GAT B Chemistry

Sample Paper – 5

Duration: 23 Minutes **Maximum Marks: 15**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct Answer), modelled on the Chemistry portion of **GAT B** entrance.
- Each correct answer carries **+1 marks**. There is **a deduction of 0.5 marks for each incorrect answer**.
- Only **one** option is correct. Choose carefully.
- Syllabus level: **NCERT Class 11 & 12 Chemistry — Physical, Organic, and Inorganic Chemistry.**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. Which of the following carbohydrates is a **non-reducing sugar**?

(A) Glucose

(B) Sucrose

(C) Maltose

(D) Lactose

Q2. Which of the following correctly matches an RNA type with its **primary biological function**?

(A) mRNA — brings amino acids to the ribosome during translation

(B) tRNA — carries the genetic message from the nucleus to the ribosome

(C) rRNA — forms the structural and catalytic core of the ribosome

(D) snRNA — decodes the codon sequence on the ribosome

Q3. Which statement about **lipase** is CORRECT?

(A) Lipase catalyses the hydrolysis of peptide bonds to yield amino acids

(B) Lipase requires NAD^+ as an essential cofactor for its activity

(C) Lipase acts on polysaccharides to release monosaccharide units

(D) Lipase hydrolyses the ester linkages in triglycerides, releasing fatty acids and glycerol

Q4. The **buffer capacity** of a weak acid buffer is MAXIMUM when:

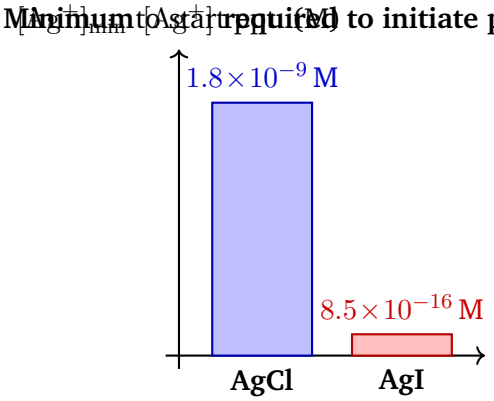
(A) $\mathrm{pH} = \mathrm{p}K_a$ of the weak acid

(B) $\mathrm{pH} = \mathrm{p}K_a + 1$

(C) The solution is at pH 7 (neutral)

(D) The weak acid is completely dissociated

Q5. A solution contains both $\mathbf{Cl^-}$ and $\mathbf{I^-}$ ions, each at 0.10 M. Silver nitrate solution is added dropwise. Given $K_{sp}(\mathrm{AgCl}) = 1.8 \times 10^{-10}$ and $K_{sp}(\mathrm{AgI}) = 8.5 \times 10^{-17}$, which ion precipitates **first**, and why?



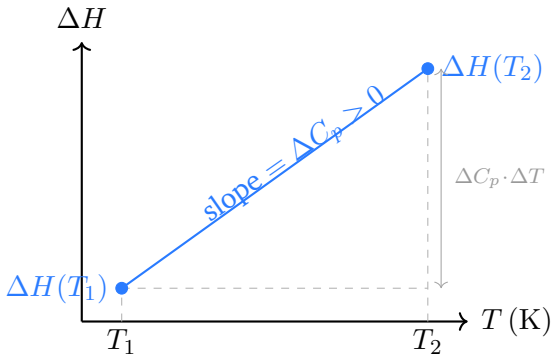
(A) Cl^-, because AgCl has a higher K_{sp} and therefore forms first

(B) I^-, because AgI has a much lower K_{sp} and needs far less Ag^+ to begin precipitating

(C) Both ions precipitate simultaneously since their concentrations are equal

(D) Cl^-, because chloride ions are smaller and more reactive than iodide ions

Q6. According to **Kirchhoff's equation**, $\Delta H(T_2) = \Delta H(T_1) + \Delta C_p\,(T_2 - T_1)$. For a reaction in which $\Delta C_p > 0$, what does the graph of ΔH *vs.* T look like?



(A) A horizontal line, because ΔH is independent of temperature

(B) A curve that decreases as T increases

(C) A straight line with a positive slope equal to ΔC_p

(D) A straight line with a negative slope equal to $-\Delta C_p$

Q7. In the **Born–Haber cycle** for the formation of NaCl(s) from Na(s) and $\frac{1}{2}Cl_2(g)$, which of the following steps is **endothermic**?

(A) Electron affinity: $Cl(g) + e^- \longrightarrow Cl^-(g)$

(B) Lattice enthalpy: $Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$

(C) Overall formation: $Na(s) + \frac{1}{2}Cl_2(g) \longrightarrow NaCl(s)$

(D) Ionisation energy: $Na(g) \longrightarrow Na^+(g) + e^-$

Q8. The exceptionally **high stability constant** of the $[Ca(EDTA)]^{2-}$ complex is primarily attributed to:

(A) The chelate effect — EDTA wraps around Ca^{2+} forming multiple five-membered chelate rings simultaneously, resulting in a large positive entropy gain

(B) The high charge density of Ca^{2+} compared with other Group 2 ions

(C) The strong π-donor ability of the amine nitrogen atoms in EDTA

(D) The unusually low coordination number of Ca^{2+} in the resulting complex

Q9. Which of the following d-block metal ions is **diamagnetic** (contains *no* unpaired electrons)?

(A) Cu^{2+} (d^9)

(B) Zn^{2+} (d^{10})

(C) Fe^{2+} (d^6, high-spin, weak-field ligands)

(D) Mn^{2+} (d^5, high-spin, weak-field ligands)

Q10. When 2-bromobutane is treated with **KOH in ethanol** (hot, concentrated), which is the **major (Zaitsev) product**?

(A) But-1-ene

(B) 2-Bromobutane (no reaction occurs)

(C) But-2-ene

(D) Butane

Q11. Which set of conditions BEST promotes **nucleophilic aromatic substitution (S_NAr)** on a benzene ring bearing a leaving group?

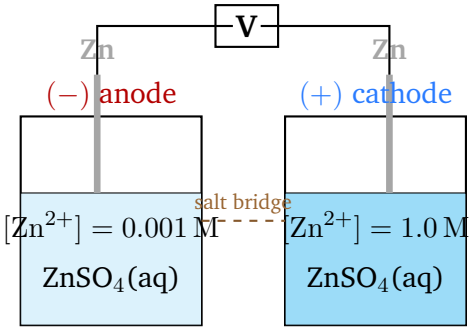
(A) Presence of electron-*donating* groups (e.g., $-NH_2$) ortho/para to the leaving group, with a weak nucleophile

(B) An unsubstituted benzene ring treated with a strong base alone

(C) Presence of electron-*donating* groups *meta* to the leaving group, with a strong nucleophile

(D) Presence of electron-*withdrawing* groups (e.g., $-NO_2$) ortho and/or para to the leaving group, with a strong nucleophile

Q12. A **concentration cell** is constructed with two zinc electrodes: one in 0.001 M $ZnSO_4$ (anode) and the other in 1.0 M $ZnSO_4$ (cathode) at 298 K. Using $E_{\text{cell}} = \dfrac{0.0592}{n} \log \dfrac{[Zn^{2+}]_{\text{cathode}}}{[Zn^{2+}]_{\text{anode}}}$, what is the EMF of the cell?



(A) 0.0888 V

(B) 0.0592 V

(C) 0.1184 V

(D) 0.0296 V

Q13. For a **zero-order reaction** $\text{A} \longrightarrow \text{Products}$ with rate constant k, which of the following correctly states the **integrated rate law**?

(A) $\ln[\text{A}] = \ln[\text{A}]_0 - kt$

(B) $[\text{A}] = [\text{A}]_0 - kt$

(C) $\dfrac{1}{[\text{A}]} = \dfrac{1}{[\text{A}]_0} + kt$

(D) $[\text{A}] = [\text{A}]_0\, e^{-kt}$

Q14. The **lanthanide contraction** refers to the steady decrease in atomic and ionic radii across the lanthanide series (La to Lu). Its **primary cause** is:

(A) Increasing nuclear charge combined with very *effective* shielding by 4f-electrons

(B) Poor shielding of nuclear charge by 3d-electrons as the series is crossed

(C) Ineffective shielding of the steadily increasing nuclear charge by 4f-electrons, which have a diffuse, non-directional radial distribution

(D) Decreasing nuclear charge accompanied by rising electron–electron repulsion within the 4f subshell

Q15. In the **vulcanisation** of natural rubber, sulfur forms covalent cross-links between adjacent polyisoprene chains. The MAIN consequence of these sulfur cross-links is:

(A) Increased tensile strength, elasticity, and resistance to heat and chemicals compared with raw, unvulcanised rubber

(B) Decreased melting point, making the rubber easier to mould at lower temperatures

(C) Increased solubility of rubber in common organic solvents such as benzene

(D) Conversion of the thermoset rubber network into a thermoplastic material

Detailed Solutions

Q1.

Solution

Concept — Reducing vs. Non-Reducing Sugars: A *reducing sugar* possesses a free anomeric carbon (free aldehyde or hemiacetal/hemiketal –OH) that can donate electrons to Fehling's or Benedict's reagent, reducing Cu^{2+} to Cu^{+}. A *non-reducing sugar* has all its anomeric carbons locked in glycosidic bonds and therefore cannot open to the aldehyde form.

Step 1 — Examine sucrose: Sucrose is a disaccharide of glucose and fructose joined by an α-1,2-glycosidic bond that links the anomeric C-1 of glucose *and* the anomeric C-2 of fructose simultaneously. Neither unit retains a free anomeric –OH, so sucrose **cannot** form an open-chain aldehyde and does not reduce Fehling's reagent.

Step 2 — Verify the other options: Glucose (free aldehyde), maltose (α-1,4 bond leaves the C-1 of one glucose free), and lactose (β-1,4 bond leaves the C-1 of galactose free) all have a free anomeric centre and are therefore reducing sugars.

Why other options are wrong:

- Option A: Glucose is the classic reducing sugar (free aldehyde group at C-1).
- Option B: **Correct** — sucrose has no free anomeric carbon and is non-reducing.
- Option C: Maltose has a free anomeric –OH on one glucose unit; it is reducing.
- Option D: Lactose has a free anomeric –OH on its galactose residue; it is reducing.

Final Answer: Sucrose is non-reducing because both anomeric carbons are locked in the α-1,2-glycosidic bond. $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 1

Q2.

Solution

Concept — Types of RNA and Their Functions: The three major RNA types — mRNA, tRNA, and rRNA — each serve a distinct, non-interchangeable role in the central dogma (transcription → translation).

Step 1 — Assign correct functions:

- **mRNA (messenger RNA):** carries the nucleotide sequence (codons) copied from a gene to the ribosome, providing the template for protein synthesis.
- **tRNA (transfer RNA):** each tRNA molecule carries a specific amino acid and recognises a complementary mRNA codon via its anticodon loop.
- **rRNA (ribosomal RNA):** constitutes the bulk of ribosomal mass; the large subunit rRNA acts as a ribozyme (peptidyl transferase) catalysing peptide bond formation.
- **snRNA (small nuclear RNA):** components of the spliceosome, involved in removing introns from pre-mRNA; not in translation.

Step 2 — Match to the options: Option C correctly states that rRNA forms the structural and catalytic core of the ribosome.

Why other options are wrong:

- Option A: Bringing amino acids to the ribosome is the role of *tRNA*, not mRNA.
- Option B: Carrying the genetic message from nucleus to ribosome is the role of *mRNA*, not tRNA.
- Option C: **Correct** — rRNA forms the structural scaffold and catalytic centre of the ribosome.
- Option D: snRNA functions in pre-mRNA splicing, not codon decoding.

Final Answer: rRNA forms the structural and catalytic core of the ribosome. ⇒ C

Answer: (C) Go Back to Q 2

Q3.

Solution

Concept — Lipase Enzyme Specificity: Lipase is a serine hydrolase (EC 3.1.1.3) with strict substrate specificity for ester bonds in glycerolipids. It belongs to the class of *esterases* and does not require any cofactor for activity.

Step 1 — Substrate and products of lipase: Triglycerides are triesters of glycerol with three fatty acid chains. Lipase catalyses the sequential hydrolysis of these ester ($-$COO$-$) bonds at the oil–water interface:

$$\text{Triglyceride} + 3\,H_2O \xrightarrow{\text{lipase}} \text{Glycerol} + 3\,\text{Fatty acids (as carboxylate)}$$

Step 2 — Eliminate wrong options:

- Peptide bond hydrolysis $\rightarrow$ *proteases* (e.g., trypsin, pepsin, chymotrypsin).
- NAD^+ is a redox cofactor for *dehydrogenases*; lipase uses no redox cofactor.
- Polysaccharide hydrolysis $\rightarrow$ *glycosidases/amylases*.

Why other options are wrong:

- Option A: Peptide bond cleavage is carried out by proteases, not lipase.
- Option B: Lipase is cofactor-independent; NAD^+ is irrelevant to its mechanism.
- Option C: Monosaccharide release from polysaccharides is the job of amylase/glycosidase.
- Option D: **Correct** — lipase hydrolyses ester bonds in triglycerides, giving fatty acids and glycerol.

Final Answer: Lipase hydrolyses the ester linkages in triglycerides to give fatty acids and glycerol. $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 3

Q4.

Solution

Concept — Buffer Capacity: Buffer capacity β measures how many moles of strong acid or base a buffer can absorb per litre per unit pH change. For a weak acid HA / conjugate base A^- buffer of total concentration C:

$$\beta = 2.303\, C\, \alpha(1-\alpha)$$

where $\alpha = [A^-]/C$ is the degree of dissociation.

Step 1 — Maximise $\alpha(1-\alpha)$: Differentiate with respect to α and set to zero:

$$\frac{d}{d\alpha}\left[\alpha(1-\alpha)\right] = 1 - 2\alpha = 0 \implies \alpha = 0.5$$

Maximum $\beta = 2.303\, C \times 0.5 \times 0.5 = 0.576\, C$.

Step 2 — Relate $\alpha = 0.5$ to pH: When $\alpha = 0.5$, $[HA] = [A^-]$. Substituting into the Henderson–Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log\frac{[A^-]}{[HA]} = \text{p}K_a + \log 1 = \text{p}K_a$$

Why other options are wrong:

- Option A: **Correct** — maximum buffer capacity occurs when $\text{pH} = \text{p}K_a$.
- Option B: At $\text{pH} = \text{p}K_a + 1$, $[A^-]/[HA] = 10$; $\alpha = 10/11 \approx 0.91$; buffer capacity is lower.
- Option C: pH 7 is not generally the maximum; it coincides with maximum capacity only if $\text{p}K_a = 7$.
- Option D: Complete dissociation ($\alpha = 1$) means no HA remains; $\beta = 0$.

Final Answer: Buffer capacity is maximum when $\text{pH} = \text{p}K_a$. $\Rightarrow$ A

Answer: (A) Go Back to Q 4

Q5.

Solution

Concept — Order of Precipitation: When two anions compete for the same precipitant cation, the one that is exceeded in its K_{sp} at the lowest concentration of precipitant will precipitate first. The minimum $[Ag^+]$ needed to just begin precipitating each ion is found from $K_{sp} = [Ag^+][X^-]$.

Step 1 — Threshold $[Ag^+]$ for each ion:

$$[Ag^+]_{\text{to ppt } Cl^-} = \frac{K_{sp}(AgCl)}{[Cl^-]} = \frac{1.8 \times 10^{-10}}{0.10} = 1.8 \times 10^{-9}\,\text{M}$$

$$[Ag^+]_{\text{to ppt } I^-} = \frac{K_{sp}(AgI)}{[I^-]} = \frac{8.5 \times 10^{-17}}{0.10} = 8.5 \times 10^{-16}\,\text{M}$$

Step 2 — Compare the thresholds: $8.5 \times 10^{-16}\,\text{M} \ll 1.8 \times 10^{-9}\,\text{M}$. As Ag^+ is added dropwise, the K_{sp} of AgI is exceeded *first*, so **I^- precipitates first** as bright yellow AgI.

Why other options are wrong:

- Option A: A higher K_{sp} for AgCl means Cl^- needs *more* Ag^+ to precipitate — it precipitates *later*.
- Option B: **Correct** — I^- precipitates first because AgI's K_{sp} is $\approx 10^7$ times smaller than AgCl's.
- Option C: Equal concentrations do not imply simultaneous precipitation; K_{sp} values differ by seven orders of magnitude.
- Option D: Ion size is not the determining factor; solubility product thermodynamics governs precipitation order.

Final Answer: I^- precipitates first because AgI has a far lower K_{sp}. $\Rightarrow$ B

Answer: (B) Go Back to Q 5

Q6.

Solution

Concept — Kirchhoff's Equation: Kirchhoff's equation relates the enthalpy of a reaction at two temperatures by integrating the heat capacity difference over the temperature range:

$$\Delta H(T_2) = \Delta H(T_1) + \Delta C_p\,(T_2 - T_1)$$

where $\Delta C_p = \sum C_p(\text{products}) - \sum C_p(\text{reactants})$.

Step 1 — Identify the mathematical form: Rewrite as $\Delta H(T) = \Delta H(T_{\text{ref}}) + \Delta C_p \cdot T$ (absorbing the constant reference term). This is a **linear** equation in T with slope $= \Delta C_p$.

Step 2 — Determine slope sign for $\Delta C_p > 0$: If $\Delta C_p > 0$, the slope is **positive**: ΔH increases as temperature increases. The graph of ΔH vs. T is a **straight line with positive slope**.

Why other options are wrong:

- Option A: A horizontal line corresponds to $\Delta C_p = 0$, contradicting the premise.
- Option B: A decreasing curve requires $\Delta C_p < 0$, the opposite of given.
- Option C: **Correct** — positive slope $= \Delta C_p > 0$, straight line.
- Option D: Negative slope requires $\Delta C_p < 0$.

Final Answer: ΔH vs. T is a straight line with positive slope equal to ΔC_p. $\Rightarrow$ C

Answer: (C) Go Back to Q 6

Q7.

Solution

Concept — Born–Haber Cycle: The Born–Haber cycle decomposes the formation of an ionic solid into a series of hypothetical steps, each with a measurable enthalpy change. Sign convention: endothermic steps have $\Delta H > 0$; exothermic steps have $\Delta H < 0$.

Step 1 — List all steps and their signs for NaCl:

- Sublimation of Na(s) $\rightarrow$ Na(g): $\Delta H_{\text{sub}} = +108\,\text{kJ mol}^{-1}$ (endothermic)
- Bond dissociation of $\frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{Cl(g)}$: $\frac{1}{2}D = +121\,\text{kJ mol}^{-1}$ (endothermic)
- **Ionisation energy** of Na(g) $\rightarrow$ Na^+(g) + e^-: $IE_1 = +496\,\text{kJ mol}^{-1}$ (endothermic)
- Electron affinity of Cl(g) + $\text{e}^- \rightarrow \text{Cl}^-$(g): $EA = -349\,\text{kJ mol}^{-1}$ (exothermic)
- Lattice enthalpy: Na^+(g) + Cl^-(g) $\rightarrow$ NaCl(s): $\Delta H_L = -787\,\text{kJ mol}^{-1}$ (exothermic)
- Overall: Na(s) + $\frac{1}{2}\text{Cl}_2$(g) $\rightarrow$ NaCl(s): $\Delta H_f = -411\,\text{kJ mol}^{-1}$ (exothermic)

Step 2 — Identify the endothermic option among the choices: Of the four options given, only the ionisation energy of Na has a *positive* ΔH.

Why other options are wrong:

- Option A: Electron affinity of Cl is exothermic ($-349\,\text{kJ mol}^{-1}$); not endothermic.
- Option B: Lattice enthalpy (ionic solid formation) is exothermic ($-787\,\text{kJ mol}^{-1}$).
- Option C: Overall formation is exothermic ($\Delta H_f = -411\,\text{kJ mol}^{-1}$).
- Option D: **Correct** — ionisation energy of Na is endothermic ($+496\,\text{kJ mol}^{-1}$).

Final Answer: The ionisation energy of Na is the endothermic step in the Born–Haber cycle. $\Rightarrow$ D

Answer: (D) Go Back to Q 7

Q8.

Solution

Concept — Stability Constants and the Chelate Effect: The stability (formation) constant K_{stab} of a complex quantifies the equilibrium $\text{M} + \text{L} \rightleftharpoons [\text{ML}]$. When a polydentate (chelating) ligand replaces several monodentate ligands simultaneously, the resulting entropy increase drives an enormous stabilisation — the *chelate effect*.

Step 1 — EDTA as a hexadentate ligand: EDTA^{4-} possesses six donor atoms (two tertiary N and four carboxylate O). On binding Ca^{2+}, all six donors coordinate simultaneously, creating **five five-membered chelate rings** in one complex.

Step 2 — Thermodynamic origin of high K_{stab}: Replacing six water molecules (six separate particles) with one EDTA molecule (one particle) increases the number of free particles in solution:

$$[\text{Ca}(\text{H}_2\text{O})_6]^{2+} + \text{EDTA}^{4-} \rightleftharpoons [\text{Ca}(\text{EDTA})]^{2-} + 6\,\text{H}_2\text{O}$$

This produces a large positive ΔS, making $\Delta G = \Delta H - T\Delta S$ very negative, and $K_{\text{stab}} \approx 10^{10.7}$ for Ca^{2+}.

Why other options are wrong:

- Option A: **Correct** — the chelate effect (entropy-driven ring formation) explains the exceptionally high stability.
- Option B: Charge density of Ca^{2+} is moderate; it does not alone explain the 10^{10} magnitude.

- Option C: Carboxylate O atoms are σ-donors; π-donation requires d-orbitals unavailable in Ca^{2+}.
- Option D: Ca^{2+} in $[Ca(EDTA)]^{2-}$ has coordination number 6, which is normal, not unusually low.

Final Answer: The chelate effect (entropy gain from multiple ring formation) accounts for the high stability of $[Ca(EDTA)]^{2-}$. $\Rightarrow$ A

Answer: (A) Go Back to Q 8

Q9.

Solution

Concept — Diamagnetic vs. Paramagnetic d-Block Ions: Diamagnetic species have *all* electrons spin-paired (net magnetic moment $\mu = 0$). Paramagnetic species have one or more unpaired electrons ($\mu > 0$). The number of unpaired electrons is determined by the electron configuration and the crystal field splitting (high-spin vs. low-spin for d^4–d^7).

Step 1 — Electron configurations:

- Cu^{2+}: [Ar] $3d^9$ $\rightarrow$ 1 unpaired electron $\rightarrow$ **paramagnetic**
- **Zn^{2+}: [Ar]** $3d^{10}$ $\rightarrow$ all 5 d-orbitals doubly occupied ($\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$) $\rightarrow$ 0 unpaired electrons $\rightarrow$ **diamagnetic**
- Fe^{2+}: [Ar] $3d^6$ (high-spin) $\rightarrow$ 4 unpaired electrons $\rightarrow$ paramagnetic
- Mn^{2+}: [Ar] $3d^5$ (high-spin) $\rightarrow$ 5 unpaired electrons $\rightarrow$ paramagnetic (maximum)

Step 2 — Conclusion: Only Zn^{2+} has a completely filled d^{10} configuration with **no unpaired electrons**.

Why other options are wrong:

- Option A: Cu^{2+} (d^9) has one unpaired electron and is paramagnetic.
- Option B: **Correct** — Zn^{2+} (d^{10}) is diamagnetic.
- Option C: Fe^{2+} (d^6, high-spin) has 4 unpaired electrons.
- Option D: Mn^{2+} (d^5, high-spin) has the maximum 5 unpaired electrons.

Final Answer: Zn^{2+} (d^{10}) is diamagnetic with no unpaired electrons. $\Rightarrow$ B

Answer: (B) Go Back to Q 9

Q10.

Solution

Concept — E2 Elimination and Zaitsev's Rule: In E2 (bimolecular elimination), a strong base abstracts a β-hydrogen concertedly as the leaving group departs, forming a double bond. **Zaitsev's rule** states that the major product is the *more substituted* (more stable) alkene, because the transition state leading to it is lower in energy (more alkyl groups on the incipient double bond stabilise it by hyperconjugation).

Step 1 — Structure of 2-bromobutane and possible eliminations: 2-Bromobutane: CH_3-CH(Br)-CH_2-CH_3. The Br is on C2. Two sets of β-H are available:

- H on C1 $\rightarrow$ **but-1-ene** (CH_2=$CHCH_2CH_3$): monosubstituted (minor).
- H on C3 $\rightarrow$ **but-2-ene** (CH_3CH=$CHCH_3$): disubstituted (major, Zaitsev).

Step 2 — Reaction conditions: KOH in hot ethanol provides a strong, relatively unhindered base under thermal conditions, which strongly favours the Zaitsev (more substituted) alkene.

Why other options are wrong:

- Option A: But-1-ene is the minor (Hofmann) product; it requires a bulky base to predominate.
- Option B: KOH/ethanol at elevated temperature is a classic E2 condition; no-reaction is incorrect.
- Option C: **Correct** — but-2-ene is the Zaitsev (major, disubstituted) product.
- Option D: Butane would require reduction, not base-promoted elimination.

Final Answer: But-2-ene is the major product (Zaitsev rule). $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 10

Q11.

Solution

Concept — Nucleophilic Aromatic Substitution (S_NAr): S_NAr proceeds via an *addition–elimination* mechanism through a carbanion intermediate called the **Meisenheimer complex**. The rate-determining step is nucleophilic addition to the ring. Substituents that stabilise the developing negative charge on the ring in this intermediate accelerate the reaction.

Step 1 — Effect of ring substituents on the Meisenheimer complex:

- **Electron-withdrawing groups (EWG)** (e.g., $-NO_2$, $-CN$, $-CHO$) at *ortho* or *para* positions delocalise the negative charge of the Meisenheimer complex by resonance $\Rightarrow$ stabilise intermediate $\Rightarrow$ **activate S_NAr**.
- **Electron-donating groups (EDG)** at ortho/para *destabilise* the Meisenheimer complex (push electron density onto an already electron-rich ring) $\Rightarrow$ **deactivate S_NAr**.

Step 2 — Additional requirements: A strong nucleophile (e.g., $-OH$, $-NH_2$, $-OR$) is needed to attack the ring and initiate the addition step. Unactivated benzene does not readily undergo S_NAr.

Why other options are wrong:

- Option A: EDG ortho/para *destabilises* the intermediate; S_NAr is *inhibited*.
- Option B: Unsubstituted benzene lacks ring activation; S_NAr does not proceed.
- Option C: EDG *meta* does not stabilise the Meisenheimer complex at the ipso carbon.
- Option D: **Correct** — EWG ortho/para to the leaving group stabilise the Meisenheimer complex and promote S_NAr.

Final Answer: EWG ortho/para to the leaving group promote S_NAr by stabilising the Meisenheimer intermediate. $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q 11

Q12.

Solution

Concept — Concentration Cells: A concentration cell uses identical electrodes immersed in electrolyte solutions of different concentrations. There is no difference in standard reduction potentials; the EMF arises entirely from the Nernst equation applied to the concentration gradient:

$$E_{\text{cell}} = \frac{0.0592}{n} \log \frac{[\text{ion}]_{\text{cathode}}}{[\text{ion}]_{\text{anode}}}$$

Step 1 — Identify anode and cathode: Electrons flow from the more dilute (lower chemical potential) to the more concentrated side.

- **Anode** (oxidation): $\mathrm{Zn(s) \rightarrow Zn^{2+}(0.001\,M) + 2e^-}$ (dilute side)
- **Cathode** (reduction): $\mathrm{Zn^{2+}(1.0\,M) + 2e^- \rightarrow Zn(s)}$ (concentrated side)

Step 2 — Calculate EMF: $n = 2$ for $\mathrm{Zn^{2+}/Zn}$.

$$E = \frac{0.0592}{2}\log\frac{1.0}{0.001} = \frac{0.0592}{2}\log\left(10^3\right) = 0.0296 \times 3 = \mathbf{0.0888\,V}$$

Why other options are wrong:

- Option A: **Correct** — 0.0888 V, from $(0.0592/2) \times 3$.
- Option B: 0.0592 V would require $n = 1$ (applicable to a $\mathrm{Cu^+/Cu}$ or $\mathrm{Ag^+/Ag}$ cell with the same ratio).
- Option C: 0.1184 V would require $\log$ ratio $= 4$, i.e., a 10^4-fold concentration difference.
- Option D: 0.0296 V would require $\log$ ratio $= 1$, i.e., only a 10:1 concentration ratio.

Final Answer: $E_{\text{cell}} = 0.0888\,\text{V}$. $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 12

Q13.

Solution

Concept — Zero-Order Kinetics: For a zero-order reaction, the rate is *independent* of the reactant concentration: rate $= k$ ($\text{mol}\,\text{L}^{-1}\,\text{s}^{-1}$). This situation arises when a catalyst surface is saturated (e.g., enzyme at high substrate, or heterogeneous catalysis) or for some photochemical reactions.

Step 1 — Derive the integrated rate law:

$$\frac{d[\text{A}]}{dt} = -k \implies \int_{[\text{A}]_0}^{[\text{A}]} d[\text{A}] = -k\int_0^t dt \implies [\text{A}] - [\text{A}]_0 = -kt$$

$$\boxed{[\text{A}] = [\text{A}]_0 - kt}$$

A plot of [A] vs. t is a straight line with slope $= -k$ and intercept $= [\text{A}]_0$.

Step 2 — Units of k: From $[\text{A}] = [\text{A}]_0 - kt$, the unit of k must equal [concentration]/[time] $= \text{mol}\,\text{L}^{-1}\,\text{s}^{-1}$.

Why other options are wrong:

- Option A: $\ln[\mathrm{A}] = \ln[\mathrm{A}]_0 - kt$ is the *first-order* integrated law.
- Option B: **Correct** — $[\mathrm{A}] = [\mathrm{A}]_0 - kt$ is the zero-order integrated law.
- Option C: $1/[\mathrm{A}] = 1/[\mathrm{A}]_0 + kt$ is the *second-order* integrated law.
- Option D: $[\mathrm{A}] = [\mathrm{A}]_0 e^{-kt}$ is the exponential decay of a first-order reaction.

Final Answer: The zero-order integrated rate law is $[\mathrm{A}] = [\mathrm{A}]_0 - kt$. $\Rightarrow$ $\boxed{\mathrm{B}}$

Answer: (B) Go Back to Q 13

Q14.

Solution

Concept — Lanthanide Contraction: Across the lanthanide series (La, $Z = 57$ to Lu, $Z = 71$), 14 electrons are progressively added to the *inner* 4f subshell while the nuclear charge increases by 14 units. The atomic and ionic radii decrease continuously — a phenomenon called **lanthanide contraction** ($\approx 17\,\mathrm{pm}$ decrease in Ln^{3+} radius from La^{3+} to Lu^{3+}).

Step 1 — Why 4f-electrons shield poorly: The 4f-orbitals have a complex, multi-lobed angular shape with many angular nodes. They penetrate the core weakly and do not efficiently screen the nucleus from *other* 4f-electrons or from the outer $5s^2 5p^6 6s^2$ electrons. As each new electron enters 4f, the nuclear charge increases by $+e$ but the additional shielding is much less than $+e$, so the effective nuclear charge (Z_{eff}) felt by all electrons **increases** across the series, contracting the electron cloud.

Step 2 — Consequence: The 4d and 5d metals that follow the lanthanides (e.g., Zr/Hf, Nb/Ta, Mo/W) have nearly identical ionic radii to their lighter congeners, causing unusual chemical similarities between 4d and 5d pairs.

Why other options are wrong:

- Option A: Nuclear charge *increases* (not decreases) across the series; shielding by 4f is *ineffective*, not effective.
- Option B: 3d-electrons are not involved in lanthanide contraction; the relevant subshell is 4f.
- Option C: **Correct** — poor shielding by 4f-electrons of the increasing nuclear charge causes contraction.
- Option D: Nuclear charge *increases* continuously from La to Lu; it does not decrease.

Final Answer: Lanthanide contraction is caused by ineffective shielding of increasing nuclear charge by 4f-electrons. $\Rightarrow$ $\boxed{\mathrm{C}}$

Answer: (C) Go Back to Q 14

Q15.

Solution

Concept — Vulcanisation of Rubber: Natural rubber (cis-polyisoprene) is a linear polymer with a $C = C$ double bond in every repeat unit. In its raw state it is soft, sticky, and prone to deformation. Vulcanisation, discovered by Charles Goodyear (1839), introduces covalent **sulfur cross-links** between polymer chains by reacting sulfur with the double bonds at 140–180°C.

Step 1 — What cross-links do structurally: Polysulfide bridges ($-S_n-$, typically $n = 1$–8) covalently bond adjacent polyisoprene chains, creating a three-dimensional network. These bridges restrict chain slippage (flow) while still permitting some chain segment flexibility.

Step 2 — Property changes upon vulcanisation:

- **Tensile strength** ↑ (cross-links prevent irreversible deformation).
- **Elasticity** ↑ (network snaps back after stretching).
- **Resistance to heat** ↑ (cross-links maintain shape at elevated T).
- **Resistance to organic solvents** ↑ (cross-linked network cannot dissolve).
- Rubber becomes *thermoset* (cannot be re-melted or re-moulded).

Why other options are wrong:

- Option A: **Correct** — vulcanisation increases tensile strength, elasticity, and chemical/thermal resistance.
- Option B: Cross-linking *raises* resistance to heat and deformation; it does not lower the effective melting point.
- Option C: Cross-linking makes rubber *less* soluble in organic solvents by forming an insoluble network.
- Option D: Vulcanised rubber is *thermoset*; it cannot be re-melted and re-moulded like a thermoplastic.

Final Answer: Vulcanisation increases tensile strength, elasticity, and resistance to heat and chemicals. $\Rightarrow$ A

Answer: (A) Go Back to Q 15

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	D	4	A	5	B
6	C	7	D	8	A	9	B	10	C
11	D	12	A	13	B	14	C	15	A