JEE Main Chemistry

Sample Paper – 19

Duration: 60 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **30 questions** modelled on the Chemistry portion of **JEE Main** entrance examination.
- **Section A** (Q1–Q20): 20 Single Correct Multiple Choice Questions. **+4 marks** for correct answer; **−1 mark** for wrong answer; **0** for unattempted.
- **Section B** (Q21–Q30): 10 Numerical Value Questions. Attempt **any 5**. **+4 marks** for correct answer; **0 marks** for incorrect or unattempted.
- Syllabus: Class 11 & 12 NCERT Chemistry (JEE Main official syllabus).
- Personal calculators, log tables, and electronic gadgets are strictly prohibited. A simple on-screen virtual calculator is provided in the CBT interface.
- Rough sheets will be provided at the examination centre. Write your roll number on every sheet.

Section A — Multiple Choice Questions (Q1–Q20)

Q1. Chromium (Cr, $Z = 24$) has the ground-state electronic configuration $[\mathrm{Ar}]3d^5 4s^1$ instead of the expected $[\mathrm{Ar}]3d^4 4s^2$. Which of the following BEST explains this anomaly?

(A) The $4s$ orbital is always lower in energy than the $3d$ orbital for all transition metals.

(B) Pairing energy within $4s^2$ is lower than exchange energy gained in $3d^5$.

(C) Extra stability is associated with a exactly half-filled d subshell ($3d^5$), which has maximum exchange energy and spherical symmetry.

(D) The $3d^4 4s^2$ configuration violates the Pauli exclusion principle.

Q2. Among the following molecules, which one has a **zero** resultant dipole moment?

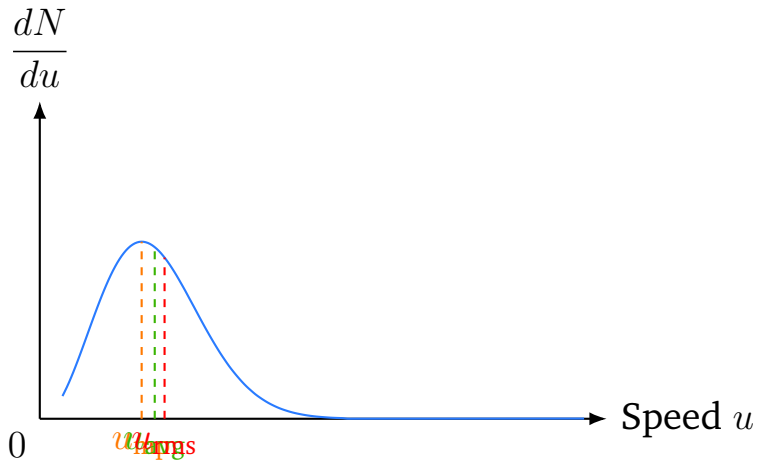
(A) SO_2 (bent, $\angle$ OSO $= 119$)

(B) H_2S (bent, $\angle$ HSH $= 92$)

(C) NF_3 (pyramidal, lone pair present on N)

(D) CO_2 (linear, symmetric)

Q3. The graph below shows the Maxwell-Boltzmann molecular speed distribution for a gas at temperature T. Three characteristic speeds are marked: u_{mp} (most probable), u_{avg} (average), and u_{rms} (root mean square). Which of the following correctly orders these three speeds?



(A) $u_{\text{rms}} > u_{\text{avg}} > u_{\text{mp}}$

(B) $u_{\text{avg}} > u_{\text{rms}} > u_{\text{mp}}$

(C) $u_{\text{mp}} > u_{\text{avg}} > u_{\text{rms}}$

(D) $u_{\text{rms}} > u_{\text{mp}} > u_{\text{avg}}$

Q4. Using the standard enthalpies of formation given below, calculate the standard enthalpy of combustion of propane (C_3H_8).

$\Delta H_f^\circ[\mathrm{CO_2(g)}] = -393.5\ \mathrm{kJ\ mol^{-1}}$
$\Delta H_f^\circ[\mathrm{H_2O(l)}] = -285.8\ \mathrm{kJ\ mol^{-1}}$
$\Delta H_f^\circ[\mathrm{C_3H_8(g)}] = -103.8\ \mathrm{kJ\ mol^{-1}}$

The combustion reaction is:

$$\mathrm{C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(l)}$$

(A) $-1564.3\ \mathrm{kJ\ mol^{-1}}$

(B) $-2220.0\ \mathrm{kJ\ mol^{-1}}$

(C) $-2323.8\ \mathrm{kJ\ mol^{-1}}$

(D) $-1874.2\ \mathrm{kJ\ mol^{-1}}$

Q5. Consider the synthesis of ammonia by the Haber process:

$$\mathrm{N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)}, \quad \Delta H = -92\ \mathrm{kJ\ mol^{-1}}$$

Which combination of conditions **both** shifts the equilibrium to give the **maximum yield of** $\mathrm{NH_3}$?

(A) Low pressure and high temperature

(B) Low pressure and low temperature

(C) High pressure and low temperature

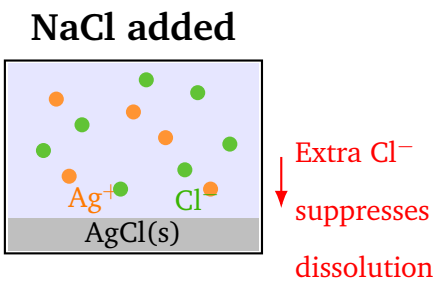
(D) High pressure and high temperature

Q6. A saturated solution of silver chloride (AgCl) is in equilibrium with its ions:

$$\mathrm{AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)}$$

When sodium chloride (NaCl) is dissolved in this solution, what happens to the solubility of AgCl, and why?

The diagram below illustrates the situation:



(A) Solubility increases because more ions are present in solution.

(B) Solubility remains unchanged because K_{sp} is a constant at fixed temperature.

(C) Solubility increases because NaCl lowers the ionic strength.

(D) Solubility decreases because the extra Cl^- ions shift the equilibrium to the left (common ion effect).

Q7. Using Kohlrausch's law of independent migration of ions, the limiting molar conductance of acetic acid (CH_3COOH) can be obtained from the expression:

$$\lambda_m^\circ(CH_3COOH) = \lambda_m^\circ(HCl) + \lambda_m^\circ(CH_3COONa) - \lambda_m^\circ(NaCl)$$

Given:

$\lambda_m^\circ(HCl) = 426.2\ \text{S cm}^2\text{mol}^{-1}$, $\lambda_m^\circ(CH_3COONa) = 91.0\ \text{S cm}^2\text{mol}^{-1}$, $\lambda_m^\circ(NaCl) =$

What is $\lambda_m^\circ(CH_3COOH)$?

(A) $390.7\ \text{S cm}^2\text{mol}^{-1}$

(B) $517.2\ \text{S cm}^2\text{mol}^{-1}$

(C) $234.7\ \text{S cm}^2\text{mol}^{-1}$

(D) $426.2\ \text{S cm}^2\text{mol}^{-1}$

Q8. For a first-order reaction, the half-life is $t_{1/2}$. After **three** successive half-lives, what fraction of the original reactant concentration remains?

(A) $\frac{1}{4}$

(B) $\frac{1}{8}$

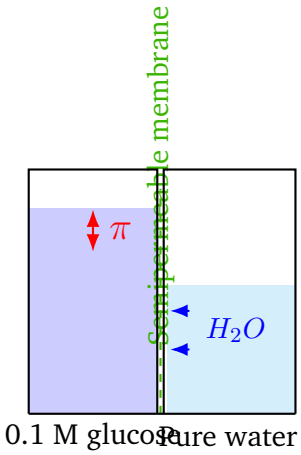
(C) $\frac{1}{16}$

(D) $\frac{1}{6}$

Q9. Calculate the osmotic pressure (π) of a 0.10 M aqueous glucose solution at 27°C.

Use the van't Hoff equation $\pi = CRT$, with $R = 0.0821$ L atm mol^{-1}K^{-1}.

The diagram below shows the osmosis setup:



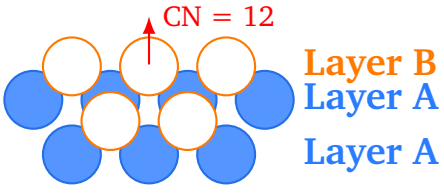
(A) 0.821 atm

(B) 1.64 atm

(C) 2.46 atm

(D) 3.28 atm

Q10. In the hexagonal close-packed (HCP) crystal structure, atoms are arranged in an ABAB... stacking sequence. The diagram below shows two layers of atoms:



What is the coordination number of each atom in HCP?

(A) 4

(B) 6

(C) 8

(D) 12

Q11. Emulsions are colloidal systems in which one liquid is dispersed as droplets in another immiscible liquid. Which of the following **correctly** describes an oil-in-water (O/W) emulsion, along with a common example?

(A) Tiny oil droplets dispersed in a continuous aqueous (water) phase; example: milk.

(B) Tiny water droplets dispersed in a continuous oil phase; example: butter.

(C) An emulsion in which both phases have equal volume; example: mayonnaise.

(D) A solid dispersed in a liquid phase; example: paint pigment.

Q12. When sodium peroxide (Na_2O_2) is added to water, it reacts vigorously. What are the **products** of this reaction?

$$2\,Na_2O_2(s) + 2\,H_2O(l) \longrightarrow ?$$

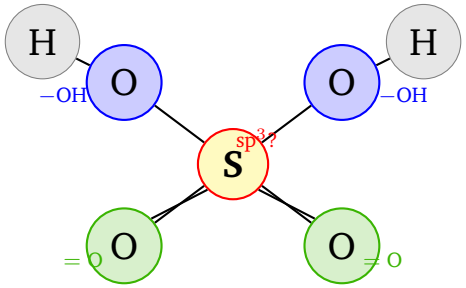
(A) NaOH and Na_2O only

(B) NaOH and H_2O_2

(C) Na_2O and O_2

(D) NaO_2 and H_2

Q13. The structure of sulphuric acid (H_2SO_4) is shown below. The central sulphur atom is bonded to two hydroxyl ($-OH$) groups and forms two double bonds with oxygen atoms.



What is the hybridisation of the sulphur atom in H_2SO_4?

(A) sp

(B) sp^2

(C) sp^3

(D) sp^3d

Q14. The spin-only magnetic moment of a transition metal ion is given by:

$$\mu = \sqrt{n(n+2)}\ \text{BM}$$

where n is the number of unpaired electrons. The electronic configuration of Fe^{3+} is $[Ar]3d^5$ (all five d electrons are unpaired in the high-spin state). What is the spin-only magnetic moment of Fe^{3+}?

(A) $\sqrt{8} \approx 2.83$ BM

(B) $\sqrt{15} \approx 3.87$ BM

(C) $\sqrt{24} \approx 4.90$ BM

(D) $\sqrt{35} \approx 5.92$ BM

Q15. The Effective Atomic Number (EAN) rule states that in stable metal carbonyls, the total electron count on the metal equals the atomic number of the next noble gas. In $Fe(CO)_5$:

- Fe (atomic number 26) has 26 electrons.
- Each CO ligand donates **2** electrons to the metal.
- $Fe(CO)_5$ has 5 CO ligands.

What is the EAN of Fe in $Fe(CO)_5$, and which noble gas configuration does it achieve?

(A) 36; krypton (Kr) configuration

(B) 18; argon (Ar) configuration

(C) 54; xenon (Xe) configuration

(D) 28; nickel (Ni) configuration

Q16. When acetaldehyde (CH_3CHO) is treated with dilute sodium hydroxide (NaOH) at low temperature, it undergoes base-catalysed **aldol condensation**. What is the **primary product** of this reaction?

(A) Crotonaldehyde ($CH_3CH = CHCHO$) — the dehydrated aldol product

(B) 3-Hydroxybutanal ($CH_3CH(OH)CH_2CHO$) — the aldol product (acetaldol)

(C) Paraldehyde — a cyclic trimer of acetaldehyde

(D) Metaldehyde — a cyclic tetramer of acetaldehyde

Q17. In electrophilic aromatic substitution (EAS), substituents already on the benzene ring direct incoming electrophiles to specific positions. Which substituent makes the benzene ring **most strongly activated** toward EAS and simultaneously directs the incoming electrophile to the **ortho and para** positions?

(A) $-NO_2$ (nitro group)

(B) $-COOH$ (carboxyl group)

(C) $-NH_2$ (amino group)

(D) $-Cl$ (chloro group)

Q18. Formaldehyde (HCHO) has no α-hydrogen atoms. When treated with concentrated aqueous NaOH, it undergoes the **Cannizzaro reaction** — a disproportionation in which one molecule is oxidised and another is reduced simultaneously. What are the **products** of this reaction?

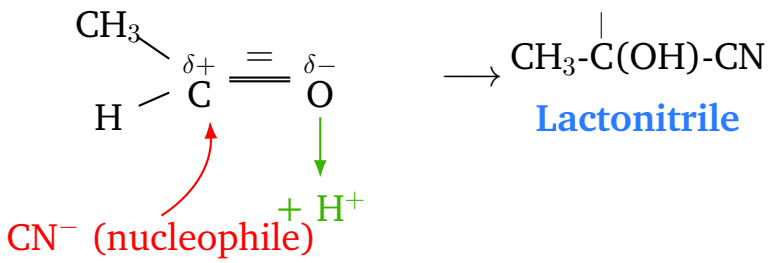
(A) HCOOH (formic acid) and HCHO (formaldehyde) — no net change

(B) CH_3OH (methanol) and CO_2 (carbon dioxide)

(C) CH_3CHO (acetaldehyde) and HCOONa (sodium formate)

(D) CH_3OH (methanol) and HCOONa (sodium formate)

Q19. When hydrogen cyanide (HCN) adds to acetaldehyde (CH_3CHO), it undergoes nucleophilic addition. The mechanism is shown below:



What is the product formed when HCN adds to CH_3CHO?

(A) $CH_3CH(OH)CN$ — lactonitrile (2-hydroxypropanenitrile)

(B) CH_3CH_2CN — propionitrile (no OH group)

(C) CH_3CN — acetonitrile (methyl cyanide)

(D) CH_3COOH — acetic acid (hydrolysis product, not direct addition)

Q20. In protein biosynthesis, two α-amino acids combine by losing a water molecule to form a **dipeptide**. What is the name of the covalent bond formed between two amino acid residues, and which functional groups are involved?

(A) Glycosidic bond, formed between two $-OH$ groups

(B) Peptide bond ($-CO-NH-$), formed by condensation between $-COOH$ of one amino acid and $-NH_2$ of another

(C) Ester bond, formed between $-COOH$ and $-OH$ groups

(D) Disulfide bond ($-S-S-$), formed by oxidation of two $-SH$ groups

Section B — Numerical Value Questions (Q21–Q30)

Instructions: Attempt any **5** of the following 10 questions. Each correct numerical answer carries **+4 marks**; incorrect or unattempted answers carry **0 marks**. Write the exact integer value.

Q21. How many sigma (σ) bonds are present in **one molecule** of ethane (C_2H_6)? (Count: one C–C bond + six C–H bonds.) *(Enter the exact numerical value as your answer.)*

Q22. What is the **oxidation state of nitrogen** (N) in nitric acid (HNO_3)?

Use the assignments: H $= +1$, each O $= -2$, and the molecule is neutral overall. *(Enter the exact numerical value as your answer.)*

Q23. How many **lone pairs of electrons** are present on the oxygen atom in a molecule of water (H_2O)?

Oxygen has 6 valence electrons; 2 are used to form bonds with each hydrogen atom. *(Enter the exact numerical value as your answer.)*

Q24. A solution of hydrochloric acid (HCl) has a concentration of 1×10^{-4} mol L^{-1}. Assuming complete dissociation, what is the **pH** of this solution?

Recall: pH $= -\log_{10}[H^+]$. *(Enter the exact numerical value as your answer.)*

Q25. Sulphur trioxide (SO_3) has a **trigonal planar** geometry and the sulphur atom is sp^2 hybridised. What is the **O–S–O bond angle** (in degrees) in SO_3? *(Enter the exact numerical value as your answer.)*

Q26. Iron (Fe, $Z = 26$) has the ground-state electronic configuration $[Ar]3d^64s^2$. When Fe forms the Fe^{2+} ion, both $4s$ electrons are removed first. How many **electrons are present in the $3d$ subshell** of Fe^{2+}? *(Enter the exact numerical value as your answer.)*

Q27. Toluene (C_7H_8) is methylbenzene. Calculate the **degree of unsaturation** (DoU), also called the Index of Hydrogen Deficiency (IHD), using the formula:

$$\text{DoU} = \frac{2C + 2 - H}{2}$$

where C is the number of carbon atoms and H is the number of hydrogen atoms. *(Enter the exact numerical value as your answer.)*

Q28. How many **geometrical (cis/trans) isomers** does pent-2-ene ($CH_3CH = CHCH_2CH_3$) have?

Recall that geometrical isomerism about a $C = C$ bond arises when each carbon of the double bond carries two **different** substituents. *(Enter the exact numerical value as your answer.)*

Q29. What is the **oxidation state of manganese** (Mn) in potassium permanganate ($KMnO_4$)?

Use: $K = +1$, each $O = -2$, and the compound is electrically neutral. *(Enter the exact numerical value as your answer.)*

Q30. Count the total number of **sigma (σ) bonds** in one molecule of propyne ($CH \equiv C - CH_3$).

Hint: A triple bond contains 1 sigma bond and 2 pi bonds. A single bond is 1 sigma bond. Count: terminal C–H (1) + C≡C sigma (1) + C–C single bond sigma (1) + three C–H in CH_3 (3). *(Enter the exact numerical value as your answer.)*

Detailed Solutions

Q1.

Solution

Concept — Atomic Structure: Anomalous Electronic Configuration of Cr: According to the Aufbau principle, filling proceeds in order of increasing energy. For chromium ($Z = 24$), the expected configuration would be $[\text{Ar}]3d^4 4s^2$. However, the actual configuration is $[\text{Ar}]3d^5 4s^1$.

Step 1 — Exchange Energy Argument: The stability of a half-filled d subshell ($3d^5$) arises because all five d orbitals contain exactly one electron each (maximum exchange interactions). The number of exchange pairs for $3d^5$ is $\binom{5}{2} = 10$, whereas for $3d^4$ it is only $\binom{4}{2} = 6$. The additional exchange energy (4 more exchange pairs) more than compensates for promoting one electron from $4s$ to $3d$.

Step 2 — Spherical Symmetry: A half-filled subshell ($l = 2$, 5 electrons, one per orbital) has spherical charge symmetry, which lowers electron-electron repulsion and provides extra stability compared to an asymmetric $3d^4$ arrangement.

Step 3 — Why the Other Options Are Wrong:

- Option A: Incorrect — $4s$ is not always lower in energy than $3d$; once $3d$ is partially filled, their energies are close and context-dependent.
- Option B: Incorrect — the relevant energy here is exchange energy of $3d$, not the pairing energy of $4s^2$.
- Option D: Incorrect — $3d^4 4s^2$ does not violate the Pauli exclusion principle; it is simply less stable.

Final Answer: Half-filled $3d^5$ gives maximum exchange energy and spherical symmetry $\Rightarrow$ Option C

Answer: (C) Go Back to Q#1

Q2.

Solution

Concept — Chemical Bonding: Dipole Moment and Molecular Symmetry: A molecule has a zero resultant dipole moment when all individual bond dipoles cancel due to the molecule's symmetry.

Step 1 — Analyse Each Molecule:

- SO_2: Bent geometry ($\angle \approx 119$). The two S=O bond dipoles do NOT cancel;

net dipole $\mu \approx 1.63$ D.

- H_2S: Bent geometry ($\angle \approx 92$). Two S$-$H dipoles do NOT cancel; net $\mu \approx 0.97$ D.
- NF_3: Trigonal pyramidal. N$-$F bond dipoles point outward AND the lone pair on N also contributes; net $\mu \approx 0.23$ D (non-zero).
- CO_2: **Linear** and **symmetric** (O = C = O). The two C=O dipoles are equal in magnitude but exactly opposite in direction, so they cancel completely. $\mu = 0$.

Step 2 — Conclusion: Only a molecule with a centre of symmetry where all bond vectors cancel will have $\mu = 0$. CO_2 satisfies this: it is linear with identical O atoms on both sides.

Why other options are wrong:

- Option A (SO_2): Bent molecule — bond dipoles do not cancel.
- Option B (H_2S): Bent molecule — bond dipoles do not cancel.
- Option C (NF_3): Pyramidal molecule — lone pair and bond dipoles reinforce to give non-zero μ.

Final Answer: CO_2 (linear, symmetric) has zero dipole moment $\Rightarrow$ Option D

Answer: (D) Go Back to Q#2

Q3.

Solution

Concept — States of Matter: Maxwell-Boltzmann Speed Distribution: For an ideal gas at temperature T, the three characteristic speeds are derived from the Maxwell-Boltzmann distribution $f(u) \propto u^2 \exp\left(-\frac{mu^2}{2k_BT}\right)$.

Step 1 — Derivation of Each Speed:

$$u_{\text{mp}} = \sqrt{\frac{2RT}{M}}, \qquad u_{\text{avg}} = \sqrt{\frac{8RT}{\pi M}}, \qquad u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

Step 2 — Numerical Comparison: Express each as a multiple of $\sqrt{RT/M}$:

$$u_{\text{mp}} = \sqrt{2} \approx 1.414, \qquad u_{\text{avg}} = \sqrt{\frac{8}{\pi}} \approx 1.596, \qquad u_{\text{rms}} = \sqrt{3} \approx 1.732$$

Therefore: $u_{\text{rms}} > u_{\text{avg}} > u_{\text{mp}}$.

Step 3 — Physical Interpretation: u_{mp} is the peak of the distribution (most molecules move at this speed). u_{avg} is the arithmetic mean. u_{rms} weights faster molecules more heavily and is related to the kinetic energy: $KE = \frac{1}{2}mu_{rms}^2$.

Why other options are wrong:

- Option B ($u_{avg} > u_{rms}$): Incorrect — $\sqrt{8/\pi} \approx 1.596 < \sqrt{3} \approx 1.732$.
- Option C ($u_{mp} > u_{avg}$): Incorrect — reverse of the correct order.
- Option D: Incorrect ordering.

Final Answer: $u_{rms} > u_{avg} > u_{mp} \Rightarrow$ Option A

Answer: (A) Go Back to Q#3

Q4.

Solution

Concept — Thermodynamics: Hess's Law and Enthalpy of Combustion: By Hess's law, the enthalpy change of a reaction equals the sum of enthalpies of formation of products minus the sum of enthalpies of formation of reactants.

Step 1 — Write the Combustion Reaction:

$$C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(l)$$

Step 2 — Apply Hess's Law:

$$\Delta H^\circ_{comb} = \sum \Delta H^\circ_f(\text{products}) - \sum \Delta H^\circ_f(\text{reactants})$$

$$= \left[3 \times (-393.5) + 4 \times (-285.8)\right] - \left[(-103.8) + 5 \times 0\right]$$

$$= \left[-1180.5 - 1143.2\right] - \left[-103.8\right]$$

$$= -2323.7 + 103.8 = -2219.9 \approx -2220.0 \text{ kJ mol}^{-1}$$

Step 3 — Note on O_2: $\Delta H^\circ_f[O_2(g)] = 0$ (standard state of oxygen is gaseous diatomic).

Why other options are wrong:

- Option A (-1564.3): Arises from only considering 3 CO_2 without the water terms.
- Option C (-2323.8): This is the magnitude of $\sum \Delta H^\circ_f(\text{products})$ without subtracting $\Delta H^\circ_f(C_3H_8)$.

- Option D (-1874.2): Incorrect arithmetic.

Final Answer: $\Delta H^\circ_{\text{comb}} = -2220.0$ kJ mol^{-1} $\Rightarrow$ Option B

Answer: (B) Go Back to Q#4

Q5.

Solution

Concept — Chemical Equilibrium: Le Chatelier's Principle Applied to Haber Process:

$$\text{N}_2(\text{g}) + 3\,\text{H}_2(\text{g}) \rightleftharpoons 2\,\text{NH}_3(\text{g}), \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

Step 1 — Effect of Pressure: The left side has $1 + 3 = 4$ moles of gas; the right side has 2 moles. Increasing pressure shifts equilibrium toward the side with **fewer moles of gas** (right), favouring NH_3 formation. Therefore, **high pressure** increases NH_3 yield.

Step 2 — Effect of Temperature: The forward reaction is **exothermic** ($\Delta H < 0$). By Le Chatelier's principle, decreasing temperature shifts equilibrium toward the exothermic (forward) direction, favouring NH_3. Therefore, **low temperature** increases equilibrium yield of NH_3.

Step 3 — Practical Note: In industry, a moderate temperature ($\sim$400–500°C) is used with an Fe catalyst because thermodynamic equilibrium yield at very low T is high but the rate becomes impractically slow. The question asks about the direction that maximises yield at equilibrium.

Why other options are wrong:

- Option A (low P, high T): Both conditions disfavour NH_3.
- Option B (low P, low T): Low pressure disfavours NH_3.
- Option D (high P, high T): High temperature reduces equilibrium yield.

Final Answer: High pressure + low temperature both favour maximum NH_3 $\Rightarrow$ Option C

Answer: (C) Go Back to Q#5

Q6.

Solution

Concept — Ionic Equilibrium: Common Ion Effect: The dissolution equilibrium of AgCl is:

$$\text{AgCl(s)} \rightleftharpoons \text{Ag}^+\text{(aq)} + \text{Cl}^-\text{(aq)}, \quad K_{sp} = [\text{Ag}^+][\text{Cl}^-]$$

Step 1 — What Happens When NaCl is Added: NaCl is a strong electrolyte; it fully dissociates to give Na^+ and Cl^-. The Cl^- ion is already a product of AgCl dissolution (the **common ion**).

Step 2 — Le Chatelier's Analysis: Adding extra Cl^- increases the ion product $Q = [\text{Ag}^+][\text{Cl}^-]$ above K_{sp}. The system responds by shifting the equilibrium to the **left** (toward the solid), causing more AgCl to precipitate until Q returns to K_{sp}.

Step 3 — Quantitative Illustration: If $K_{sp} = 1.8 \times 10^{-10}$ and $[\text{Cl}^-]$ is increased from 1.34×10^{-5} M (pure water) to 0.1 M (by NaCl), then $[\text{Ag}^+] = \frac{K_{sp}}{[\text{Cl}^-]} = \frac{1.8 \times 10^{-10}}{0.1} = 1.8 \times 10^{-9}$ M — a dramatic decrease in solubility.

Why other options are wrong:

- Option A: Incorrect — solubility decreases, not increases.
- Option B: Incorrect — K_{sp} is constant at fixed T, but the *solubility* (moles dissolving) does change via the common ion effect.
- Option C: Incorrect — ionic strength effects (activity coefficients) are a secondary, weaker effect; the dominant effect is the common ion suppression.

Final Answer: Common ion effect (Cl^- from NaCl) decreases AgCl solubility $\Rightarrow$ Option D

Answer: (D) Go Back to Q#6

Q7.

Solution

Concept — Electrochemistry: Kohlrausch's Law of Independent Migration of Ions: At infinite dilution, each ion contributes independently to the total molar conductance. For weak electrolytes (like CH_3COOH), λ_m° cannot be measured directly, but can be obtained by combining values for strong electrolytes.

Step 1 — The Kohlrausch Combination:

$$\lambda_m^\circ(\text{CH}_3\text{COOH}) = \lambda_{m,\text{H}^+}^\circ + \lambda_{m,\text{CH}_3\text{COO}^-}^\circ$$

From the given data:

$$\lambda_m^\circ(\text{HCl}) = \lambda_{m,\text{H}^+}^\circ + \lambda_{m,\text{Cl}^-}^\circ = 426.2$$
$$\lambda_m^\circ(\text{CH}_3\text{COONa}) = \lambda_{m,\text{CH}_3\text{COO}^-}^\circ + \lambda_{m,\text{Na}^+}^\circ = 91.0$$
$$\lambda_m^\circ(\text{NaCl}) = \lambda_{m,\text{Na}^+}^\circ + \lambda_{m,\text{Cl}^-}^\circ = 126.5$$

Step 2 — Calculate:

$$\lambda_m^\circ(\text{CH}_3\text{COOH}) = 426.2 + 91.0 - 126.5 = 390.7 \text{ S cm}^2\text{mol}^{-1}$$

Step 3 — Verification: This matches the known experimental value of $\lambda_m^\circ(\text{CH}_3\text{COOH}) \approx 390.7$ S cm^{2}mol^{-1}, confirming the calculation is correct.

Why other options are wrong:

- Option B (517.2): Error of adding NaCl instead of subtracting.
- Option C (234.7): Uses wrong arithmetic.
- Option D (426.2): Simply the value for HCl, not acetic acid.

Final Answer: $\lambda_m^\circ(\text{CH}_3\text{COOH}) = 390.7$ S cm^{2}mol^{-1} $\Rightarrow$ Option A

Answer: (A) Go Back to Q#7

Q8.

Solution

Concept — Chemical Kinetics: First-Order Reaction and Half-Life: For a first-order reaction, the integrated rate law is:

$$[A]_t = [A]_0 \cdot \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

Step 1 — After One Half-Life:

$$[A]_{t_{1/2}} = \frac{[A]_0}{2}$$

Step 2 — After Two Half-Lives:

$$[A]_{2t_{1/2}} = \frac{[A]_0}{4}$$

Step 3 — After Three Half-Lives:

$$[A]_{3t_{1/2}} = \frac{[A]_0}{8}$$

Therefore, the fraction remaining is $\frac{1}{8}$.

General Formula: After n half-lives, fraction remaining $= \left(\frac{1}{2}\right)^n$. For $n = 3$: $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$.

Why other options are wrong:

- Option A ($\frac{1}{4}$): Corresponds to $n = 2$ half-lives.
- Option C ($\frac{1}{16}$): Corresponds to $n = 4$ half-lives.
- Option D ($\frac{1}{6}$): No physical meaning in first-order kinetics.

Final Answer: $\frac{1}{8}$ of the reactant remains after 3 half-lives $\Rightarrow$ Option B

Answer: (B) Go Back to Q#8

Q9.

Solution

Concept — Solutions: Osmotic Pressure via van't Hoff Equation: The osmotic pressure is given by:

$$\pi = CRT$$

where C is the molar concentration (mol L^{-1}), R is the gas constant, and T is the absolute temperature.

Step 1 — Identify Given Values:

$$C = 0.10 \text{ mol L}^{-1}, \quad R = 0.0821 \text{ L atm mol}^{-1}\text{K}^{-1}, \quad T = 27 + 273 = 300 \text{ K}$$

Step 2 — Note on van't Hoff Factor: Glucose ($C_6H_{12}O_6$) is a non-electrolyte; it does not dissociate in water. Therefore, van't Hoff factor $i = 1$, and $\pi = iCRT = 1 \times CRT$.

Step 3 — Calculate Osmotic Pressure:

$$\pi = 0.10 \times 0.0821 \times 300 = 2.463 \approx 2.46 \text{ atm}$$

Why other options are wrong:

- Option A (0.821): Uses $C = 0.10$ and $T = 100$ K (wrong temperature).
- Option B (1.64): Uses $T = 200$ K (wrong).
- Option D (3.28): Uses $T = 400$ K (wrong).

Final Answer: $\pi = 2.46$ atm $\Rightarrow$ Option C

Answer: (C) Go Back to Q#9

Q10.

Solution

Concept — Solid State: Hexagonal Close Packing (HCP) Coordination Number: In HCP, atoms adopt an ABAB. . . stacking sequence. Each atom is surrounded by the maximum number of nearest neighbours.

Step 1 — Count Nearest Neighbours in HCP: For any atom in layer B (middle layer of a three-layer sequence ABA):

- **6 neighbours in the same layer** (hexagonal arrangement)
- **3 neighbours in the layer above** (nestled in hollows)
- **3 neighbours in the layer below** (nestled in hollows)

Total: $6 + 3 + 3 = 12$

Step 2 — Packing Efficiency: HCP (like FCC/CCP) achieves the maximum packing efficiency of approximately 74%, and both structures have coordination number 12. HCP uses ABAB stacking; CCP (FCC) uses ABCABC stacking.

Step 3 — Distinguish from Other Structures:

- Simple cubic: CN = 6
- Body-centred cubic (BCC): CN = 8
- Face-centred cubic (FCC/CCP): CN = 12
- Hexagonal close-packed (HCP): CN = **12**

Why other options are wrong:

- Option A (4): Coordination number of diamond cubic structure.
- Option B (6): Coordination number of simple cubic.
- Option C (8): Coordination number of BCC.

Final Answer: Coordination number in HCP $= 12 \Rightarrow$ Option D

Answer: (D) Go Back to Q#10

Q11.

Solution

Concept — Surface Chemistry: Classification of Emulsions: An emulsion is a colloidal dispersion of two immiscible liquids stabilised by an emulsifier. There are two main types:

- **O/W (oil-in-water) emulsion**: Oil is the dispersed phase; water is the continuous phase.
- **W/O (water-in-oil) emulsion**: Water is the dispersed phase; oil is the continuous phase.

Step 1 — Identify O/W Emulsions: In an O/W emulsion, tiny oil droplets are dispersed throughout a continuous aqueous medium. The emulsifier (e.g., casein in milk) has a hydrophilic head that interacts with water and a hydrophobic tail that interacts with oil.

Step 2 — Common Examples:

- **O/W emulsions**: Milk (fat droplets in water), mayonnaise (partially), vanishing cream, salad dressings.
- **W/O emulsions**: Butter (water droplets in fat), cold cream, margarine.

Step 3 — Evaluate Options: Option A correctly states that O/W means oil droplets in water, and milk is a classic example.

Why other options are wrong:

- Option B describes a W/O emulsion (butter is W/O).
- Option C (equal volumes) is not the definition of emulsion type.
- Option D describes a suspension, not an emulsion.

Final Answer: O/W = oil droplets dispersed in water; example: milk $\Rightarrow$ Option A

Answer: (A) Go Back to Q#11

Q12.

Solution

Concept — s-Block Elements: Reaction of Sodium Peroxide with Water: Sodium peroxide (Na_2O_2) is an ionic compound containing the peroxide ion (O_2^{2-}). When it reacts with water, the peroxide ion hydrolyses.

Step 1 — Write the Balanced Equation:

$$2\,Na_2O_2(s) + 2\,H_2O(l) \longrightarrow 4\,NaOH(aq) + O_2(g)$$

Wait — more precisely, the direct hydrolysis gives hydrogen peroxide first:

$$Na_2O_2 + 2\,H_2O \longrightarrow 2\,NaOH + H_2O_2$$

Hydrogen peroxide may then decompose ($2H_2O_2 \rightarrow 2H_2O + O_2$), but the **primary products** of the reaction of Na_2O_2 with water are **NaOH and H_2O_2**.

Step 2 — Oxidation State Analysis: In Na_2O_2, oxygen is in the -1 oxidation state. In H_2O_2, oxygen is also -1. In NaOH, oxygen is -2. This is a disproportionation: O^{-1} goes to both O^{-2} (in OH^-) and O^{-1} (in H_2O_2, no change for the H_2O_2 pathway).

Step 3 — The Primary Products: The question asks for the primary products of Na_2O_2 + H_2O: these are **NaOH** and **H_2O_2**.

Why other options are wrong:

- Option A: Na_2O is the oxide, not the peroxide product.
- Option C: Na_2O not formed; O_2 is only a secondary product from H_2O_2 decomposition.
- Option D: NaO_2 (sodium superoxide) and H_2 are not formed in this reaction.

Final Answer: NaOH and H_2O_2 are the primary products $\Rightarrow$ Option B

Answer: (B) Go Back to Q#12

Q13.

Solution

Concept — p-Block Elements: Hybridisation of S in Sulphuric Acid: Hybridisation is determined by the total number of regions of electron density (bonding pairs + lone pairs) around the central atom.

Step 1 — Count Electron Domains Around S in H_2SO_4: The structure of H_2SO_4 shows sulphur bonded to:

- 2 oxygen atoms via S−OH (single bonds)
- 2 oxygen atoms via S=O (double bonds, or formally S^+-O^- in Lewis structures)

Total electron domains around S: $2 + 2 = 4$ bonding regions (no lone pairs on S).

Step 2 — Assign Hybridisation: With 4 electron domains (and 0 lone pairs), the geometry is **tetrahedral** and S is **sp^3** hybridised. The four hybrid orbitals point toward the four oxygen atoms.

Step 3 — Note on the Double Bonds: In more advanced treatments, the S=O double bonds involve d-orbital participation ($p\pi$-$d\pi$ back-bonding), but the VSEPR/hybridisation model for JEE Main treats H_2SO_4 as sp^3 at sulphur.

Why other options are wrong:

- Option A (sp): Requires only 2 electron domains; not applicable here.
- Option B (sp^2): Requires 3 electron domains; e.g., SO_3.
- Option D (sp^3d): Would require 5 electron domains (e.g., PCl_5); S in H_2SO_4 has only 4.

Final Answer: S in H_2SO_4 is sp^3 hybridised (tetrahedral geometry) $\Rightarrow$ Option C

Answer: (C) Go Back to Q#13

Q14.

Solution

Concept — d-Block Elements: Magnetic Moment of Transition Metal Ions: The spin-only magnetic moment is:

$$\mu = \sqrt{n(n+2)}\ \text{BM}$$

where n is the number of unpaired electrons.

Step 1 — Electronic Configuration of Fe^{3+}:

$$\text{Fe } (Z = 26): \ [\text{Ar}]3d^6 4s^2$$

Fe^{3+} loses 3 electrons (first the two $4s$ electrons, then one $3d$):

$$Fe^{3+}: \ [\text{Ar}]3d^5$$

In the high-spin state, 5 electrons occupy 5 different d orbitals (Hund's rule): all 5 are unpaired. So $n = 5$.

Step 2 — Calculate μ:

$$\mu = \sqrt{5(5+2)} = \sqrt{5 \times 7} = \sqrt{35} \approx 5.92 \text{ BM}$$

Step 3 — Physical Significance: Fe^{3+} with 5 unpaired electrons is paramagnetic and exhibits the highest spin-only magnetic moment among common first-row transition metal ions in the +3 state.

Why other options are wrong:

- Option A ($\sqrt{8} \approx 2.83$): Corresponds to $n = 2$ (e.g., Cu^{2+}, Ni^{2+}... actually $n = 2$ is Co^{2+} in some states — specifically Cu^{2+} has $n = 1$, $\mu = 1.73$; $n = 2$ gives Ni^{2+}).
- Option B ($\sqrt{15} \approx 3.87$): Corresponds to $n = 3$ (e.g., Co^{2+} in some complexes).
- Option C ($\sqrt{24} \approx 4.90$): Corresponds to $n = 4$ (e.g., Fe^{2+}, Cr^{2+}).

Final Answer: $\mu(Fe^{3+}) = \sqrt{35} \approx 5.92$ BM $\Rightarrow$ Option D

Answer: (D) Go Back to Q#14

Q15.

Solution

Concept — Coordination Chemistry: Effective Atomic Number (EAN) Rule: The EAN rule (proposed by Sidgwick) states that in stable metal carbonyls, the metal achieves the electronic configuration of the nearest noble gas.

Step 1 — Electron Count for $Fe(CO)_5$:

- Fe (neutral metal, $Z = 26$): **26 electrons**
- 5 CO ligands, each donating 2 electrons: $5 \times 2 =$ **10 electrons**

$$\text{EAN} = 26 + 10 = 36$$

Step 2 — Noble Gas Identification: Atomic number 36 is **krypton (Kr)**, a noble gas. Thus $Fe(CO)_5$ achieves the krypton configuration.

Step 3 — 18-Electron Rule Connection: The EAN rule is equivalent to the 18-electron rule: Fe has 8 valence electrons (Group 8 metal); 5 CO contribute 10 electrons; total = 18 valence electrons. This fills all bonding/non-bonding MOs.

Why other options are wrong:

- Option B (18, Ar): Incorrect — 18 electrons is the *valence electron count*, but EAN includes core electrons. Also, Ar has $Z = 18$, not 36.
- Option C (54, Xe): Would require $54 - 26 = 28$ electrons donated by ligands, which would need 14 CO — not the case here.
- Option D (28, Ni): $Z = 28$ is Ni, not a noble gas.

Final Answer: EAN of Fe in $Fe(CO)_5$ = 36 (krypton configuration) $\Rightarrow$ Option A

Answer: (A) Go Back to Q#15

Q16.

Solution

Concept — Organic Chemistry: Aldol Condensation: The aldol condensation involves a base abstracting an α-hydrogen, generating an enolate ion, which then attacks the carbonyl carbon of another molecule.

Step 1 — Mechanism Overview:

$$CH_3CHO \xrightarrow{OH^-} \underbrace{{}^-CH_2CHO}_{\text{enolate}} \xrightarrow{+CH_3CHO} CH_3CH(OH)CH_2CHO$$

Step 2 — Primary Product (Aldol Addition): At low temperature, the reaction stops at the **aldol addition product**: **3-hydroxybutanal** (acetaldol):

$$CH_3CH(OH)CH_2CHO$$

This molecule has both an alcohol ($-OH$) and an aldehyde ($-CHO$) functional group — hence the name "aldol."

Step 3 — Dehydration Product (only at high T): On heating, the aldol undergoes dehydration ($-H_2O$) to give **crotonaldehyde** ($CH_3CH = CHCHO$). But at low

temperature, the aldol product is the primary product.

Why other options are wrong:

- Option A (crotonaldehyde): This is the dehydrated product, formed only on heating.
- Option C (paraldehyde): A cyclic trimer formed under acid catalysis, not base catalysis.
- Option D (metaldehyde): A cyclic tetramer, again formed under specific acid conditions.

Final Answer: 3-Hydroxybutanal (acetaldol) is the primary aldol condensation product $\Rightarrow$ Option B

Answer: (B) Go Back to Q#16

Q17.

Solution

Concept — Organic Chemistry: EAS Directing Effects of Ring Substituents: Substituents on a benzene ring are classified as:

- **Activating, ortho/para directors**: Electron-donating groups (EDG) increase electron density on the ring, especially at ortho and para positions.
- **Deactivating, meta directors**: Electron-withdrawing groups (EWG) decrease electron density.

Step 1 — Evaluate Each Group:

- $-NO_2$: Strong EWG (via induction and resonance); **deactivating, meta director**.
- $-COOH$: EWG (resonance + induction); **deactivating, meta director**.
- $-NH_2$: Strong EDG (lone pair donates into ring by resonance, $+M$ effect); **strongly activating, ortho/para director**.
- $-Cl$: Weak deactivating group (induction $-I$, but weak $+M$ ortho/para director); net deactivating but ortho/para directing (due to lone pair donation despite inductive withdrawal).

Step 2 — Identify the Strongest Activator: $-NH_2$ donates its lone pair directly into the π system of benzene (resonance donation), creating high electron density especially at ortho and para positions. This makes the ring highly reactive toward electrophiles and strongly directs them to ortho/para.

Step 3 — Reactivity Order for Activating Groups: $-OH \approx -NH_2$ (strongest) $>$ $-OR > -R > -X$ (halogen, weakly deactivating but o/p director).

Why other options are wrong:

- Option A ($-NO_2$): Strong deactivator, meta director.
- Option B ($-COOH$): Deactivator, meta director.
- Option D ($-Cl$): Net deactivating despite being ortho/para director.

Final Answer: $-NH_2$ is the strongest activator and an ortho/para director $\Rightarrow$ Option C

Answer: (C) Go Back to Q#17

Q18.

Solution

Concept — Organic Chemistry: Cannizzaro Reaction: The Cannizzaro reaction is a **disproportionation** of an aldehyde with no α-hydrogen atoms in the presence of concentrated NaOH. One molecule is oxidised to a carboxylate salt, and another is reduced to a primary alcohol.

Step 1 — Why Formaldehyde Undergoes Cannizzaro: HCHO has **no** α**-H** (the only H in HCHO is directly on the carbonyl carbon, not on an adjacent carbon), so it cannot undergo aldol condensation. Instead, it undergoes disproportionation.

Step 2 — The Reaction:

$$2\,HCHO \xrightarrow{\text{conc. NaOH}} CH_3OH + HCOONa$$

- One HCHO is **reduced** (gains electrons): HCHO $\rightarrow$ CH_3OH (methanol). The C goes from oxidation state 0 to -2.
- One HCHO is **oxidised** (loses electrons): HCHO $\rightarrow$ $HCOO^-$ (formate ion). The C goes from 0 to $+2$.

Step 3 — Mechanism (Hydride Transfer): NaOH adds OH^- to the carbonyl carbon of one HCHO to form a tetrahedral intermediate, which then transfers a hydride (H^-) to the carbonyl carbon of a second HCHO, yielding methanol and sodium formate.

Why other options are wrong:

- Option A: No reaction (wrong); Cannizzaro is a reaction, not "no change."

- Option B ($CH_3OH + CO_2$): CO_2 is not formed in the Cannizzaro reaction (formate, not carbonate, is the product).
- Option C: CH_3CHO (acetaldehyde) has no connection to HCHO disproportionation.

Final Answer: CH_3OH (methanol) and HCOONa (sodium formate) $\Rightarrow$ Option D

Answer: (D) Go Back to Q#18

Q19.

Solution

Concept — Organic Chemistry: Nucleophilic Addition (Cyanohydrin Formation): The carbonyl group (C=O) is polarised: $C^{\delta+}$ and $O^{\delta-}$. Nucleophiles attack the electrophilic carbon.

Step 1 — Role of HCN: HCN acts as a source of the nucleophile CN^- (cyanide ion). In base, CN^- is generated and attacks the carbonyl carbon.

Step 2 — Mechanism:

(a) CN^- attacks the $\delta+$ carbon of CH_3CHO nucleophilically.
(b) The C=O π bond breaks; electrons move to oxygen, forming an alkoxide intermediate.
(c) The alkoxide is protonated (by HCN or solvent) to give the hydroxyl group ($-OH$).

Overall:

$$CH_3CHO + HCN \longrightarrow CH_3CH(OH)CN$$

Step 3 — Product Identification: The product is **lactonitrile** (systematic name: 2-hydroxypropanenitrile). It has:

- A hydroxyl group ($-OH$) at C-2.
- A cyano group ($-CN$) at C-2.
- A chiral centre at C-2 (racemic mixture formed).

Why other options are wrong:

- Option B (CH_3CH_2CN): Would require reduction of C=O and addition of C without OH; wrong product.
- Option C (CH_3CN): Acetonitrile; results from the nitrile of acetic acid, not from HCN addition to acetaldehyde.

- Option D (CH_3COOH): Acetic acid results from hydrolysis/oxidation of acetaldehyde, not HCN addition.

Final Answer: $CH_3CH(OH)CN$ (lactonitrile) $\Rightarrow$ Option A

Answer: (A) Go Back to Q#19

Q20.

Solution

Concept — Biomolecules: Peptide Bond Formation: Proteins are polypeptide chains in which amino acid residues are linked by peptide bonds.

Step 1 — Condensation Reaction: When two α-amino acids combine, the $-COOH$ group of one reacts with the $-NH_2$ group of another, releasing one molecule of water:

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

Step 2 — Nature of the Peptide Bond: The peptide bond ($-CO-NH-$) has partial double-bond character due to resonance between the C=O and the lone pair on N:

$$-\overset{\overset{O}{\|}}{C}-NH- \longleftrightarrow -\overset{\overset{O^-}{|}}{C}=\overset{+}{N}H-$$

This makes the peptide bond planar and restricts rotation.

Step 3 — Significance: All proteins are assembled by this reaction (in ribosomes, driven by GTP energy). The peptide backbone ($-CO-NH-$) repeats in every protein.

Why other options are wrong:

- Option A (glycosidic bond): Formed between two sugar units ($-OH$ to $-OH$ with loss of water); not relevant to amino acids.
- Option C (ester bond): Formed between $-COOH$ and $-OH$; occurs in lipids/polyesters, not between amino acid pairs.
- Option D (disulfide bond): Formed by oxidation of two $-SH$ (thiol) groups in cysteine residues; stabilises tertiary structure but is not the primary linking bond.

Final Answer: Peptide bond ($-CO-NH-$) formed by condensation of $-COOH$

and $-NH_2 \Rightarrow$ Option B

Answer: (B) Go Back to Q#20

Q21.

Solution

Concept — Chemical Bonding: Sigma Bonds in Ethane: A sigma (σ) bond is formed by the head-on overlap of orbitals. Every single bond between atoms is a σ bond.

Step 1 — Structure of Ethane (C_2H_6): Ethane has the structural formula: H_3C-CH_3

- 1 C–C single bond: **1 sigma bond**
- 3 C–H bonds on the first carbon: **3 sigma bonds**
- 3 C–H bonds on the second carbon: **3 sigma bonds**

Step 2 — Total Count:

$$\text{Total } \sigma \text{ bonds} = 1 + 3 + 3 = 7$$

Step 3 — Verification Using Formula: For an alkane C_nH_{2n+2}, total bonds $= (n-1)$ C–C bonds $+(2n+2)$ C–H bonds. For $n = 2$: $(2-1)+(2\times2+2) = 1+6 = 7$.

Final Answer: Total sigma bonds in ethane $= \boxed{7}$

Answer: (7) Go Back to Q#21

Q22.

Solution

Concept — Redox Chemistry: Oxidation State of N in HNO_3: The oxidation state of an element is calculated by assigning standard values to other atoms and using the constraint that the algebraic sum equals the overall charge of the species.

Step 1 — Assign Known Oxidation States: In HNO_3 (neutral molecule):

$$\underbrace{+1}_{\text{H}} + \underbrace{x}_{\text{N}} + 3\underbrace{(-2)}_{\text{O}} = 0$$

Step 2 — Solve for x:

$$1 + x - 6 = 0 \implies x = +5$$

Step 3 — Contextual Note: Nitrogen can exist in oxidation states from -3 (in NH_3) to $+5$ (in HNO_3, N_2O_5). The $+5$ state represents the maximum oxidation state for nitrogen (group 15, 5 valence electrons). This is why HNO_3 is a powerful oxidising agent.

Final Answer: Oxidation state of N in $HNO_3 = \boxed{5}$

Answer: (5) Go Back to Q#22

Q23.

Solution

Concept — Chemical Bonding: Lone Pairs on Oxygen in Water: Water (H_2O) has an oxygen atom with 6 valence electrons.

Step 1 — Lewis Structure of Water:

- O has 6 valence electrons.
- Each O−H bond uses 2 electrons (one from O, one from H): $2 \times 1 = 2$ electrons used in bonding.
- Remaining electrons on O: $6 - 2 = 4$ electrons.
- These 4 electrons form $\frac{4}{2} = 2$ lone pairs.

Step 2 — VSEPR and Geometry: The 2 bonding pairs and 2 lone pairs give O a total of 4 electron domains. This leads to:

- Electron geometry: tetrahedral
- Molecular geometry: bent (V-shaped)
- Bond angle: ≈ 104.5 (reduced from 109.5 due to lone pair repulsion)

Step 3 — Importance of Lone Pairs: The 2 lone pairs on O make water a good nucleophile and hydrogen bond acceptor (each lone pair can accept one H-bond), explaining water's high boiling point relative to its molar mass.

Final Answer: 2 lone pairs on oxygen in $H_2O = \boxed{2}$

Answer: (2) Go Back to Q#23

Q24.

Solution

Concept — Ionic Equilibrium: pH of Strong Acid Solution: HCl is a strong acid that undergoes complete dissociation in dilute aqueous solution:

$$\text{HCl} \longrightarrow \text{H}^+ + \text{Cl}^-$$

Step 1 — Calculate [H^+]: For 1×10^{-4} M HCl, complete dissociation gives:

$$[\text{H}^+] = 1 \times 10^{-4} \text{ mol L}^{-1}$$

Step 2 — Apply pH Formula:

$$\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(1 \times 10^{-4}) = -(-4) = 4$$

Step 3 — Verification: Since $10^{-4} < 10^{-7}$ (water's own $[\text{H}^+]$) is not the case here — $10^{-4} > 10^{-7}$ — the acid contribution dominates and no correction for autoionisation of water is needed. pH $= 4$ is valid (pH < 7, confirming acidic solution).

Final Answer: pH of 1×10^{-4} M HCl $= \boxed{4}$

Answer: (4) Go Back to Q#24

Q25.

Solution

Concept — Chemical Bonding/Molecular Geometry: Bond Angle in SO_3: Sulphur trioxide (SO_3) is formed when SO_2 is oxidised by O_2 (in the contact process for H_2SO_4 manufacture).

Step 1 — VSEPR Analysis of SO_3: Central atom: S. Bonds: 3 S=O double bonds (or delocalized, but treated as 3 electron domains). Lone pairs on S: **0**. Total electron domains around S $= 3$. Electron geometry $=$ **trigonal planar**. Molecular geometry $=$ **trigonal planar** (no lone pairs to distort).

Step 2 — Bond Angle: In a trigonal planar arrangement with 3 identical bond pairs and no lone pairs, all O$-$S$-$O angles are equal:

$$\angle\text{O-S-O} = \frac{360}{3} = 120$$

Step 3 — Hybridisation: S in SO_3 is **sp**^{2} hybridised. The 3 sp^2 hybrid orbitals form sigma bonds with 3 oxygen atoms; the remaining unhybridised p orbital on S participates in π bonding (delocalised over the ring).

Final Answer: O$-$S$-$O bond angle in $SO_3 = \boxed{120}$ degrees

Answer: (120) Go Back to Q#25

Q26.

Solution

Concept — d-Block Elements: Electronic Configuration of Fe^{2+}: When a transition metal forms a cation, electrons are removed from the outermost shell first (i.e., $4s$ before $3d$).

Step 1 — Configuration of Neutral Fe:

$$\text{Fe } (Z = 26): \ [\text{Ar}]3d^6 4s^2$$

Step 2 — Remove Electrons to Form Fe^{2+}: Fe^{2+} has lost 2 electrons. Since $4s$ electrons are removed first from transition metals when forming ions:

$$\text{Fe}^{2+}: \ [\text{Ar}]3d^6$$

The $4s^2$ electrons are both removed.

Step 3 — Count 3d Electrons: The configuration $3d^6$ means there are **6 electrons** in the $3d$ subshell of Fe^{2+}. (Compare with Fe^{3+}: $3d^5$, and neutral Fe: $3d^6 4s^2$.)

Orbital Diagram for Fe^{2+} ($3d^6$):

$$\underbrace{\uparrow\downarrow}_{d_{xy}} \ \underbrace{\uparrow}_{d_{xz}} \ \underbrace{\uparrow}_{d_{yz}} \ \underbrace{\uparrow}_{d_{x^2-y^2}} \ \underbrace{\uparrow}_{d_{z^2}}$$

One pair + four unpaired = 6 electrons total, 4 unpaired.

Final Answer: Fe^{2+} has **6** electrons in the $3d$ subshell $= \boxed{6}$

Answer: (6) Go Back to Q#26

Q27.

Solution

Concept — Organic Chemistry: Degree of Unsaturation (DoU) / Index of Hydrogen Deficiency (IHD): The DoU counts the total number of rings and multiple bonds (double bonds count as 1, triple bonds as 2).

Step 1 — Apply the Formula: For toluene (C_7H_8), with no heteroatoms (no N, O, halogens):

$$\text{DoU} = \frac{2C + 2 - H}{2} = \frac{2(7) + 2 - 8}{2} = \frac{14 + 2 - 8}{2} = \frac{8}{2} = 4$$

Step 2 — Verify by Structure: Toluene is methylbenzene ($C_6H_5CH_3$). The benzene ring contributes:

- 1 ring $\rightarrow$ DoU = 1
- 3 C=C double bonds $\rightarrow$ DoU = 3

Total DoU from benzene ring $= 1 + 3 = 4$. The methyl group ($-CH_3$) has no unsaturation (DoU = 0). Total DoU $= 4$. ✓

Step 3 — Physical Significance: A DoU of 4 is characteristic of aromatic rings (benzene ring = 4 DoU). Any compound with DoU ≥ 4 may be aromatic.

Final Answer: Degree of unsaturation of toluene (C_7H_8) $= \boxed{4}$

Answer: (4) Go Back to Q#27

Q28.

Solution

Concept — Organic Chemistry: Geometrical Isomerism about C=C: Geometrical (cis/trans) isomerism arises about a C=C double bond when each carbon carries **two different substituents**.

Step 1 — Structural Analysis of Pent-2-ene:

$$CH_3 - CH = CH - CH_2CH_3$$

Label the double bond carbons:

- C-2 carries: $-CH_3$ and $-H$ [two different groups ✓]
- C-3 carries: $-CH_2CH_3$ and $-H$ [two different groups ✓]

Both carbons of the double bond have two different substituents, so geometric

isomerism exists.

Step 2 — Count the Isomers:

- **cis-pent-2-ene**: CH_3 and C_2H_5 on the *same* side.
- **trans-pent-2-ene**: CH_3 and C_2H_5 on *opposite* sides.

Total geometrical isomers $= 2$.

Step 3 — Note on Nomenclature: Using IUPAC E/Z notation: *cis* corresponds to (Z) (same priority groups on same side) and *trans* corresponds to (E) for pent-2-ene.

Final Answer: Pent-2-ene has $\boxed{2}$ geometrical isomers (cis and trans)

Answer: (2) Go Back to Q#28

Q29.

Solution

Concept — Redox Chemistry: Oxidation State of Mn in $KMnO_4$: Potassium permanganate is an important oxidising agent. The oxidation state of Mn can be found by the standard method.

Step 1 — Assign Known Oxidation States: In $KMnO_4$ (neutral compound):

$$\underbrace{+1}_{\text{K}} + \underbrace{x}_{\text{Mn}} + 4\underbrace{(-2)}_{\text{O}} = 0$$

Step 2 — Solve for x:

$$1 + x - 8 = 0 \implies x = +7$$

Step 3 — Contextual Note: $+7$ is the **maximum oxidation state** of manganese (Group 7, 7 valence electrons). $KMnO_4$ is a powerful oxidising agent because Mn can be reduced to lower states:

- In acidic medium: $Mn^{7+} \rightarrow Mn^{2+}$ ($MnSO_4$, colourless)
- In neutral/faintly basic medium: $Mn^{7+} \rightarrow Mn^{4+}$ (MnO_2, brown precipitate)
- In strongly alkaline medium: $Mn^{7+} \rightarrow Mn^{6+}$ (MnO_4^{2-}, green manganate)

Final Answer: Oxidation state of Mn in $KMnO_4 = \boxed{7}$

Answer: (7) Go Back to Q#29

Q30.

Solution

Concept — Chemical Bonding: Sigma Bonds in Propyne: In any molecule, only sigma (σ) bonds contribute to the connectivity (the framework). Pi (π) bonds in double or triple bonds are additional bonds layered onto the sigma framework.

Step 1 — Structure of Propyne:

$$\underbrace{H}_{\text{terminal H}} - \underbrace{C}_{C1} \equiv \underbrace{C}_{C2} - \underbrace{C}_{C3}\underbrace{H_3}_{\text{methyl}}$$

Step 2 — Count Each Sigma Bond:

- C1$-$H (terminal alkyne H): **1 sigma bond**
- C1$\equiv$C2 triple bond: contains **1 sigma** + 2 pi bonds; count **1 sigma bond**
- C2$-$C3 single bond: **1 sigma bond**
- C3$-$H (three C$-$H bonds of CH_3): **3 sigma bonds**

Step 3 — Total Count:

$$\text{Total } \sigma \text{ bonds} = 1 + 1 + 1 + 3 = 6$$

Verification: Propyne: C_3H_4. Degrees of unsaturation $= \frac{2(3)+2-4}{2} = \frac{4}{2} = 2$ (one triple bond $= 2$ DoU: 1 from the sigma-based counting perspective + 2 pi bonds). Total bonds $=$ sigma bonds + pi bonds $= 6 + 2 = 8$ bonds total. Checking: propyne has $3 + 4 = 7$ atoms and 8 bonds, giving a connected structure with $8 - 7 + 1 = 2$ independent cycles... (actually DoU from structural formula confirms 2, consistent).

Final Answer: Total sigma bonds in propyne $= \boxed{6}$

Answer: (6) Go Back to Q#30

Answer Key

Section A (MCQ):

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	D	3	A	4	B	5	C
6	D	7	A	8	B	9	C	10	D
11	A	12	B	13	C	14	D	15	A
16	B	17	C	18	D	19	A	20	B

Section B (Numerical Value):

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
21	7	22	5						
23	2	24	4						
25	120	26	6						
27	4	28	2						
29	7	30	6						