KEAM Chemistry

Sample Paper – 2

Duration: 36 Minutes **Maximum Marks: 120**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer), modelled on the Chemistry portion of **KEAM** entrance.
- Each correct answer carries **+4 marks**. There is **a penalty of** -1 **mark** for each incorrect answer. Unattempted questions carry no penalty.
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 (NCERT / Kerala State Board) — Physical, Inorganic and Organic Chemistry.**
- Use of mobile phones, personal calculators, log tables, or any electronic gadgets is strictly prohibited inside the examination hall.

Questions

Q1. An H_2SO_4 solution is prepared by dissolving sufficient acid such that the concentration is **0.490 g per 100 mL** of solution. What is the **normality** of this solution when used as an acid–base reaction? (Molar mass of $H_2SO_4 = 98\,\text{g mol}^{-1}$)

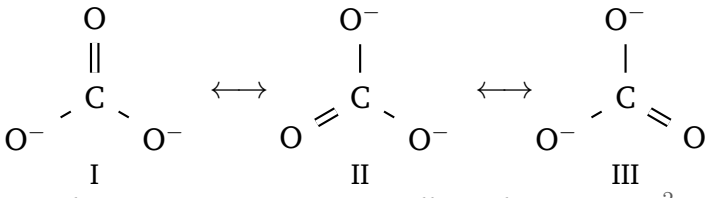
(A) 0.05 N
(B) 0.025 N
(C) 0.20 N
(D) 0.10 N

Q2. An electron is accelerated from rest through a potential difference of **100 V**. What is the approximate **de Broglie wavelength** of this electron? (Use: $\lambda = \dfrac{12.27}{\sqrt{V}}$ Å)

(A) 2.45 Å

(B) 1.23 Å
(C) 0.61 Å
(D) 4.90 Å

Q3. The **carbonate ion** CO_3^{2-} is best described by resonance. The three resonance structures are shown below. What is the **total number of resonance structures** for CO_3^{2-}?



(Each structure carries an overall $2-$ charge on CO_3^{2-})

(A) 3
(B) 2
(C) 4
(D) 1

Q4. Despite fluorine being **more electronegative** than oxygen, water (H_2O, bp = 100 °C) has a **significantly higher boiling point** than hydrogen fluoride (HF, bp = 19.5 °C). Which of the following best explains this observation?

(A) Each HF molecule forms stronger hydrogen bonds per bond than H_2O
(B) H_2O has a lower molar mass than HF, so less energy is needed to vaporise it
(C) Each H_2O molecule can act as both **donor and acceptor for 2 H-bonds**, while each HF can donate only 1 H-bond despite having 3 lone pairs
(D) HF is non-polar while H_2O is polar, reducing the intermolecular forces in HF

Q5. Which of the following molecules is **non-polar**?

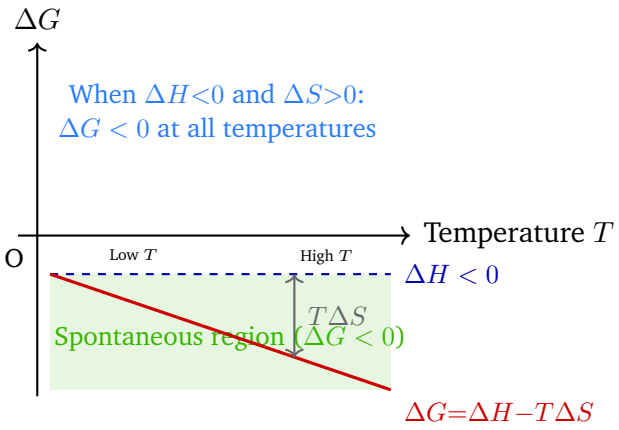
(A) SO_2 (angular/bent geometry)
(B) NH_3 (trigonal pyramidal)

(C) $CHCl_3$ (tetrahedral, asymmetric)
(D) SF_6 (octahedral, symmetric)

Q6. In the **van der Waals equation** $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, which of the following correctly interprets the constants a and b?

(A) a corrects for the finite volume of gas molecules; b corrects for intermolecular attractive forces
(B) a represents the magnitude of **intermolecular attractive forces**; b represents the **finite (excluded) volume** of gas molecules
(C) Both a and b are correction factors for intermolecular forces only
(D) a is a temperature correction factor; b is a pressure correction factor

Q7. The diagram below shows ΔG as a function of temperature T for a reaction where $\Delta H < 0$ and $\Delta S > 0$. Which combination of signs of ΔH and ΔS makes a reaction **spontaneous at all temperatures**?



(A) $\Delta H < 0$ and $\Delta S > 0$
(B) $\Delta H > 0$ and $\Delta S < 0$
(C) $\Delta H > 0$ and $\Delta S > 0$
(D) $\Delta H < 0$ and $\Delta S < 0$

Q8. The standard Gibbs energy change for a reaction at 298 K is $\Delta G^\circ = -5.74$ kJ mol^{-1}. Using the relation $\Delta G^\circ = -RT \ln K_{eq}$, what is the value of $\ln K_{eq}$?
($R = 8.314$ J K^{-1}mol^{-1})

(A) -2.3

(B) 0.23
(C) 2.3
(D) 23.0

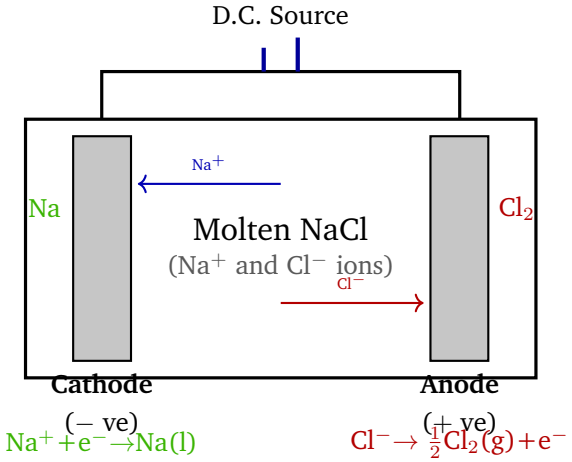
Q9. A buffer solution is prepared by mixing **equal volumes** of 0.2 M acetic acid and 0.2 M sodium acetate. If the pK_a of acetic acid is **4.74**, what is the **pH** of this buffer?
(Henderson–Hasselbalch: $\text{pH} = pK_a + \log \frac{[\text{salt}]}{[\text{acid}]}$)

(A) 4.44
(B) 4.74
(C) 5.04
(D) 3.74

Q10. The solubility product K_{sp} of AgCl at 25 °C is 1.8×10^{-10}. What is the **molar solubility** of AgCl in pure water?

(A) 1.8×10^{-10} mol L^{-1}
(B) 9.0×10^{-11} mol L^{-1}
(C) 3.6×10^{-10} mol L^{-1}
(D) 1.34×10^{-5} mol L^{-1}

Q11. The diagram below represents the **electrolytic cell** used for the electrolysis of **molten NaCl**. Which product is formed at the **cathode**?



(A) Chlorine gas (Cl_2)
(B) Sodium hydroxide (NaOH)

(C) Sodium metal (Na)
(D) Hydrogen gas (H_2)

Q12. For the concentration cell $Zn(s) \mid Zn^{2+}(0.01\ M) \parallel Zn^{2+}(1.0\ M) \mid Zn(s)$, what is the **EMF** of the cell at 298 K?
(Use: $E = \frac{0.0592}{n} \log \frac{[Zn^{2+}]_{high}}{[Zn^{2+}]_{low}}$)

(A) 0.030 V
(B) 0.059 V
(C) 0.118 V
(D) 0.148 V

Q13. The rate constant of a reaction **doubles** when the temperature is raised from 300 K to 310 K. What is the approximate **activation energy** of the reaction?
$(R = 8.314\ J\,K^{-1}mol^{-1};\ \ln 2 = 0.693)$

(A) 53.6 kJ mol^{-1}
(B) 26.8 kJ mol^{-1}
(C) 107.2 kJ mol^{-1}
(D) 13.4 kJ mol^{-1}

Q14. A first-order reaction has a rate constant $k = 6.93 \times 10^{-3}$ min^{-1}. How long will it take for **75%** of the reactant to decompose?
$(\ln 2 = 0.693)$

(A) 50 min
(B) 100 min
(C) 150 min
(D) 200 min

Q15. When **2.0 g** of a non-volatile, non-electrolyte solute is dissolved in **200 g** of benzene, the boiling point rises by **0.252 °C**. Given K_b for benzene $= 2.52$ K kg mol^{-1}, what is the **molar mass** of the solute?

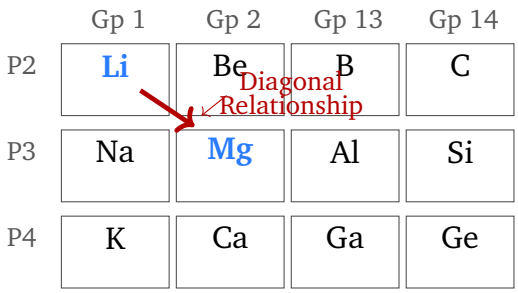
(A) 50 g mol^{-1}
(B) 200 g mol^{-1}

(C) $100\,\text{g mol}^{-1}$
(D) $25\,\text{g mol}^{-1}$

Q16. Two solutions are said to be **isotonic** when they have:

(A) The same mass concentration (g L^{-1}) of solute
(B) The same **osmotic pressure** at the same temperature
(C) The same mole fraction of solute
(D) The same elevation in boiling point

Q17. Which pair of elements shows the **diagonal relationship** in the periodic table? The partial periodic table fragment is shown below.



(A) Li and Mg
(B) Na and Ca
(C) K and Ca
(D) Li and Na

Q18. Which of the following dissolved salts is responsible for the **temporary hardness** of water and can be removed by simple **boiling** (Clark's method)?

(A) $CaSO_4$
(B) $MgSO_4$
(C) $MgCl_2$
(D) $Ca(HCO_3)_2$

Q19. In the molecular structure of **sulfuric acid** (H_2SO_4), the sulfur atom has a tetrahedral arrangement of oxygen atoms. How many S=O (sulfonyl) bonds and S−OH (hydroxyl) bonds are present?

(A) 1 S=O and 3 S−OH

(B) 3 S=O and 1 S−OH
(C) 2 S=O and 2 S−OH
(D) 4 S=O and 0 S−OH

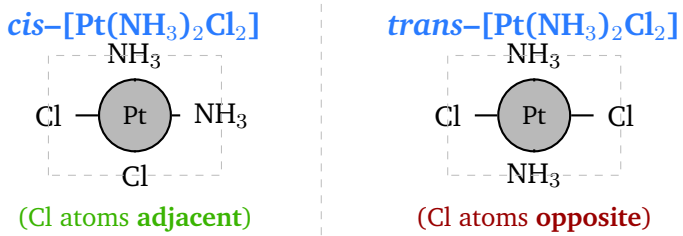
Q20. Which of the following statements **correctly** distinguishes graphite from diamond?

(A) Diamond is a good conductor of electricity; graphite is not
(B) Carbon in graphite is **sp^2 hybridised** while carbon in diamond is **sp^3 hybridised**
(C) Graphite is harder than diamond due to its three-dimensional network structure
(D) Diamond has a layered structure while graphite has a tetrahedral network

Q21. Transition metals exhibit **variable oxidation states**. The primary reason for this behaviour is:

(A) Availability of both $(n-1)d$ **and** ns **electrons** for bond formation, as these orbitals have comparable energies
(B) Large atomic radii which allow multiple bonds to form simultaneously
(C) High ionisation enthalpy which stabilises multiple oxidation states
(D) Completely filled d orbitals that can donate electrons easily

Q22. The square planar complex $[Pt(NH_3)_2Cl_2]$ exists as **cis** and **trans** geometric isomers, shown below. Which statement about the **cis isomer** (cisplatin) is correct?



(A) The two Cl atoms are on **opposite** sides in the cis isomer
(B) The NH_3 groups are trans (opposite) to each other in the cis isomer

(C) The cis isomer is optically active and rotates plane-polarised light
(D) The two Cl atoms are on the **same side** (adjacent) in the cis isomer

Q23. The stability order of carbocations is: $(CH_3)_3C^+ > (CH_3)_2CH^+ > CH_3CH_2^+ > CH_3^+$. The **primary factor** responsible for this trend is:

(A) Inductive effect: electron-donating methyl groups push electron density toward the cationic carbon
(B) Resonance stabilisation through ring formation around the carbocation
(C) **Hyperconjugation**: delocalisation of electron density from adjacent C−H σ bonds into the empty p orbital of the carbocation
(D) Electromeric effect: displacement of π electrons towards the cationic centre

Q24. In the **electrophilic aromatic substitution** of benzene with Br_2 in the presence of $FeBr_3$ as a Lewis acid catalyst, the **actual electrophile** that attacks the benzene ring is:

(A) Br_2 molecule directly
(B) Br^+ (electrophilic bromine cation generated from Br_2–$FeBr_3$ interaction)
(C) $FeBr_4^-$ anion
(D) $FeBr_3$ Lewis acid itself

Q25. When **2-bromobutane** ($CH_3CHBrCH_2CH_3$) reacts with **KOH in alcoholic** solution, the **major product** according to **Zaitsev's rule** is:

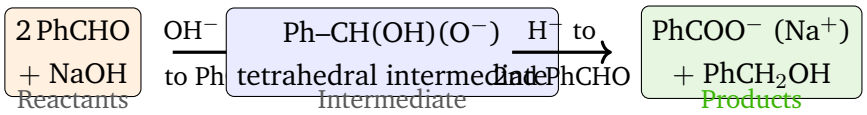
(A) But-2-ene (more substituted alkene)
(B) But-1-ene (less substituted alkene)
(C) 1-Butanol (substitution product)
(D) Butane (reduction product)

Q26. The reaction of **acetic acid** with **ethanol** in the presence of a catalytic amount of concentrated H_2SO_4 to form **ethyl acetate** is an example of:

(A) Nucleophilic addition forming a hemiacetal intermediate

(B) Elimination reaction producing an alkene
(C) **Condensation reaction** (esterification) with the loss of water under H^+ catalysis
(D) Free-radical substitution at the carbonyl carbon

Q27. Benzaldehyde (PhCHO) undergoes the **Cannizzaro reaction** when treated with concentrated NaOH. The mechanism (shown below) involves a **hydride transfer**. What are the final products?



(No α-hydrogen $\Rightarrow$ Cannizzaro; disproportionation of aldehyde)

(A) Benzene and sodium formate (HCOONa)
(B) Benzoic acid (PhCOOH) and CO_2
(C) Acetophenone ($PhCOCH_3$) and benzyl alcohol
(D) **Sodium benzoate** (PhCOONa) and **benzyl alcohol** ($PhCH_2OH$)

Q28. Among the following, which benzoic acid derivative has the **highest acidity** (largest K_a)?

(A) Benzoic acid (C_6H_5COOH)
(B) 4-Nitrobenzoic acid (p-NO_2–C_6H_4–COOH)
(C) 4-Methylbenzoic acid (p-CH_3–C_6H_4–COOH)
(D) 4-Methoxybenzoic acid (p-OCH_3–C_6H_4–COOH)

Q29. When **aniline** ($C_6H_5NH_2$) is treated with **$NaNO_2$** and **HCl** at **0–5 °C**, the primary product formed is:

(A) Benzenediazonium chloride ($C_6H_5N_2^+Cl^-$)
(B) Nitrosobenzene (C_6H_5NO)
(C) Diphenylamine ($(C_6H_5)_2NH$)
(D) Azobenzene (C_6H_5–N=N–C_6H_5)

Q30. In a **protein**, the **peptide bond** ($-CO-NH-$) is formed between the:

(A) Two amino ($-NH_2$) groups of adjacent amino acids

(B) Carboxyl and amino groups of the **same** amino acid

(C) **Carboxyl group (−COOH) of one amino acid** and the **amino group ($-NH_2$) of the next amino acid** with elimination of water

(D) Two carboxyl (−COOH) groups of adjacent amino acids

Solutions

1.

Solution

Concept — Normality and n-factor: Normality (N) = Molarity (M) × n-factor. For H_2SO_4 in acid-base reactions, n-factor = 2 because each mole of H_2SO_4 furnishes 2 moles of H^+ ions. Hence $N = 2M$.

Step 1 — Calculate Molarity:

$$M = \frac{w \text{ (g per litre)}}{\text{Molar mass}} = \frac{0.490 \times 10}{98} = \frac{4.90}{98} = 0.05 \text{ mol L}^{-1}$$

Step 2 — Calculate Normality:

$$N = n\text{-factor} \times M = 2 \times 0.05 = 0.10 \text{ N}$$

Why other options are wrong:

- Option A (0.05 N): Equals the molarity; the n-factor was ignored.
- Option B (0.025 N): This halves the molarity — incorrect arithmetic.
- Option C (0.20 N): Doubles the molarity a second time — overcounts the n-factor.

Final Answer: Normality of $H_2SO_4 = 0.10\,\text{N} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 1

2.

Solution

Concept — de Broglie Wavelength: The de Broglie wavelength of an electron accelerated through potential difference V is $\lambda = h/\sqrt{2meV}$. A convenient formula derived from this is $\lambda = 12.27/\sqrt{V}$ Å, where V is in volts.

Step 1 — Apply the formula:

$$\lambda = \frac{12.27}{\sqrt{100}} = \frac{12.27}{10} = 1.227 \text{ Å} \approx 1.23 \text{ Å}$$

Why other options are wrong:

- Option A (2.45 Å): Would correspond to $V \approx 25\,\text{V}$, not 100 V.

- Option C (0.61 Å): Would correspond to $V \approx 400\,\text{V}$.
- Option D (4.90 Å): Would correspond to $V \approx 6.3\,\text{V}$.

Final Answer: de Broglie wavelength $\approx 1.23\,\text{Å} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 2

3.

Solution

Concept — Resonance in CO_3^{2-}: Resonance occurs when a single Lewis structure cannot adequately describe the bonding in a molecule/ion. The carbonate ion has one C=O double bond which can be placed at any of the three C–O positions, giving 3 equivalent resonance structures. The actual ion is a hybrid with all three C–O bond lengths equal ($\approx 129\,\text{pm}$, between a single and double bond).

Counting resonance structures:

- Structure I: C=O at position 1, C–O^- at positions 2 and 3.
- Structure II: C=O at position 2, C–O^- at positions 1 and 3.
- Structure III: C=O at position 3, C–O^- at positions 1 and 2.

Total $= 3$ resonance structures.

Why other options are wrong:

- Option B (2): Only two structures drawn — misses the third.
- Option C (4): Overcounts; the trigonal planar CO_3^{2-} has exactly 3 equivalent positions.
- Option D (1): A single Lewis structure — incorrect; the ion requires resonance.

Final Answer: CO_3^{2-} has **3** resonance structures $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 3

4.

Solution

Concept — Hydrogen Bonding and Boiling Point: Boiling point depends on the extent of the hydrogen-bond network per mole of substance, not just the strength of a single H-bond.

Step 1 — H-bond capacity per molecule:

- **H_2O**: 2 O–H bonds (can donate 2 H-bonds) + 2 lone pairs on O (can accept 2 H-bonds) $\Rightarrow$ up to 4 H-bonds per molecule, creating an extensive 3D network.
- **HF**: 1 H–F bond (donates 1 H-bond) + 3 lone pairs on F (can accept up to 3), but only 1 H is available for donation $\Rightarrow$ chain structure, fewer H-bonds per molecule than H_2O.

Step 2 — Consequence: More H-bonds per molecule in H_2O means more energy is needed to vaporise it, hence higher boiling point despite F being more electronegative.

Why other options are wrong:

- Option A: H–F bonds are individually stronger, but fewer of them per molecule.
- Option B: HF (M = 20) is actually lighter than H_2O (M = 18) — the premise is wrong.
- Option D: Both HF and H_2O are polar; HF is not non-polar.

Final Answer: H_2O has higher bp because each molecule forms more H-bonds $\Rightarrow$ C

Answer: (C) Go Back to Q 4

5.

Solution

Concept — Molecular Polarity: A molecule is non-polar if (i) all bonds are non-polar, or (ii) the bond dipoles cancel due to symmetric geometry.

Step 1 — Analyse each option:

- SO_2 — bent geometry (lone pair on S); bond dipoles do *not* cancel $\Rightarrow$ **polar**.
- NH_3 — trigonal pyramidal (lone pair on N); net dipole present $\Rightarrow$ **polar**.
- $CHCl_3$ — tetrahedral but asymmetric (3 Cl and 1 H); net dipole $\Rightarrow$ **polar**.
- **SF_6** — *regular octahedral* geometry; all 6 S–F bond dipoles are equal and cancel in pairs $\Rightarrow$ **non-polar**.

Why other options are wrong: SO_2, NH_3, $CHCl_3$ all have asymmetric charge distributions, giving a net dipole moment.

Final Answer: SF_6 is non-polar (octahedral symmetry) $\Rightarrow$ D

Answer: (D) Go Back to Q 5

6.

Solution

Concept — van der Waals Equation Corrections: The ideal gas equation $PV = nRT$ fails at high pressures and low temperatures. van der Waals made two corrections: (1) pressure is lower than ideal because gas molecules attract each other (corrected by $+a/V^2$), and (2) available volume is less than total volume because molecules have finite size (corrected by $-b$).

Physical interpretation:

- **Constant** a: Measures the magnitude of **intermolecular attractive forces**. Larger a means stronger intermolecular attraction (e.g., a for $H_2O > a$ for He).
- **Constant** b: Measures the **excluded (finite) volume** of one mole of gas molecules. $b \approx 4 \times N_A \times V_{\text{molecule}}$.

Why other options are wrong:

- Option A: Reverses the meanings of a and b.
- Options C, D: Misidentify the physical origin of both constants.

Final Answer: a = intermolecular attraction; b = finite molecular volume $\Rightarrow$ B

Answer: (B) Go Back to Q 6

7.

Solution

Concept — Gibbs Free Energy and Spontaneity: $\Delta G = \Delta H - T\Delta S$. For a reaction to be spontaneous, $\Delta G < 0$. Spontaneity at *all temperatures* requires $\Delta G < 0$ regardless of the value of T (> 0).

Step 1 — Analyse each case:

Case	ΔH	ΔS	Spontaneous?
A	< 0	> 0	$\Delta G = (-) - (+) < 0$ **always**
B	> 0	< 0	$\Delta G = (+) + (+) > 0$ **never**
C	> 0	> 0	$\Delta G < 0$ only at *high* T
D	< 0	< 0	$\Delta G < 0$ only at *low* T

Step 2 — Conclusion: Only when $\Delta H < 0$ and $\Delta S > 0$ is $\Delta G < 0$ for *all* values of temperature.

Why other options are wrong: Options B, C, D are either never spontaneous or only spontaneous over a limited temperature range.

Final Answer: $\Delta H < 0$ and $\Delta S > 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 7

8.

Solution

Concept — Relationship between ΔG° and K_{eq}: The standard Gibbs free energy change is related to the equilibrium constant by $\Delta G^\circ = -RT \ln K_{eq}$. Rearranging: $\ln K_{eq} = -\dfrac{\Delta G^\circ}{RT}$.

Step 1 — Substitute values:

$$\ln K_{eq} = -\frac{\Delta G^\circ}{RT} = -\frac{-5740\ \text{J mol}^{-1}}{8.314\ \text{J K}^{-1}\text{mol}^{-1} \times 298\ \text{K}}$$

Step 2 — Calculate:

$$\ln K_{eq} = \frac{5740}{2477.6} = 2.317 \approx 2.3$$

Why other options are wrong:

- Option A (-2.3): Sign error — ΔG° is negative, so $\ln K > 0$.
- Option B (0.23): Off by a factor of 10 — unit conversion error (kJ vs J).
- Option D (23.0): Off by a factor of 10 — forgot to divide correctly.

Final Answer: $\ln K_{eq} = 2.3 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 8

9.

Solution

Concept — Henderson–Hasselbalch Equation: For a buffer prepared from a weak acid HA and its conjugate base A^-:

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

Step 1 — Find concentrations after mixing: Equal volumes of 0.2 M acid and 0.2 M salt are mixed. After mixing, each concentration is halved: both become 0.1 M. The *ratio* [salt]/[acid] $= 0.1/0.1 = 1$.

Step 2 — Apply formula:

$$\text{pH} = 4.74 + \log(1) = 4.74 + 0 = 4.74$$

Why other options are wrong:

- Option A (4.44): Would require [salt]/[acid] $= 0.5$ — wrong ratio.
- Option C (5.04): Would require [salt]/[acid] $= 2$ — wrong ratio.
- Option D (3.74): Uses an incorrect $\text{p}K_a$ value of 3.74.

Final Answer: pH of buffer $= 4.74 \Rightarrow$ B

Answer: (B) Go Back to Q 9

10.

Solution

Concept — Solubility Product (K_{sp}): For the dissolution $\text{AgCl}(s) \rightleftharpoons \text{Ag}^+(aq) + \text{Cl}^-(aq)$, if molar solubility $= s$, then $[\text{Ag}^+] = [\text{Cl}^-] = s$ and $K_{sp} = s^2$.

Step 1 — Solve for s:

$$s = \sqrt{K_{sp}} = \sqrt{1.8 \times 10^{-10}}$$

Step 2 — Calculate:

$$s = \sqrt{18 \times 10^{-11}} = \sqrt{18} \times 10^{-5.5} \approx 4.243 \times 3.162 \times 10^{-6}$$

More directly: $s = \sqrt{1.8} \times 10^{-5} = 1.342 \times 10^{-5}$ mol L^{-1}

Why other options are wrong:

- Option A (1.8×10^{-10}): This is K_{sp} itself, not the square root.
- Option B (9.0×10^{-11}): This is $K_{sp}/2$ — no physical meaning.
- Option C (3.6×10^{-10}): This is $2K_{sp}$ — incorrect formula used.

Final Answer: Molar solubility of AgCl $= 1.34 \times 10^{-5}$ mol L^{-1} $\Rightarrow$ D

Answer: (D) Go Back to Q 10

11.

Solution

Concept — Electrolysis of Molten NaCl: In molten NaCl, Na^+ and Cl^- ions are free to move. At the **cathode** (negative electrode), reduction occurs; at the **anode** (positive electrode), oxidation occurs.

Step 1 — Cathode reaction (reduction):

$$Na^+ + e^- \longrightarrow Na(l) \quad \text{(sodium metal is deposited)}$$

Step 2 — Anode reaction (oxidation):

$$2Cl^- \longrightarrow Cl_2(g) + 2e^- \quad \text{(chlorine gas is evolved)}$$

Why other options are wrong:

- Option A (Cl_2): Cl_2 is produced at the *anode*, not the cathode.
- Option B (NaOH): NaOH would form if water were present (electrolysis of *brine*); molten NaCl contains no water.
- Option D (H_2): H_2 is produced at the cathode in aqueous NaCl solution, not in molten NaCl.

Final Answer: Cathode product = Sodium metal (Na) $\Rightarrow$ C

Answer: (C) Go Back to Q 11

12.

Solution

Concept — Nernst Equation for Concentration Cell: In a concentration cell both electrodes are the same metal; the EMF arises purely from the difference in ion concentrations. Since $E^\circ = 0$:

$$E = \frac{0.0592}{n} \log \frac{[\text{Zn}^{2+}]_{\text{higher}}}{[\text{Zn}^{2+}]_{\text{lower}}}$$

Step 1 — Identify anode/cathode: The electrode in dilute solution (0.01 M) acts as the **anode** (oxidation); the electrode in concentrated solution (1.0 M) acts as the **cathode** (reduction).

Step 2 — Calculate EMF:

$$E = \frac{0.0592}{2} \log \frac{1.0}{0.01} = \frac{0.0592}{2} \times \log(100) = 0.0296 \times 2 = 0.0592\,\text{V} \approx 0.059\,\text{V}$$

Why other options are wrong:

- Option A (0.030 V): Uses $\log(10) = 1$ instead of $\log(100) = 2$.
- Option C (0.118 V): Forgets to divide by $n = 2$ (uses 0.0592 directly).
- Option D (0.148 V): Arithmetic error in applying the formula.

Final Answer: EMF of concentration cell $= 0.059\,\text{V} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 12

13.

Solution

Concept — Arrhenius Equation: $\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$. When the rate constant doubles, $k_2/k_1 = 2$.

Step 1 — Set up equation:

$$\ln 2 = \frac{E_a}{R}\left(\frac{1}{300} - \frac{1}{310}\right) = \frac{E_a}{R} \times \frac{310 - 300}{300 \times 310} = \frac{E_a}{R} \times \frac{10}{93000}$$

Step 2 — Solve for E_a:

$$0.693 = \frac{E_a}{8.314} \times \frac{10}{93000}$$

$$E_a = \frac{0.693 \times 8.314 \times 93000}{10} = \frac{0.693 \times 773202}{10} = 53,563\ \text{J mol}^{-1} \approx 53.6\ \text{kJ mol}^{-1}$$

Why other options are wrong:

- Option B (26.8): Half of correct value — forgot that $\ln 2 = 0.693$, not 1.
- Option C (107.2): Double the correct value — used $\Delta T = 20$ instead of 10.
- Option D (13.4): Used incorrect temperature product.

Final Answer: $E_a \approx 53.6\,\text{kJ mol}^{-1} \Rightarrow$ A

Answer: (A) Go Back to Q 13

14.

Solution

Concept — Half-life of First-order Reaction: For a first-order reaction, $t_{1/2} = 0.693/k$ and the time to decompose any fraction is $t = (1/k)\ln([A]_0/[A])$.

Step 1 — Find $t_{1/2}$:

$$t_{1/2} = \frac{0.693}{6.93 \times 10^{-3}} = \frac{0.693}{0.00693} = 100\ \text{min}$$

Step 2 — Time for 75% decomposition: 75% decomposed $\Rightarrow$ 25% remains, i.e., $[A] = [A]_0/4$.

$$t = \frac{1}{k}\ln\frac{[A]_0}{[A]_0/4} = \frac{1}{k}\ln 4 = \frac{2\ln 2}{k} = 2 \times t_{1/2} = 2 \times 100 = 200\ \text{min}$$

(Two half-lives: after 1st $t_{1/2}$, 50% remains; after 2nd $t_{1/2}$, 25% remains.)

Why other options are wrong:

- Option A (50 min): Time for only $\sim 29.3\%$ decomposition at this k.
- Option B (100 min): This is $t_{1/2}$ — time for 50% decomposition.
- Option C (150 min): Corresponds to $\sim 1.5\,t_{1/2}$, giving $\sim 64.6\%$ decomposition.

Final Answer: Time for 75% decomposition $= 200$ min $\Rightarrow$ D

Answer: (D) Go Back to Q 14

15.

Solution

Concept — Boiling Point Elevation: $\Delta T_b = K_b \times m$, where m is the molality (mol of solute per kg of solvent). Rearranging for molar mass M:

$$M = \frac{K_b \times w \times 1000}{\Delta T_b \times W}$$

where w = mass of solute (g), W = mass of solvent (g).

Step 1 — Substitute known values:

$$M = \frac{2.52\ \text{K kg mol}^{-1} \times 2.0\ \text{g} \times 1000\ \text{g kg}^{-1}}{0.252\ \text{K} \times 200\ \text{g}}$$

Step 2 — Calculate:

$$M = \frac{2.52 \times 2000}{0.252 \times 200} = \frac{5040}{50.4} = 100\ \text{g mol}^{-1}$$

Why other options are wrong:

- Option A (50): Obtained if $W = 400\,\text{g}$ (doubled the solvent mass).
- Option B (200): Obtained if $\Delta T_b = 0.126\,\text{K}$ (halved the elevation).
- Option D (25): Obtained if $w = 0.5\,\text{g}$ (quartered the solute mass).

Final Answer: Molar mass of solute $= 100\,\text{g mol}^{-1} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 15

16.

Solution

Concept — Isotonic Solutions: Osmotic pressure is $\pi = CRT$ where C is the molar concentration of solute particles, R is the gas constant, and T is the absolute temperature. Two solutions are isotonic (iso-osmotic) when they exert the **same osmotic pressure**; no net movement of solvent occurs across a semipermeable membrane separating them.

Step 1 — Evaluate each option:

- Option A (same mass concentration): Two solutions can have the same g L^{-1} but different molar masses, giving different C and different π.
- **Option B (same osmotic pressure)**: By definition, isotonic. $\pi_1 = \pi_2$.

- Option C (same mole fraction): Irrelevant criterion — does not equate to equal osmotic pressure.
- Option D (same boiling point): True if molalities are equal, but osmotic pressure depends on molarity, not molality.

Final Answer: Isotonic solutions have the **same osmotic pressure** $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 16

17.

Solution

Concept — Diagonal Relationship: In the periodic table, certain pairs of elements in Period 2 and Period 3 (diagonal to each other) show similar chemical properties because their charge-to-radius ratios (ionic potential = charge/radius) are comparable. The three classical diagonal pairs are: **Li–Mg**, Be–Al, and B–Si.

Step 1 — Common properties of Li and Mg:

- Both react with N_2 to form **nitrides**: $6Li + N_2 \rightarrow 2Li_3N$; $3Mg + N_2 \rightarrow Mg_3N_2$.
- Both form **normal oxides** (not peroxides or superoxides): Li_2O and MgO.
- Both **decompose water** slowly; hydroxides are **sparingly soluble**.
- Both carbonates are thermally less stable than those of heavier congeners.

Why other options are wrong:

- Option B (Na and Ca): Na is in Group 1, Period 3; Ca is in Group 2, Period 4 — not diagonal neighbours.
- Option C (K and Ca): Same period — no diagonal relationship.
- Option D (Li and Na): Same Group 1 — vertical relationship, not diagonal.

Final Answer: **Li** and **Mg** show the diagonal relationship $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 17

18.

Solution

Concept — Hardness of Water: Hardness of water is caused by dissolved Ca^{2+} and Mg^{2+} salts. **Temporary hardness** is due to **bicarbonates** ($Ca(HCO_3)_2$ and $Mg(HCO_3)_2$) and can be removed by boiling. **Permanent hardness** is due to chlorides and sulfates ($CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$) and cannot be removed by boiling.

Step 1 — Boiling reaction for temporary hardness:

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

The insoluble $CaCO_3$ precipitates out, removing the hardness.

Clark's process adds $Ca(OH)_2$ (lime) to convert bicarbonates to insoluble $CaCO_3$:

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

Why other options are wrong:

- Options A, B, C ($CaSO_4$, $MgSO_4$, $MgCl_2$): These cause *permanent* hardness — cannot be removed by boiling.

Final Answer: Temporary hardness is due to $Ca(HCO_3)_2 \Rightarrow$ D

Answer: (D) Go Back to Q 18

19.

Solution

Concept — Structure of H_2SO_4: Sulfuric acid has sulfur at the centre with **tetrahedral** geometry. The four oxygen atoms are arranged as: two **S=O** (sulfonyl/terminal oxo groups, non-ionisable) and two **S–OH** (hydroxyl groups, which ionise to give H^+ in solution).

Structural breakdown:

$$H_2SO_4 = (HO)_2S(=O)_2$$

- **2 S=O bonds**: The doubly-bonded oxygens (S–O bond order > 2 due to $d\pi$–$p\pi$ back-donation).
- **2 S–OH bonds**: The OH groups; each loses one proton successively when ionised.

Total bonds: $2 + 2 = 4$ S–O bonds in tetrahedral arrangement.

Why other options are wrong:

- Option A (1 S=O, 3 S–OH): Resembles H_3PO_4 structure, not H_2SO_4.
- Option B (3 S=O, 1 S–OH): Resembles SO_3 with one OH.
- Option D (4 S=O): Would make it SO_4 with no OH — not sulfuric acid.

Final Answer: H_2SO_4 has 2 S=O and 2 S–OH bonds $\Rightarrow$ C

Answer: (C) Go Back to Q 19

20.

Solution

Concept — Allotropes of Carbon: Diamond and graphite are the two main allotropes of carbon with very different structures and properties due to different hybridisations.

Step 1 — Hybridisation comparison:

- **Graphite**: Each carbon is **sp^2 hybridised**, forming 3 sigma bonds in hexagonal layers. The unhybridised p_z orbitals form delocalized π bonds across the layers $\Rightarrow$ conducts electricity.
- **Diamond**: Each carbon is **sp^3 hybridised**, forming 4 sigma bonds in a 3D tetrahedral network. No free electrons $\Rightarrow$ non-conductor, hardest natural substance.

Why other options are wrong:

- Option A: Reverses the conductivity — graphite conducts, diamond does not.
- Option C: Graphite is *softer* than diamond; diamond (sp^3 network) is hardest.
- Option D: Diamond has the 3D network; graphite has the layered structure.

Final Answer: Graphite is sp^2; diamond is sp^3 $\Rightarrow$ B

Answer: (B) Go Back to Q 20

21.

Solution

Concept — Variable Oxidation States in Transition Metals: Transition metals (d-block) have partially filled $(n-1)d$ orbitals in addition to ns electrons. Both sets of electrons can participate in bonding because their energies are comparable.

Step 1 — Key reasoning: For transition metals, the energy difference between $(n-1)d$ and ns orbitals is small. Electrons from both can be used in bond formation or lost to form ions. For example, Mn can exhibit oxidation states from $+2$ to $+7$ by progressively using $4s$ and then $3d$ electrons.

Step 2 — Contrast with main group: In s-block metals (e.g., Na, Ca), only ns electrons are valence electrons, limiting oxidation states to $+1$ or $+2$.

Why other options are wrong:

- Option B (large atomic radii): Not the primary reason; many large atoms don't show variable oxidation states.
- Option C (high IE): High IE would actually *hinder* multiple oxidation states.
- Option D (filled d orbitals): Filled d orbitals characterise Zn, Cd, Hg, which show *fewer* variable oxidation states.

Final Answer: Variable O.S. due to $(n-1)d$ and ns electrons with comparable energies $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 21

22.

Solution

Concept — Geometric Isomerism in Square Planar Complexes: In a square planar complex of the type $[MA_2B_2]$, **cis** means the two identical ligands (here Cl) are **adjacent** (90° apart), and **trans** means they are **opposite** (180° apart).

Step 1 — Identify cis-$[Pt(NH_3)_2Cl_2]$ (Cisplatin): In the cis isomer: both Cl ligands occupy **adjacent** positions; both NH_3 groups are also adjacent. This geometric arrangement is responsible for cisplatin's anticancer activity — it can crosslink adjacent guanine bases on DNA.

Step 2 — Verify option D: "Two Cl atoms on the same side (adjacent)" $\equiv$ cis configuration. This is correct.

Why other options are wrong:

- Option A: Cl atoms opposite = *trans* isomer, not cis.
- Option B: In cis isomer, NH_3 groups are adjacent (cis), not opposite.
- Option C: Square planar $[Pt(NH_3)_2Cl_2]$ lacks a chiral centre — not optically active.

Final Answer: In cis isomer (cisplatin), the two Cl atoms are on the **same side** $\Rightarrow$ D

Answer: (D) Go Back to Q 22

23.

Solution

Concept — Hyperconjugation: Hyperconjugation (Baker–Nathan effect) is the delocalisation of electrons from a C–H σ bond adjacent to a carbocation (or π system) into the empty p orbital. More C–H bonds adjacent to the carbocation centre $\Rightarrow$ greater hyperconjugation $\Rightarrow$ greater stability.

Step 1 — Count hyperconjugating C–H bonds:

- CH_3^+ (methyl): **0** α C–H bonds from adjacent carbons $\Rightarrow$ least stable.
- $CH_3CH_2^+$ (primary): 3 C–H bonds (α-CH_3) $\Rightarrow$ 3 hyperconjugating structures.
- $(CH_3)_2CH^+$ (secondary): 6 C–H bonds $\Rightarrow$ 6 structures.
- $(CH_3)_3C^+$ (tertiary): 9 C–H bonds $\Rightarrow$ 9 structures $\Rightarrow$ most stable.

Why other options are wrong:

- Option A (inductive only): Inductive effect also contributes, but hyperconjugation is the major stabilising factor for carbocations.
- Option B (resonance/ring): No ring formation involved in simple alkyl carbocations.
- Option D (electromeric effect): Applies to π bonds in reactions, not to alkyl carbocation stability order.

Final Answer: Hyperconjugation from C–H σ bonds stabilises carbocations $\Rightarrow$ C

Answer: (C) Go Back to Q 23

24.

Solution

Concept — Electrophilic Aromatic Substitution (EAS): In bromination of benzene, $FeBr_3$ acts as a Lewis acid catalyst. It activates Br_2 by accepting a lone pair from one Br atom:

$$Br_2 + FeBr_3 \longrightarrow Br^{\delta+} \cdots Br \cdots FeBr_3$$

This generates a highly electrophilic **Br^+** (or δ^+Br), which attacks the electron-rich benzene ring.

Step 1 — Mechanism:

(a) $Br_2 + FeBr_3 \rightarrow [Br\text{–}Br\text{–}FeBr_3] \rightarrow Br^+ + FeBr_4^-$
(b) Br^+ attacks benzene $\rightarrow \sigma$-complex (arenium ion / Wheland intermediate)
(c) $FeBr_4^-$ acts as base, removes $H^+ \rightarrow$ bromobenzene + HBr + $FeBr_3$ (catalyst regenerated)

Why other options are wrong:

- Option A (Br_2): Br_2 alone is insufficiently electrophilic to attack benzene.
- Option C ($FeBr_4^-$): This is the Lewis base by-product; acts as a base in step 3.
- Option D ($FeBr_3$): This is the catalyst; does not directly attack benzene.

Final Answer: The electrophile in benzene bromination is **Br^+** $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q 24

25.

Solution

Concept — E2 Elimination and Zaitsev's Rule: In bimolecular elimination (E2) with a strong base, the proton is removed from the β-carbon. **Zaitsev's rule** states that the **more substituted alkene** is the major product (greater number of alkyl substituents on the double bond $\Rightarrow$ more stable $\Rightarrow$ major product).

Step 1 — Identify possible products from 2-bromobutane:

$$CH_3\underbrace{CH}_{\beta_1}Br\underbrace{CH_2}_{\beta_2}CH_3 \xrightarrow{KOH/alc}$$

- Removal of H from C-1 $\rightarrow$ **But-1-ene** ($CH_2{=}CHCH_2CH_3$) — monosubstituted, less stable.
- Removal of H from C-3 $\rightarrow$ **But-2-ene** ($CH_3CH{=}CHCH_3$) — disubstituted, more

stable.

Step 2 — Apply Zaitsev's rule: But-2-ene is **more substituted** (2 alkyl groups on double bond) $\Rightarrow$ **major product**.

Why other options are wrong:

- Option B (But-1-ene): Less substituted alkene — minor product (Hofmann product).
- Options C, D: Substitution and reduction products, not elimination products under E2 conditions.

Final Answer: Major product is **But-2-ene** (Zaitsev product) $\Rightarrow$ A

Answer: (A) Go Back to Q 25

26.

Solution

Concept — Esterification (Fischer–Speier): When a carboxylic acid reacts with an alcohol in the presence of a mineral acid catalyst (H^+), an **ester** is formed with the elimination of water. This is a **condensation reaction** — two molecules combine with the loss of a small molecule (here, H_2O).

Step 1 — Overall reaction:

$$CH_3COOH + C_2H_5OH \xrightarrow{H^+,\ \Delta} CH_3COOC_2H_5 + H_2O$$

(Acetic acid + Ethanol $\rightarrow$ Ethyl acetate + Water)

Step 2 — Mechanism summary: Protonation of carboxyl oxygen $\rightarrow$ nucleophilic attack by alcohol $\rightarrow$ tetrahedral intermediate $\rightarrow$ proton transfer $\rightarrow$ water loss $\rightarrow$ ester product. The reaction is reversible; using excess alcohol or removing water drives equilibrium toward ester.

Why other options are wrong:

- Option A (nucleophilic addition to aldehyde): Describes hemiacetal formation, not esterification.
- Option B (elimination): No C=C double bond forms; water is lost but it's a condensation, not elimination.
- Option D (free-radical substitution): Esterification proceeds via ionic mechanism, not free radicals.

Final Answer: Esterification is a **condensation reaction** with loss of $H_2O \Rightarrow$ C

Answer: (C) Go Back to Q 26

27.

Solution

Concept — Cannizzaro Reaction: Aldehydes that lack an α-hydrogen (e.g., HCHO, PhCHO, $(CH_3)_3CCHO$) undergo **disproportionation** in concentrated NaOH. One molecule is **oxidised** to the carboxylate salt; another is **reduced** to the alcohol.

Step 1 — Overall reaction:

$$2\ \mathrm{PhCHO} + \mathrm{NaOH} \longrightarrow \underbrace{\mathrm{PhCOONa}}_{\text{Sodium benzoate (oxidised)}} + \underbrace{\mathrm{PhCH_2OH}}_{\text{Benzyl alcohol (reduced)}}$$

Step 2 — Mechanism:

(a) OH^- attacks the carbonyl carbon of PhCHO nucleophilically $\rightarrow$ tetrahedral alkoxide intermediate: Ph–CH(OH)(O^-).
(b) The hydride (H^-) from the intermediate is transferred to the carbonyl carbon of a second PhCHO molecule.
(c) Products: $PhCOO^-$ (benzoate) + $PhCH_2OH$ (benzyl alcohol).

Why other options are wrong:

- Option A: Benzene and formate would require breaking a C–C bond — not what happens.
- Option B: Benzoic acid + CO_2 would be decarboxylation — wrong reaction type.
- Option C: Acetophenone formation requires a methyl group — PhCHO has no methyl on carbonyl carbon.

Final Answer: Products are sodium benzoate and benzyl alcohol $\Rightarrow$ D

Answer: (D) Go Back to Q 27

28.

Solution

Concept — Acidity of Substituted Benzoic Acids: The acidity of a substituted benzoic acid depends on whether the substituent stabilises or destabilises the conjugate base (benzoate anion). **Electron-withdrawing groups** (EWG) stabilise the negative charge $\Rightarrow$ increase acidity. **Electron-donating groups** (EDG) destabilise the carboxylate $\Rightarrow$ decrease acidity.

Step 1 — Classify substituents:

- $-NO_2$ (para): **Strong EWG** (both $-M$ and $-I$) $\Rightarrow$ greatly stabilises conjugate base $\Rightarrow$ **highest acidity**.
- H (benzoic acid): Reference compound.
- $-CH_3$ (para): **EDG** ($+I$) $\Rightarrow$ destabilises conjugate base $\Rightarrow$ lower acidity than benzoic acid.
- $-OCH_3$ (para): **EDG** ($+M$, $-I$; net electron-donating) $\Rightarrow$ lowest acidity.

Acidity order: 4-NO_2-C_6H_4COOH > C_6H_5COOH > 4-CH_3-C_6H_4COOH > 4-OCH_3-C_6H_4COOH.

Why other options are wrong: CH_3 and OCH_3 groups are electron-donating, reducing acidity below that of benzoic acid itself.

Final Answer: 4-Nitrobenzoic acid has the highest acidity $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q 28

29.

Solution

Concept — Diazotisation Reaction: Primary aromatic amines react with $NaNO_2$/HCl at **0–5 °C** to form **diazonium salts**. The low temperature prevents the diazonium salt from decomposing. This reaction is called diazotisation.

Step 1 — Reaction:

$$\underbrace{C_6H_5NH_2}_{\text{Aniline}} + \underbrace{NaNO_2 + HCl}_{\text{in situ } HNO_2 \text{ source}} \xrightarrow{0-5\,^\circ C} \underbrace{C_6H_5N_2^+Cl^-}_{\text{Benzenediazonium chloride}} + NaCl + H_2O$$

Step 2 — Mechanism summary: HNO_2 (generated in situ from $NaNO_2$ + HCl) protonates and activates the nitrous acid $\rightarrow$ nitrosonium ion (NO^+) attacks the amine nitrogen $\rightarrow$ N-nitrosamine intermediate $\rightarrow$ tautomerism and loss of H_2O $\rightarrow$ diazonium ion.

Why other options are wrong:

- Option B (nitrosobenzene): PhNO forms only if the reaction is performed at a higher temperature or with different conditions.
- Option C (diphenylamine): Requires two aniline molecules and different conditions.
- Option D (azobenzene): Azo coupling of diazonium salt with aniline gives azobenzene — a secondary reaction.

Final Answer: Product is benzenediazonium chloride $\Rightarrow$ A

Answer: (A) Go Back to Q 29

30.

Solution

Concept — Peptide Bond and Protein Structure: Amino acids are joined by **peptide bonds** ($-$CO$-$NH$-$) to form polypeptides and proteins. A peptide bond forms between the **α-carboxyl group ($-$COOH) of one amino acid** and the **α-amino group ($-NH_2$) of the next**, with the elimination of one molecule of water.

Step 1 — Formation of peptide bond:

$$H_2N\text{–}CHR_1\text{–}COOH + H_2N\text{–}CHR_2\text{–}COOH \longrightarrow$$

$$H_2N\text{–}CHR_1\underbrace{\text{–CO–NH–}}_{\text{peptide bond}}CHR_2\text{–}COOH + H_2O$$

Step 2 — Structural levels:

- **Primary structure**: Sequence of amino acids linked by peptide bonds.
- **Secondary structure**: α-helix or β-pleated sheet stabilised by H-bonds between C=O and N–H of the peptide backbone.

Why other options are wrong:

- Option A (two amino groups): Amide bonds form between $-$COOH and $-NH_2$, not between two $-NH_2$ groups.
- Option B (same amino acid): Describes a five-membered ring formation (diketopiperazine from a single AA) — not a standard protein linkage.
- Option D (two carboxyl groups): An anhydride bond, not a peptide bond.

Final Answer: Peptide bond joins $-$**COOH** of one AA to $-$**NH_2** of next $\Rightarrow$ C

Answer: (C) Go Back to Q 30

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	B	3	A	4	C	5	D
6	B	7	A	8	C	9	B	10	D
11	C	12	B	13	A	14	D	15	C
16	B	17	A	18	D	19	C	20	B
21	A	22	D	23	C	24	B	25	A
26	C	27	D	28	B	29	A	30	C