydrogen, $-\mathrm{CHO}$, is introduced, i.e. an aldehyde group.

Step 3 – reject the distractors: The primary oxo product is the aldehyde; alcohols arise only on a further (separate) hydrogenation step, and no acid or ketone is formed directly.

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

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – coordination number in a BCC lattice: The coordination number is the count of nearest-neighbour atoms touching a given atom.

Step 1 – take the body-centre atom as reference: The atom at the centre of the cube is equidistant from all eight corner atoms.

Step 2 – count the nearest neighbours: Those eight corner atoms are the nearest neighbours, so the coordination number is 8.

Step 3 – confirm the symmetry: By translational symmetry every atom (corner or centre) has the same environment, so the BCC coordination number is 8 for all atoms.

Final Answer: coordination number of BCC $= 8 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – point defects in ionic solids: A Frenkel defect displaces an ion (usually the smaller cation) from its lattice site into an interstitial hole, whereas a Schottky defect removes a cation–anion pair entirely.

Step 1 – match the description: "A cation leaves its site and occupies an interstitial position" is precisely the Frenkel defect.

Step 2 – note the density consequence: No ions leave the crystal, so the mass and volume are essentially unchanged and the density stays the same, as stated.

Step 3 – reject the distractors: A Schottky defect lowers density (ions are missing); a substitutional defect swaps in a foreign ion; an F-centre is a trapped electron at an anion vacancy.

Final Answer: the defect described is a Frenkel defect $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q28

Q29.

Solution

Concept – metal centre of chlorophyll: Chlorophyll holds a single central metal ion inside its chlorin (modified porphyrin) ring.

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

Step 2 – identify the metal and its charge: The central ion is magnesium in the $+2$ state, Mg^{2+}.

Step 3 – reject the distractors: Fe^{2+} is in haemoglobin, Zn^{2+} in carbonic anhydrase, and Ca^{2+} is not a porphyrin metal here.

Final Answer: central metal of chlorophyll $= \mathrm{Mg}^{2+} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – staggered conformation of ethane: In the lowest-energy (staggered) conformation the front and back $\mathrm{C}-\mathrm{H}$ bonds are offset so the torsional (eclipsing) strain is minimized.

Step 1 – recall the geometry of the two carbons: Each carbon carries three $\mathrm{C}-\mathrm{H}$ bonds separated by 120° when viewed end-on.

Step 2 – offset the back carbon for the staggered form: The staggered arrangement places each back $\mathrm{C}-\mathrm{H}$ bond exactly halfway between two front bonds, i.e. offset by half of 120°.

Step 3 – compute the dihedral angle: Half of 120° is 60°, so a front bond and its nearest back bond are separated by a 60° dihedral angle.

Step 4 – confirm it is the minimum: This 60° staggered form is the energy minimum, whereas 0° (eclipsed) is the maximum.

Final Answer: dihedral angle $= 60^\circ \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

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

Step 1 – set the number of centres: $n = 3$ dissimilar stereocentres.

Step 2 – apply the 2^n rule: Maximum stereoisomers $= 2^3$

Step 3 – evaluate: $= 8$

Step 4 – note the make-up: These 8 comprise four pairs of enantiomers; since the centres are dissimilar, there is no meso reduction of the count.

Final Answer: maximum stereoisomers $= 8 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – axial/equatorial placement in a substituted cyclohexane: Substituents prefer equatorial positions to avoid $1,3$-diaxial strain; whether both can be equatorial depends on cis/trans and the ring positions.

Step 1 – analyse the $1,4$-relationship: On positions 1 and 4 of a chair, a *trans* arrangement lets both substituents be equatorial (or both axial).

Step 2 – choose the lower-energy chair: The diequatorial chair avoids all $1,3$-diaxial clashes and is therefore the more stable one.

Step 3 – conclude: In the most stable conformation of *trans*-$1,4$-dimethylcyclohexane, both methyl groups are equatorial.

Final Answer: both methyls are equatorial $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – mechanism for a tertiary substrate under solvolysis: A tertiary carbon forms a stable carbocation, and a polar protic solvent stabilizes ions, favouring a stepwise ionization (S_N1).

Step 1 – consider the carbocation stability: The tertiary cation $(CH_3)_3C^+$ is well stabilized, making ionization feasible.

Step 2 – consider the conditions: No strong nucleophile is present and the solvent is polar protic (aqueous ethanol), which favours the unimolecular S_N1 pathway.

Step 3 – rule out S_N2: Backside attack on a bulky tertiary carbon is sterically blocked, so S_N2 is not viable.

Step 4 – conclude: Substitution proceeds through the rate-determining formation of the carbocation, i.e. S_N1.

Final Answer: mechanism is $S_N1 \Rightarrow$ B

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – carbocation stabilization by resonance vs hyperconjugation: Resonance (full delocalization of the positive charge) generally stabilizes a cation more than hyperconjugation alone.

Step 1 – examine the allyl cation: The positive charge is delocalized over two carbons by π resonance, giving strong stabilization.

Step 2 – examine the others: Methyl and primary cations have little stabilization; the vinyl cation is especially unstable (sp carbon bearing the charge, no resonance donor).

Step 3 – rank and pick: allyl $>$ primary $>$ methyl $>$ vinyl, so the allyl carbocation is the most stable of the four.

Final Answer: most stable is the allyl carbocation $\Rightarrow$ A

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – why a racemate is optically inactive: A racemic mixture contains equal amounts of two enantiomers; each rotates plane-polarized light by the same magnitude but in opposite directions.

Step 1 – note each enantiomer is chiral and optically active: Individually the (R) and (S) forms rotate light $+\alpha$ and $-\alpha$ respectively.

Step 2 – add the contributions of a $50:50$ mixture: The equal, opposite rotations sum to zero: $(+\alpha) + (-\alpha) = 0$.

Step 3 – name the effect: This cancellation is called external compensation, so the racemate shows no net rotation despite each component being optically active.

Step 4 – reject the distractors: It is not a meso compound (no single molecule has an internal mirror plane here), and each enantiomer does rotate light and does have a stereocentre.

Final Answer: equal and opposite rotations cancel (external compensation) $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – Hofmann orientation with a bulky base: A large, hindered base abstracts the more accessible (less hindered) β-hydrogen, giving mainly the less substituted alkene.

Step 1 – identify the β-hydrogens of 2-bromobutane: Removal from the terminal $\text{C}1$ gives 1-butene; removal from the internal $\text{C}3$ gives 2-butene.

Step 2 – apply the steric preference of t-butoxide: The bulky base cannot easily reach the internal, crowded hydrogen, so it takes a terminal (primary) hydrogen.

Step 3 – identify the major product: Abstracting the terminal hydrogen gives the less substituted alkene, 1-butene (Hofmann product).

Final Answer: major alkene $=$ 1-butene $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q36

Q37.

Solution

Concept – protecting a carbonyl as a cyclic acetal: A ketone (or aldehyde) reacts with a $1,2$-diol under acid to give a cyclic acetal, a robust group stable to bases and nucleophiles.

Step 1 – identify the reagents: Ethylene glycol ($\text{HOCH}_2\text{CH}_2\text{OH}$) plus acid catalyst react with the carbonyl.

Step 2 – form the ring: Both hydroxyl oxygens add to the former carbonyl carbon, building a five-membered $1,3$-dioxolane ring with two $\text{C}-\text{O}$ single bonds.

Step 3 – classify the group: A carbon bearing two $-\text{OR}$ groups (and no OH) is an acetal; here it is a cyclic acetal (a $1,3$-dioxolane).

Step 4 – note its use: It masks the carbonyl during later steps and is later removed by aqueous acid to regenerate the ketone.

Final Answer: the protecting group is a cyclic acetal (1,3-dioxolane) $\Rightarrow$ A

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – the Rosenmund reduction: Hydrogen over a palladium catalyst poisoned with $BaSO_4$ reduces an acyl chloride only as far as the aldehyde, stopping before the alcohol.

Step 1 – write the transformation: $RCOCl \xrightarrow{H_2,\ Pd\text{-}BaSO_4} RCHO$

Step 2 – explain the selectivity: The poisoned (deactivated) catalyst prevents over-reduction of the aldehyde to RCH_2OH.

Step 3 – reject the strong hydrides: $LiAlH_4$ (and even $NaBH_4$ over time) would push the reduction on to the primary alcohol, and HNO_3 is an oxidant, not a reductant.

Final Answer: reagent $= H_2$ over Pd–$BaSO_4$ $\Rightarrow$ D

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – Friedel–Crafts acylation: An acyl chloride with anhydrous $AlCl_3$ generates an acylium ion that substitutes onto the aromatic ring, giving an aryl ketone.

Step 1 – generate the electrophile: $CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$ (the acylium ion).

Step 2 – substitute onto benzene: The ring attacks the acylium carbon, and loss of a proton restores aromaticity.

Step 3 – identify the product: An acetyl group is now bonded to the ring, giving $C_6H_5COCH_3$, acetophenone.

Final Answer: product $=$ acetophenone $\Rightarrow$ C

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – electrophile in Friedel–Crafts alkylation: The Lewis acid $AlCl_3$ removes chloride from the alkyl halide to make a carbocation, which is the attacking electrophile.

Step 1 – generate the electrophile: $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + AlCl_4^-$

Step 2 – identify the active species: The methyl carbocation CH_3^+ is the electrophile that attacks the electron-rich ring.

Step 3 – reject the distractors: CH_3^- is a nucleophile (wrong charge), and $AlCl_3$ and HCl are not the ring-attacking species.

Final Answer: electrophile $= CH_3^+ \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – Grignard addition to formaldehyde: A Grignard reagent adds to a carbonyl; with formaldehyde (the smallest aldehyde) the product after hydrolysis is a primary alcohol.

Step 1 – nucleophilic addition: $R{-}MgX$ adds to $H_2C{=}O$ to give the alkoxide $RCH_2O{-}MgX$.

Step 2 – acidic work-up: $RCH_2O{-}MgX + H^+ \rightarrow RCH_2OH$.

Step 3 – classify the product: The carbon bearing the $-OH$ also carries two hydrogens ($-CH_2OH$), so it is a primary alcohol.

Step 4 – contrast: Formaldehyde gives a primary alcohol; other aldehydes give secondary, and ketones give tertiary alcohols.

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

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – the Wolff–Kishner reduction: Heating a ketone (or aldehyde) with hydrazine and a strong base converts the carbonyl fully to a methylene group under *basic* conditions.

Step 1 – write the transformation: $R{-}CO{-}R' \xrightarrow{NH_2NH_2,\ KOH,\ \Delta} R{-}CH_2{-}R'$

Step 2 – trace the pathway: The carbonyl first forms a hydrazone ($C{=}N{-}NH_2$), which base then decomposes with loss of N_2 to give the methylene.

Step 3 – distinguish from Clemmensen: Clemmensen ($Zn(Hg)/HCl$) reaches the same CH_2 but under *acidic* conditions; here the medium is basic.

Final Answer: the reaction is the Wolff–Kishner reduction $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – anti-Markovnikov (peroxide) addition of HBr: With peroxides, HBr adds by a radical chain mechanism, and the bromine ends up on the *less* substituted (terminal) carbon.

Step 1 – form the more stable radical: The $Br\cdot$ radical adds to the terminal CH_2, giving the more stable secondary carbon radical $CH_3\dot{C}HCH_2Br$.

Step 2 – abstract hydrogen: This radical takes an H from HBr, placing the H on the central carbon.

Step 3 – identify the product: Bromine sits on the terminal carbon, giving $CH_3CH_2CH_2Br$, i.e. 1-bromopropane.

Step 4 – contrast with the ionic route: Without peroxide, ionic addition would give 2-bromopropane (Markovnikov); the peroxide reverses the regiochemistry.

Final Answer: major product $=$ 1-bromopropane $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – the Claisen rearrangement: The thermal $[3,3]$-sigmatropic rearrangement of an allyl vinyl ether gives a γ,δ-unsaturated carbonyl compound.

Step 1 – recognize the substrate: An allyl vinyl ether has an O linking an allyl group to a vinyl group, the classic Claisen substrate.

Step 2 – carry out the $[3,3]$ shift: A concerted, six-membered cyclic transition state breaks the $C{-}O$ σ bond and forms a new $C{-}C$ σ bond, shifting the double bonds.

Step 3 – identify the product and name: The oxygen becomes a carbonyl, giving a γ,δ-unsaturated aldehyde/ketone; this $[3,3]$ rearrangement of an allyl vinyl ether

is the Claisen rearrangement.

Step 4 – distinguish from Cope: The all-carbon $1,5$-diene analogue would be the Cope rearrangement; the presence of oxygen makes this specifically a Claisen.

Final Answer: the reaction is the Claisen rearrangement $\Rightarrow$ D

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – Woodward–Hoffmann rules for electrocyclic reactions: For a $4n+2$ π-electron system, the thermal mode is disrotatory and the *photochemical* mode is the opposite, conrotatory.

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

Step 2 – apply the photochemical rule: Photoexcitation promotes an electron, changing the symmetry of the highest occupied orbital, so the allowed mode reverses relative to thermal.

Step 3 – state the mode: Since the thermal 6π closure is disrotatory, the photochemical 6π closure is conrotatory.

Final Answer: photochemical 6π closure is conrotatory $\Rightarrow$ C

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – complementary base pairing in DNA: In the double helix, a purine always pairs with a pyrimidine: adenine with thymine (two H-bonds) and guanine with cytosine (three H-bonds).

Step 1 – classify adenine: Adenine is a purine base.

Step 2 – apply the pairing rule: Adenine pairs specifically with the pyrimidine thymine through two hydrogen bonds.

Step 3 – reject the distractors: Guanine pairs with cytosine (not adenine); uracil replaces thymine in RNA, not in DNA.

Final Answer: adenine pairs with thymine $\Rightarrow$ B

Answer: (B) Go Back to Q46

Answer Key

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