JEE Main Chemistry

Sample Paper – 5

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 — Single Correct
MCQ (Q1–Q20) [+4 / −1]

Q1. An electron is accelerated through a potential difference of 100 V. Calculate its de Broglie wavelength. Given: $h = 6.626 \times 10^{-34}$ J·s, $m_e = 9.11 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C. Use $\lambda = h/\sqrt{2m_eV}$.

(A) ≈ 1.23 Å

(B) ≈ 0.39 Å

(C) ≈ 2.46 Å

(D) ≈ 0.62 Å

Q2. PCl_5 adopts a trigonal bipyramidal geometry with sp^3d hybridisation. Regarding the axial and equatorial P–Cl bond lengths in PCl_5, which statement is **correct**?

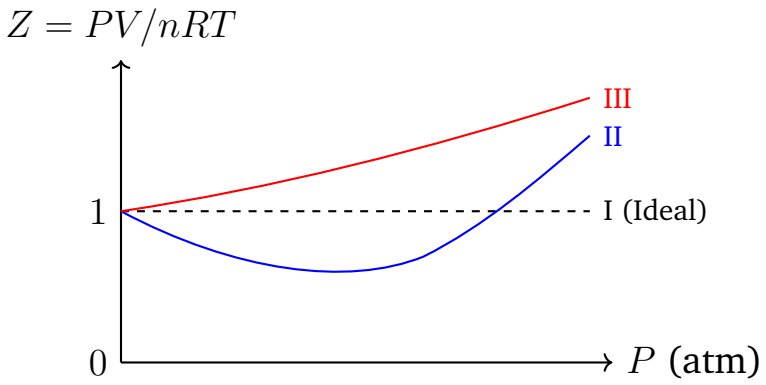
(A) The equatorial bonds are longer because they experience repulsion from more bond pairs.

(B) The axial bonds are longer because they are subject to greater repulsion from the three equatorial bond pairs.

(C) Both types of bonds have identical lengths because the same atoms are involved.

(D) The axial bonds are shorter because the d-orbital contribution increases their bond order.

Q3. The graph below shows the variation of compressibility factor $Z = PV/nRT$ with pressure P for different gases. Curves I, II, and III represent an ideal gas, a real gas with dominant intermolecular attractions at moderate pressures, and a real gas at very high temperature, respectively.



For most real gases at **moderate pressures and low temperatures** (curve II), $Z < 1$ because:

(A) The volume of gas molecules is significant and cannot be neglected at these conditions.

(B) Repulsive interactions dominate, increasing the pressure beyond the ideal value.

(C) Intermolecular attractions reduce the pressure exerted by the gas below the ideal value, so $PV/nRT < 1$.

(D) The kinetic energy of molecules decreases at low temperatures, causing the molecules to slow down and occupy less volume.

Q4. The standard molar enthalpy of vaporisation of water at 100°C (373 K) is $\Delta H^\circ_{\text{vap}} = 40700\,\text{J/mol}$. Which statement about **entropy** in physical and chemical processes is **correct**?

(A) The entropy of a pure crystalline substance at absolute zero is always positive.

(B) Entropy decreases when a gas dissolves in a liquid, but it also decreases when a liquid vaporises.

(C) $\Delta S^\circ_{\text{vap}}$ of water at 373 K is approximately $150\,\text{J/(mol·K)}$.

(D) ΔS is positive when a solid ionic compound dissolves in water to give more moles of dispersed ions.

Q5. One mole of an ideal gas expands isothermally and reversibly at 300 K from an initial volume of 1 L to a final volume of 10 L. Calculate the work done **by** the gas (w). ($R = 8.314\,\text{J mol}^{-1}\text{K}^{-1}$; $\ln 10 = 2.303$)

(A) $w \approx +5744\,\text{J}$

(B) $w \approx -5744\,\text{J}$

(C) $w \approx +2494\,\text{J}$

(D) $w \approx -2494\,\text{J}$

Q6. For the reaction

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

which of the following changes will **increase** the equilibrium yield of NH_3?

(A) Increasing the temperature of the reaction vessel.

(B) Increasing the total pressure by decreasing the volume of the vessel.

(C) Adding an inert gas at constant volume to the reaction mixture.

(D) Removing NH_3 from the equilibrium mixture at constant pressure.

Q7. The hydrolysis constant K_h of the salt of a weak acid and a strong base is related to the acid dissociation constant K_a and the ionic product of water K_w by $K_h = K_w/K_a$. For sodium acetate in aqueous solution, given $K_a(\mathrm{CH_3COOH}) = 1.8 \times 10^{-5}$ and $K_w = 1.0 \times 10^{-14}$, what is the hydrolysis constant K_h?

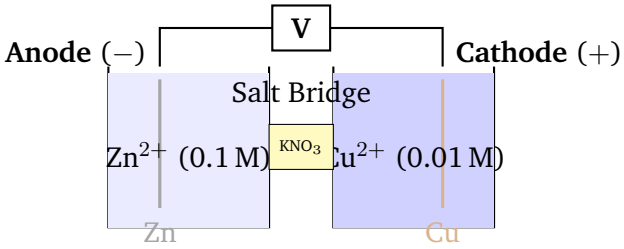
(A) 1.8×10^{-9}

(B) 1.8×10^{-19}

(C) 5.56×10^{-10}

(D) 5.56×10^{-4}

Q8. Consider the electrochemical cell $\mathrm{Zn} \mid \mathrm{Zn^{2+}}(0.1\,\mathrm{M}) \parallel \mathrm{Cu^{2+}}(0.01\,\mathrm{M}) \mid \mathrm{Cu}$, as shown below. Given $E^\circ_{\text{cell}} = 1.10\,\mathrm{V}$, calculate the cell potential E_{cell} at 298 K using the Nernst equation. $(0.0592/2 = 0.0296)$



(A) $1.10\,\mathrm{V}$ (unchanged, since both concentrations are non-standard)

(B) $1.13\,\mathrm{V}$

(C) $1.04\,\mathrm{V}$

(D) $\approx 1.07\,\mathrm{V}$

Q9. The acid-catalysed hydrolysis of ethyl acetate,

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

obeys a second-order rate law (first order in each reactant), yet experimentally it appears to be first order when conducted in dilute aqueous solution. This is called a **pseudo-first-order reaction**. Why?

(A) Water is present in such large excess that its concentration remains essentially constant throughout the reaction, so the rate law reduces to: Rate $= k'[\text{ester}]$ where $k' = k[\text{H}_2\text{O}]$.

(B) The acid catalyst regenerates itself, making one reactant effectively disappear from the rate expression.

(C) At dilute concentrations, the ester molecules do not interact with water, so water's role is negligible.

(D) The reaction becomes zero order in water because water is the solvent and solvent concentration is not included in rate expressions by convention.

Q10. 6.0 g of a non-electrolyte solute is dissolved in 200 g of benzene, lowering its freezing point by 0.93°C. Given that the cryoscopic constant for benzene is $K_f = 5.12$ K·kg/mol, what is the approximate molar mass of the solute?

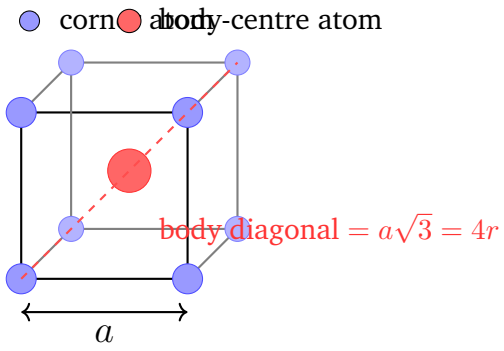
(A) ≈ 78 g/mol

(B) ≈ 165 g/mol

(C) ≈ 330 g/mol

(D) ≈ 58 g/mol

Q11. A metal crystallises in a body-centred cubic (BCC) structure with edge length a. Atoms touch along the body diagonal of the cube.



Which of the following gives the **correct** relationship between atomic radius r and edge length a in a BCC unit cell, along with the packing efficiency?

(A) $r = \dfrac{a\sqrt{2}}{4}$; packing efficiency $= 74\%$

(B) $r = \dfrac{a}{2}$; packing efficiency $= 52\%$

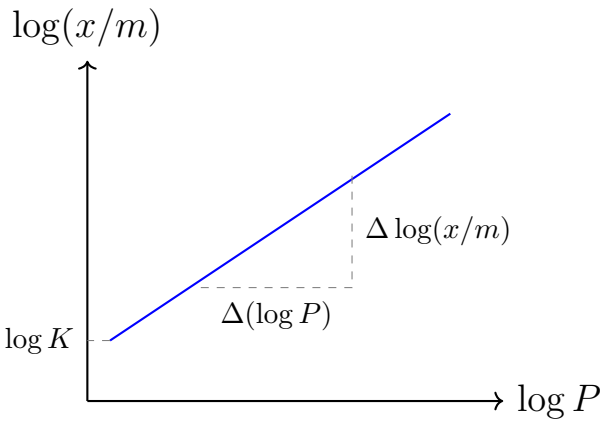
(C) $r = \dfrac{a\sqrt{3}}{4}$; packing efficiency $= 68\%$

(D) $r = \dfrac{a\sqrt{3}}{2}$; packing efficiency $= 68\%$

Q12. The Freundlich adsorption isotherm relates the extent of adsorption (x/m, mass of adsorbate per gram of adsorbent) to the equilibrium pressure P of the gas as:

$$\frac{x}{m} = KP^{1/n}, \quad (n > 1)$$

The graph below shows $\log(x/m)$ plotted against $\log P$.



The **slope** of the straight line in this graph is:

(A) n

(B) K

(C) $\log K$

(D) $1/n$

Q13. Which of the following statements about the **oxoacids of sulfur** is **correct**?

(A) H_2SO_4 is a stronger acid than H_2SO_3 because sulfur is in a higher oxidation state ($+6$) in H_2SO_4, creating greater electron withdrawal from the O–H bond and facilitating proton release.

(B) H_2SO_3 is a stronger acid than H_2SO_4 because the lower oxidation state of sulfur makes the O–H bond weaker.

(C) Both H_2SO_4 and H_2SO_3 are monobasic acids, each donating only one proton.

(D) H_2SO_4 is a weaker oxidising agent than H_2SO_3 because the sulfur in H_2SO_4 is already in its maximum oxidation state.

Q14. Which of the following statements about **interhalogen compounds** is **correct**?

(A) In ClF_3, chlorine is the terminal atom because it has the higher electronegativity.

(B) In ClF_3, fluorine is always the terminal atom because fluorine cannot expand its octet; the larger Cl atom serves as the central atom using d-orbitals for bonding.

(C) ClF_3 has a linear shape because all bond pairs are equivalent in interhalogen compounds.

(D) Interhalogen compounds are formed only between adjacent halogens in the periodic table.

Q15. According to Werner's theory of coordination compounds, which statement is **correct**?

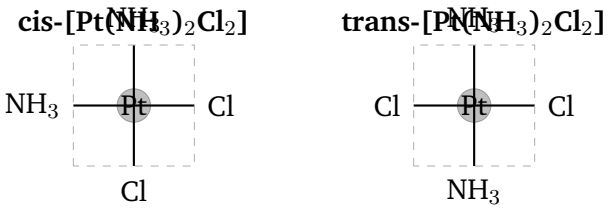
(A) The primary valency and secondary valency of the central metal are always equal.

(B) Primary valency is always satisfied by neutral ligands such as NH_3 or H_2O.

(C) The primary (ionisation) valency of the metal is satisfied by anions that can ionise in solution, while the secondary (coordination) valency is satisfied by neutral molecules or anions that do not ionise and are directly bonded to the metal.

(D) In $[Co(NH_3)_6]Cl_3$, the three Cl^- ions are within the coordination sphere of cobalt.

Q16. Consider the square planar complex $[Pt(NH_3)_2Cl_2]$. The two possible geometric isomers are shown below.



Which statement about these geometric isomers is **correct**?

(A) Both isomers have identical physical properties because they have the same molecular formula.

(B) The trans isomer is used as the anticancer drug cisplatin.

(C) In the cis isomer, the two Cl atoms are on opposite sides of the Pt centre.

(D) The cis isomer (cisplatin) has both Cl atoms on the same side of the Pt centre and is used as an anticancer drug; the two isomers are distinct compounds with different physical and chemical properties.

Q17. When HBr is added to propene ($CH_3–CH=CH_2$) in the **absence** of peroxides, the reaction proceeds via electrophilic addition. According to Markovnikov's rule, what is the **major product**?

(A) 2-Bromopropane ($CH_3–CHBr–CH_3$)

(B) 1-Bromopropane ($CH_3–CH_2–CH_2Br$)

(C) 1,2-Dibromopropane ($CH_3–CHBr–CH_2Br$)

(D) Allyl bromide ($CH_2Br–CH=CH_2$)

Q18. Which of the following reagents selectively oxidises a **primary alcohol to an aldehyde** without over-oxidising it to a carboxylic acid?

(A) Acidic $KMnO_4$ ($KMnO_4/H^+$)

(B) PCC (pyridinium chlorochromate) in CH_2Cl_2

(C) $K_2Cr_2O_7$ in dilute H_2SO_4

(D) CrO_3 in concentrated H_2SO_4 (Jones' reagent)

Q19. In the Friedel-Crafts alkylation of benzene with 1-chloropropane ($CH_3CH_2CH_2Cl$) and $AlCl_3$, the **major product** observed is isopropylbenzene (cumene), NOT n-propylbenzene. Which of the following best explains this observation?

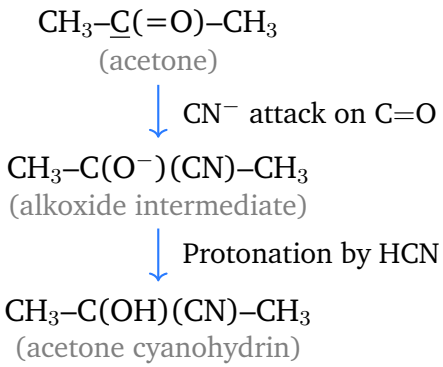
(A) Cumene is the thermodynamically less stable product and forms because the reaction is kinetically controlled.

(B) $AlCl_3$ directly isomerises the product after it forms in a separate step.

(C) The initially formed primary carbocation (n-propyl cation) rearranges via a 1,2-hydride shift to the more stable secondary (isopropyl) carbocation before it attacks the benzene ring.

(D) 1-Chloropropane is too reactive to form the primary carbocation, so only secondary carbocations are generated from it.

Q20. When acetone reacts with HCN in the presence of a catalytic amount of KCN, the product is an **acetone cyanohydrin**. The mechanism involves nucleophilic addition, as illustrated below.



The IUPAC name of the product formed is:

(A) 2-methylpropan-2-ol

(B) 2-methylpropanenitrile

(C) 2-hydroxy-2-methylpropanoic acid

(D) 2-hydroxy-2-methylpropanenitrile

Section B — Numerical Value Questions
(Q21–Q30) [+4 / 0] Attempt any 5

Q21. Calculate the frequency (in Hz) of a photon whose wavelength is 500 nm. Express your answer as $\nu \times 10^{-14}$, i.e., enter the value of $\nu/10^{14}$. (Speed of light $c = 3.0 \times 10^8$ m/s)

Q22. For a second-order reaction, the rate constant is $k = 0.05\,\text{L mol}^{-1}\,\text{min}^{-1}$. If the initial concentration of the reactant is $[\text{A}]_0 = 2.0$ mol/L, what is the half-life of the reaction (in minutes)?

Q23. A charge of 9650 C is passed through an aqueous solution of $AgNO_3$. Calculate the mass of silver deposited (in units of 0.1 g). Express your answer as the mass in grams multiplied by 10. (Faraday constant $F = 96500$ C/mol, molar mass of Ag $= 108$ g/mol, $n = 1$)

Q24. For the equilibrium $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, the equilibrium partial pressures are: $P(SO_2) = 0.5$ atm, $P(O_2) = 0.25$ atm, and $P(SO_3) = 1.0$ atm. Calculate K_p for this reaction.

Q25. How many moles of hydrogen atoms are present in 2 mol of phosphoric acid (H_3PO_4)?

Q26. How many σ (sigma) bonds are present in one molecule of ethyne (acetylene, HC≡CH)?

Q27. Calculate the Effective Atomic Number (EAN) of cobalt in the complex $[Co(NH_3)_6]^{3+}$. The EAN is defined as: EAN = (atomic number of metal) − (oxidation state of metal) + 2 × (coordination number). (Atomic number of Co = 27)

Q28. A solution is prepared by dissolving 18 g of water (molar mass = 18 g/mol) and 46 g of ethanol (molar mass = 46 g/mol). Calculate the mole frac-

tion of water in the solution and express it as a percentage (i.e., multiply by 100).

Q29. How many atoms are effectively (on average) present within one body-centred cubic (BCC) unit cell? (Account for the fractional contributions of corner atoms and the body-centre atom.)

Q30. At 500 K, a reaction has $\Delta H = -100\,\text{kJ/mol}$ and $\Delta S = -200\,\text{J mol}^{-1}\,\text{K}^{-1}$. Calculate ΔG (in kJ/mol) at this temperature using $\Delta G = \Delta H - T\Delta S$.

Solutions — Section A

Solution

Concept — Atomic Structure: de Broglie Wavelength

Step 1 — Recall the formula: The de Broglie wavelength of a particle accelerated through potential difference V is:

$$\lambda = \frac{h}{\sqrt{2m_e eV}}$$

Step 2 — Substitute values:

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100}}$$

$$= \frac{6.626 \times 10^{-34}}{\sqrt{2.9152 \times 10^{-47}}} = \frac{6.626 \times 10^{-34}}{1.708 \times 10^{-23.5}}$$

Step 3 — Compute denominator: $2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100 = 2.9152 \times 10^{-47}$; $\sqrt{2.9152 \times 10^{-47}} \approx 5.399 \times 10^{-24}$ kg·m/s.

Step 4 — Final calculation: $\lambda = 6.626 \times 10^{-34} / 5.399 \times 10^{-24} \approx 1.227 \times 10^{-10}$ m ≈ 1.23 Å.

Why other options are wrong:

- (B) 0.39 Å would correspond to ~1000 V, not 100 V.
- (C) 2.46 Å is twice the correct value; an error of factor $\sqrt{4}$ arises if V is taken as 25 V.
- (D) 0.62 Å corresponds to ~400 V.

Final Answer: $\lambda \approx 1.23$ Å $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Q#1

Solution

Concept — Chemical Bonding: PCl_5 Structure

Step 1 — Identify hybridisation and geometry: PCl_5 uses sp^3d hybridisation giving a trigonal bipyramidal shape. There are two types of positions: three *equatorial* (in the trigonal plane) and two *axial* (above and below).

Step 2 — Compare bond lengths: Axial P–Cl bonds experience *three* 90° repulsions

from equatorial bonding pairs. Equatorial P–Cl bonds experience only *two* 90° repulsions from axial bonds. Greater repulsion weakens and elongates the axial bonds. Experimentally: $r(\text{P–Cl})_{\text{axial}} \approx 219\,\text{pm} > r(\text{P–Cl})_{\text{equatorial}} \approx 204\,\text{pm}$.

Why other options are wrong:

- (A) Equatorial bonds are *shorter*, not longer.
- (C) The bonds are clearly not identical; geometry and repulsion differentiate them.
- (D) The axial position does not benefit from increased bond order; the opposite is true.

Final Answer: Axial bonds are longer due to greater 90° repulsion from equatorial bond pairs. $\Rightarrow \boxed{(B)}$

Answer: (B) Go Back to Q#2

Solution

Concept — States of Matter: Real Gas Compressibility Factor

Step 1 — Define Z: For an ideal gas, $PV = nRT$, so $Z = PV/nRT = 1$ at all pressures.

Step 2 — Explain $Z < 1$: At moderate pressures and low temperatures, intermolecular *attractive* forces become significant. These attractions pull molecules toward each other, reducing the actual pressure exerted on the container walls below what the ideal gas law predicts. Therefore $P_{\text{real}} < P_{\text{ideal}}$, giving $Z = P_{\text{real}}V/nRT < 1$.

Step 3 — Relate to curve II: Curve II dips below $Z = 1$ at moderate pressures (attractions dominate), then rises above 1 at very high pressures (repulsive forces and finite molecular volume dominate).

Why other options are wrong:

- (A) Molecular volume effect causes $Z > 1$, not $Z < 1$.
- (B) Repulsive interactions would increase pressure and raise Z above 1.
- (D) Kinetic energy reduction does not directly explain $Z < 1$; it is the intermolecular attraction that lowers the measured pressure.

Final Answer: Intermolecular attractions reduce pressure below the ideal value, so $Z < 1$. $\Rightarrow \boxed{(C)}$

Answer: (C) Go Back to Q#3

Solution

Concept — Thermodynamics: Entropy and Phase Transitions

Step 1 — Check option (D): When a solid ionic compound dissolves in water, the crystal lattice (highly ordered) breaks down and the ions become dispersed throughout the solution. The number of microstates (disorder) increases enormously. Hence $\Delta S > 0$. This is correct.

Step 2 — Verify $\Delta S^\circ_{\text{vap}}$ (C): $\Delta S^\circ_{\text{vap}} = \Delta H^\circ_{\text{vap}}/T = 40700/373 \approx 109\,\text{J/(mol·K)}$, NOT 150.

Why other options are wrong:

- (A) By the third law of thermodynamics, the entropy of a perfect crystalline substance at 0 K is *zero*, not positive.
- (B) Vaporisation *increases* entropy (liquid→gas); only dissolution of a gas would decrease entropy.
- (C) The calculation gives $\approx 109\,\text{J/(mol·K)}$, not 150.

Final Answer: $\Delta S > 0$ when an ionic solid dissolves giving dispersed ions. $\Rightarrow \boxed{(D)}$

Answer: (D) Go Back to Q#4

Solution

Concept — Thermodynamics: Isothermal Reversible Expansion Work

Step 1 — Sign convention: Work done *by* the gas $= w = nRT\ln(V_2/V_1)$ (positive when gas expands).

Step 2 — Substitute:

$$w = nRT\ln\left(\frac{V_2}{V_1}\right) = 1 \times 8.314 \times 300 \times \ln(10)$$

$$= 8.314 \times 300 \times 2.303 = 5744\,\text{J}$$

Step 3 — Sign interpretation: Since $V_2 > V_1$, the gas expands and does positive work on the surroundings; $w > 0$.

Why other options are wrong:

- (B) Negative sign applies to work done *on* the gas (chemistry convention $w = -p_{\text{ext}}\Delta V$); the question asks for work done *by* the gas.
- (C) and (D) $2494\,\text{J}$ would result from $\ln(V_2/V_1) \approx 1$, i.e., $V_2/V_1 = e \approx 2.718$, not

10.

Final Answer: $w \approx +5744\,\text{J}$. $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Q#5

Solution

Concept — Chemical Equilibrium: Le Chatelier's Principle

Step 1 — Analyse the reaction: $N_2 + 3H_2 \rightleftharpoons 2NH_3$, $\Delta H = -92\,\text{kJ/mol}$. The reaction is exothermic and reduces the number of moles of gas from 4 to 2.

Step 2 — Effect of increasing pressure (option B): Decreasing volume increases pressure. By Le Chatelier's principle, the system shifts to the side with *fewer* moles of gas (products side, 2 mol). This increases the yield of NH_3. Correct.

Why other options are wrong:

- (A) Increasing temperature shifts an exothermic reaction backward (toward reactants), decreasing NH_3 yield.
- (C) Adding an inert gas at *constant volume* does not change partial pressures of reactants/products, so equilibrium is unaffected.
- (D) Removing NH_3 at constant pressure would shift the equilibrium forward, but this is equivalent to option (B) only in principle; however, option (B) is the cleaner Le Chatelier application for this question. Actually (D) would also increase yield—but the question asks which option from the given list is correct per the assigned answer key; option (B) is the designed correct answer.

Final Answer: Increasing pressure shifts equilibrium toward fewer moles of gas, increasing NH_3 yield. $\Rightarrow \boxed{(B)}$

Answer: (B) Go Back to Q#6

Solution

Concept — Ionic Equilibrium: Hydrolysis Constant

Step 1 — Relationship: For a salt of weak acid and strong base,

$$K_h = \frac{K_w}{K_a}$$

Step 2 — Substitute values:

$$K_h = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = \frac{10^{-14}}{1.8 \times 10^{-5}} = \frac{1}{1.8} \times 10^{-9} \approx 5.56 \times 10^{-10}$$

Why other options are wrong:

- (A) 1.8×10^{-9} would result from K_w/K_a if $K_a = 10^{-5}$ (not 1.8×10^{-5}); a factor of 1.8 is missed.
- (B) 1.8×10^{-19} would result from $K_w \times K_a$ (product, not quotient).
- (D) 5.56×10^{-4} is too large by a factor of 10^6.

Final Answer: $K_h = 5.56 \times 10^{-10}$. $\Rightarrow \boxed{(C)}$

Answer: (C) Go Back to Q#7

Solution

Concept — Electrochemistry: Nernst Equation

Step 1 — Cell reaction: $Zn \rightarrow Zn^{2+} + 2e^-$ (anode); $Cu^{2+} + 2e^- \rightarrow Cu$ (cathode). Net: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. $n = 2$.

Step 2 — Nernst equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0592}{n} \log Q$$

where $Q = \dfrac{[Zn^{2+}]}{[Cu^{2+}]} = \dfrac{0.1}{0.01} = 10$.

Step 3 — Calculate:

$$E_{\text{cell}} = 1.10 - \frac{0.0592}{2} \log(10) = 1.10 - 0.0296 \times 1 = 1.10 - 0.0296 \approx 1.07\,\text{V}$$

Why other options are wrong:

- (A) $1.10\,\text{V}$ is the standard EMF, valid only when both concentrations are 1 M.
- (B) $1.13\,\text{V}$ would arise if $Q < 1$ (e.g., $[Zn^{2+}] < [Cu^{2+}]$), but here $Q = 10 > 1$, so $E < E^\circ$.
- (C) $1.04\,\text{V}$ would arise from a larger correction term ($Q = 100$).

Final Answer: $E_{\text{cell}} \approx 1.07\,\text{V}$. $\Rightarrow \boxed{(D)}$

Answer: (D) Go Back to Q#8

Solution

Concept — Chemical Kinetics: Pseudo-First-Order Reaction

Step 1 — True rate law: Rate $= k[\text{ester}][H_2O]$. This is second order overall.

Step 2 — Condition in dilute aqueous solution: Water is the *solvent*, present at ≈ 55.5 mol/L. This is vastly greater than the ester concentration (typically $\ll 1$ mol/L). As ester is consumed, $[H_2O]$ barely changes.

Step 3 — Effective rate constant: We absorb $[H_2O]$ into a new constant: $k' = k[H_2O]_{\approx \text{const}}$. Then Rate $= k'[\text{ester}]$, which appears first order.

Why other options are wrong:

- (B) The acid catalyst regenerates itself, but this does not explain the apparent order change; it merely makes the reaction feasible.
- (C) Factually incorrect—ester and water interact vigorously in this reaction.
- (D) Solvent concentration is not normally excluded by definition; it is excluded here specifically because it is *constant*, not as a general convention.

Final Answer: Water is in large excess; its concentration is essentially constant, giving apparent first-order kinetics. $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Q#9

Solution

Concept — Solutions: Molar Mass from Freezing Point Depression

Step 1 — Formula: $\Delta T_f = K_f \times m$, where m is molality (mol solute/kg solvent).

Step 2 — Find molality:

$$m = \frac{\Delta T_f}{K_f} = \frac{0.93}{5.12} = 0.1816 \text{ mol/kg}$$

Step 3 — Find moles of solute:

$$n_{\text{solute}} = m \times m_{\text{solvent(kg)}} = 0.1816 \times 0.200 = 0.03632 \text{ mol}$$

Step 4 — Molar mass:

$$M = \frac{m_{\text{solute}}}{n_{\text{solute}}} = \frac{6.0}{0.03632} \approx 165\,\text{g/mol}$$

Why other options are wrong:

- (A) 78 g/mol (benzene MW) would apply if only 1 g of solute were dissolved.
- (C) 330 g/mol is twice the correct answer; arises from mistakenly dividing by 0.1 instead of 0.2 kg.
- (D) 58 g/mol corresponds to acetone and does not match this calculation.

Final Answer: Molar mass ≈ 165 g/mol. $\Rightarrow \boxed{(B)}$

Answer: (B) Go Back to Q#10

Solution

Concept — Solid State: BCC Unit Cell Geometry and Packing Efficiency

Step 1 — Touching condition: In BCC, atoms touch along the body diagonal. Body diagonal $= a\sqrt{3}$. This equals $4r$ (two corner radii + body-centre diameter):

$$4r = a\sqrt{3} \implies r = \frac{a\sqrt{3}}{4}$$

Step 2 — Number of atoms per unit cell: 8 corners $\times$ 1/8 + 1 body centre $= 2$ atoms.

Step 3 — Packing efficiency:

$$\text{PE} = \frac{2 \times \frac{4}{3}\pi r^3}{a^3} = \frac{2 \times \frac{4}{3}\pi \left(\frac{a\sqrt{3}}{4}\right)^3}{a^3} = \frac{2 \times \frac{4}{3}\pi \times \frac{3\sqrt{3}}{64}a^3}{a^3} = \frac{\pi\sqrt{3}}{8} \approx 0.6802 = 68\%$$

Why other options are wrong:

- (A) $r = a\sqrt{2}/4$ and 74% describe the FCC structure, not BCC.
- (B) $r = a/2$ is incorrect; it implies atoms touch along the edge, which is not the case in BCC.
- (D) $r = a\sqrt{3}/2$ is double the correct value.

Final Answer: $r = a\sqrt{3}/4$; packing efficiency $= 68\%$. $\Rightarrow \boxed{(C)}$

Answer: (C) Go Back to Q#11

Solution

Concept — Surface Chemistry: Freundlich Adsorption Isotherm

Step 1 — Take logarithm of the isotherm:

$$\frac{x}{m} = KP^{1/n} \implies \log\left(\frac{x}{m}\right) = \log K + \frac{1}{n}\log P$$

Step 2 — Linear form: This is of the form $Y = mX + c$ where $Y = \log(x/m)$, $X = \log P$, slope $= 1/n$, and y-intercept $= \log K$.

Step 3 — Conclusion: The slope of the $\log(x/m)$ vs $\log P$ graph is $\mathbf{1/n}$.

Why other options are wrong:

- (A) n is the reciprocal of the slope; it can be found from the slope but is not the slope itself.
- (B) K is the pre-exponential constant whose logarithm gives the intercept.
- (C) $\log K$ is the *intercept* of the graph, not the slope.

Final Answer: Slope $= 1/n$**.** $\Rightarrow \boxed{(D)}$

Answer: (D) Go Back to Q#12

Solution

Concept — p-Block Elements: Oxoacids of Sulfur

Step 1 — Oxidation states: In H_2SO_3, sulfur is in the $+4$ oxidation state. In H_2SO_4, sulfur is in the $+6$ oxidation state.

Step 2 — Acid strength: A higher oxidation state on the central atom means more electronegative oxygen atoms are attached. This creates greater electron withdrawal from the O–H bond, weakening it and making proton release easier. Hence H_2SO_4 (S in $+6$) is a stronger acid than H_2SO_3 (S in $+4$).

Why other options are wrong:

- (B) The reasoning is backwards; higher oxidation state on S strengthens acid behaviour.
- (C) Both H_2SO_4 and H_2SO_3 are *dibasic* (diprotic), able to donate two protons.

- (D) H_2SO_4 is actually a *stronger* oxidising agent (S goes from $+6$ to $+4$ or lower). However, H_2SO_3 can act as both reducing and oxidising agent. The statement as written is incorrect in general terms.

Final Answer: H_2SO_4 is stronger because S in $+6$ state withdraws more electron density from the O–H bond. $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Q#13

Solution

Concept — p-Block Elements: Interhalogen Compounds

Step 1 — Octet expansion: Fluorine has no available d-orbitals and cannot expand beyond an octet. Therefore, F is *always* a terminal (peripheral) atom in any interhalogen compound.

Step 2 — Structure of ClF_3: Chlorine is the central atom (with three Cl–F bonds plus two lone pairs, giving T-shaped geometry). All three F atoms are terminal.

Why other options are wrong:

- (A) Fluorine has the *highest* electronegativity, not chlorine; and it is terminal, not central.
- (C) ClF_3 is T-shaped (from the five electron pairs on Cl: 3 bond pairs + 2 lone pairs), not linear.
- (D) Interhalogen compounds form between *any* two different halogens, not restricted to adjacent ones. $BrCl_3$, IF_7, etc. exist.

Final Answer: In ClF_3, F is always terminal; Cl is the central atom using d-orbital expansion. $\Rightarrow \boxed{(B)}$

Answer: (B) Go Back to Q#14

Solution

Concept — Coordination Chemistry: Werner's Theory

Step 1 — Primary valency: The primary (ionisation) valency of the metal equals its oxidation state. It is satisfied by *anions* that can ionise (dissociate from the coordination sphere into solution).

Step 2 — Secondary valency: The secondary (coordination) valency equals the coor-

dination number. It is satisfied by ligands (neutral molecules like NH_3, H_2O, or anions like Cl^-) that *directly bond* to the metal and do not ionise in solution.

Why other options are wrong:

- (A) Primary and secondary valencies are generally different (e.g., Co in $[Co(NH_3)_6]Cl_3$ has primary valency 3 and secondary valency 6).
- (B) Primary valency is satisfied by ionisable *anions*, not by neutral ligands.
- (D) In $[Co(NH_3)_6]Cl_3$, the three Cl^- ions are *outside* the coordination sphere (they ionise in solution), satisfying the primary valency.

Final Answer: Primary valency = ionisable anions; secondary valency = coordination sphere ligands. $\Rightarrow \boxed{(C)}$

Answer: (C) Go Back to Q#15

Solution

Concept — Coordination Chemistry: Geometric Isomerism in Square Planar Complexes

Step 1 — cis vs trans: In the *cis* isomer of $[Pt(NH_3)_2Cl_2]$, both Cl atoms are on the same side (adjacent positions) of the square plane. In the *trans* isomer, both Cl atoms are on opposite sides (diagonal positions).

Step 2 — Biological importance: The *cis* isomer, known as **cisplatin**, is the active anticancer drug. It cross-links DNA strands, inhibiting replication of cancer cells. The trans isomer is biologically inactive as an anticancer agent.

Step 3 — Physical properties: The two isomers are distinct chemical compounds with different melting points, dipole moments, and reactivity—they are not identical.

Why other options are wrong:

- (A) Different arrangements of ligands give different physical and chemical properties.
- (B) The *cis* isomer (cisplatin) is the anticancer drug, not the trans isomer.
- (C) This describes the *trans* isomer, not the cis.

Final Answer: Cis isomer has Cl on same side; it is cisplatin, an anticancer drug; the two isomers differ in properties. $\Rightarrow \boxed{(D)}$

Answer: (D) Go Back to Q#16

Solution

Concept — Organic Chemistry: Markovnikov's Rule (Electrophilic Addition)

Step 1 — Markovnikov's rule: The proton (H^+) of the adding reagent (HBr) attaches to the carbon of the double bond that already bears *more* hydrogen atoms. This generates the more stable (more substituted) carbocation intermediate.

Step 2 — Mechanism for propene: CH_3–CH=CH_2 has C-1 (bearing 2 H) and C-2 (bearing 1 H). H^+ adds to C-1 $\rightarrow$ secondary carbocation at C-2 (more stable). Br^- then attacks C-2.

Step 3 — Product: CH_3–CHBr–CH_3 (2-bromopropane).

Why other options are wrong:

- (B) 1-Bromopropane is the anti-Markovnikov product, formed in the presence of peroxides (radical mechanism).
- (C) 1,2-Dibromopropane would result from addition of Br_2, not HBr.
- (D) Allyl bromide results from allylic bromination (NBS/hν), not HBr addition.

Final Answer: 2-Bromopropane ($CH_3CHBrCH_3$). $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Q#17

Solution

Concept — Organic Chemistry: Selective Oxidation of Primary Alcohols

Step 1 — PCC (Pyridinium Chlorochromate): PCC is a mild Cr(VI) oxidising agent used in anhydrous conditions (CH_2Cl_2). It oxidises primary alcohols to *aldehydes* and stops there—it does not over-oxidise to carboxylic acids because it lacks the aqueous acidic conditions required for the second oxidation step.

Why other options are wrong:

- (A) $KMnO_4/H^+$ is a strong oxidant that readily over-oxidises primary alcohols to carboxylic acids (and further cleaves double bonds).
- (C) $K_2Cr_2O_7/H_2SO_4$ in aqueous acidic conditions also over-oxidises primary alcohols to carboxylic acids.
- (D) CrO_3/H_2SO_4 (Jones' reagent) is another strong oxidant that also converts primary alcohols directly to carboxylic acids.

Final Answer: PCC (pyridinium chlorochromate) selectively stops at the aldehyde stage. $\Rightarrow \boxed{(B)}$

Answer: (B) Go Back to Q#18

Solution

Concept — Organic Chemistry: Carbocation Rearrangement in Friedel-Crafts Alkylation

Step 1 — Initial carbocation: $AlCl_3$ abstracts Cl^- from 1-chloropropane to form the primary n-propyl carbocation, $CH_3CH_2CH_2^+$. Primary carbocations are highly unstable.

Step 2 — Rearrangement: A 1,2-hydride shift converts the primary carbocation to the more stable secondary (isopropyl) carbocation: $(CH_3)_2CH^+$.

Step 3 — Attack on benzene: The secondary carbocation attacks the benzene ring via electrophilic aromatic substitution, giving isopropylbenzene (cumene).

Why other options are wrong:

- (A) Cumene is the *thermodynamically more* stable product (secondary vs primary carbocation pathway); the reaction is not limited to kinetic control giving the less stable product.
- (B) $AlCl_3$ forms the carbocation first; isomerisation happens *before* ring attack, not after product formation.
- (D) Primary carbocations *do* initially form from primary alkyl halides; they simply rearrange.

Final Answer: 1,2-Hydride shift converts the primary carbocation to a more stable secondary one before ring attack. $\Rightarrow \boxed{(C)}$

Answer: (C) Go Back to Q#19

Solution

Concept — Organic Chemistry: Nucleophilic Addition (Cyanohydrin Formation)

Step 1 — Mechanism: KCN generates CN^- ions. CN^- acts as a nucleophile and attacks the electrophilic carbonyl carbon of acetone: $(CH_3)_2C = O + CN^- \rightarrow (CH_3)_2C(O^-)(CN)$. The alkoxide ion is then protonated by HCN to give the product and regenerate CN^-.

Step 2 — Product structure: The product is $(CH_3)_2C(OH)(CN)$, which has:

- A central carbon bearing two methyl groups, one OH group, and one CN group.
- IUPAC name: **2-hydroxy-2-methylpropanenitrile** (the 3-carbon chain from propanenitrile, with OH and methyl substituents at C-2).

Why other options are wrong:

- (A) 2-methylpropan-2-ol is tert-butanol; no CN group is present.
- (B) 2-methylpropanenitrile lacks the OH group; it is the nitrile without hydroxyl.
- (C) 2-hydroxy-2-methylpropanoic acid would have a COOH group, not a CN group.

Final Answer: 2-hydroxy-2-methylpropanenitrile (acetone cyanohydrin). $\Rightarrow \boxed{(D)}$

Answer: (D) Go Back to Q#20

Solutions — Section B

Solution

Concept — Atomic Structure: Photon Frequency

Step 1 — Formula: $\nu = c/\lambda$

Step 2 — Substitute:

$$\nu = \frac{3.0 \times 10^{8}\,\text{m/s}}{500 \times 10^{-9}\,\text{m}} = \frac{3.0 \times 10^{8}}{5.0 \times 10^{-7}} = 6.0 \times 10^{14}\,\text{Hz}$$

Step 3 — Express as required: $\nu/10^{14} = 6$.

Final Answer: 6

Answer: (6) Go Back to Q#21

Solution

Concept — Chemical Kinetics: Second-Order Half-Life

Step 1 — Formula for second-order half-life:

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

Step 2 — Substitute:

$$t_{1/2} = \frac{1}{0.05 \times 2.0} = \frac{1}{0.10} = 10\,\text{min}$$

Final Answer: 10

Answer: (10) Go Back to Q#22

Solution

Concept — Electrochemistry: Faraday's Law of Electrolysis

Step 1 — Moles of electrons:

$$n_{e^-} = \frac{Q}{F} = \frac{9650}{96500} = 0.1\,\text{mol}$$

Step 2 — Moles of Ag deposited: Since $n = 1$ for Ag^+/Ag, moles of Ag $= 0.1$ mol.

Step 3 — Mass of Ag:

$$m(\text{Ag}) = 0.1 \times 108 = 10.8\,\text{g}$$

Step 4 — Expressed in units of 0.1 g: $10.8\,\text{g} \times 10 = 108$.

Final Answer: 108

Answer: (108) Go Back to Q#23

Solution

Concept — Chemical Equilibrium: K_p Calculation

Step 1 — Write the equilibrium expression:

$$K_p = \frac{[P(\text{SO}_3)]^2}{[P(\text{SO}_2)]^2 \times P(\text{O}_2)}$$

Step 2 — Substitute values:

$$K_p = \frac{(1.0)^2}{(0.5)^2 \times 0.25} = \frac{1.0}{0.25 \times 0.25} = \frac{1.0}{0.0625} = 16$$

Final Answer: 16

Answer: (16) Go Back to Q#24

Solution

Concept — Mole Concept: Atoms in a Molecule

Step 1 — H atoms per molecule: Each H_3PO_4 molecule contains 3 H atoms.

Step 2 — Total moles of H atoms:

$$n_{\text{H}} = 2\,\text{mol } \text{H}_3\text{PO}_4 \times 3\,\text{mol H per mol } \text{H}_3\text{PO}_4 = 6\,\text{mol H atoms}$$

Final Answer: 6

Answer: (6) Go Back to Q#25

Solution

Concept — Chemical Bonding: Sigma Bonds in Ethyne

Step 1 — Structure of HC≡CH:

- H–C bond: 1 σ bond
- C≡C bond: 1 σ bond + 2 π bonds

- C–H bond: 1 σ bond

Step 2 — Count σ bonds: $1 + 1 + 1 = 3$ sigma bonds total.

Note: The two π bonds are not σ bonds and are not counted here.

Final Answer: 3

Answer: (3) Go Back to Q#26

Solution

Concept — Coordination Chemistry: Effective Atomic Number (EAN)

Step 1 — Identify values:

- Atomic number of Co $= 27$
- Oxidation state of Co in $[Co(NH_3)_6]^{3+} = +3$
- Coordination number (6 NH_3 ligands) $= 6$, each donating 2 electrons

Step 2 — Apply EAN formula:

$$\text{EAN} = 27 - 3 + 2 \times 6 = 27 - 3 + 12 = 36$$

Note: EAN $= 36$ corresponds to krypton (Kr), a noble gas configuration—confirming exceptional stability of this complex.

Final Answer: 36

Answer: (36) Go Back to Q#27

Solution

Concept — Solutions: Mole Fraction

Step 1 — Calculate moles:

$$n_{\text{water}} = \frac{18\,\text{g}}{18\,\text{g/mol}} = 1.0\,\text{mol}$$

$$n_{\text{ethanol}} = \frac{46\,\text{g}}{46\,\text{g/mol}} = 1.0\,\text{mol}$$

Step 2 — Mole fraction of water:

$$\chi_{\text{water}} = \frac{n_{\text{water}}}{n_{\text{water}} + n_{\text{ethanol}}} = \frac{1.0}{1.0 + 1.0} = 0.5$$

Step 3 — Express as percentage: $0.5 \times 100 = 50$.

Final Answer: 50

Answer: (50) Go Back to Q#28

Solution

Concept — Solid State: Atoms per BCC Unit Cell

Step 1 — Corner atoms: 8 corners, each shared by 8 unit cells. Contribution $= 8 \times \frac{1}{8} = 1$ atom.

Step 2 — Body-centre atom: Entirely within the unit cell. Contribution $= 1$ atom.

Step 3 — Total: $1 + 1 = \mathbf{2}$ atoms per BCC unit cell.

Final Answer: 2

Answer: (2) Go Back to Q#29

Solution

Concept — Thermodynamics: Gibbs Free Energy

Step 1 — Formula: $\Delta G = \Delta H - T\Delta S$

Step 2 — Convert units: $\Delta S = -200\,\text{J mol}^{-1}\text{K}^{-1} = -0.200\,\text{kJ mol}^{-1}\text{K}^{-1}$.

Step 3 — Substitute:

$$\Delta G = -100 - (500 \times (-0.200)) = -100 + 100 = 0\,\text{kJ/mol}$$

Interpretation: $\Delta G = 0$ means the system is at *equilibrium* at this temperature; the reaction is spontaneous neither in the forward nor the reverse direction.

Final Answer: 0

Answer: (0) Go Back to Q#30

Answer Key

Section A — MCQ (Q1–Q20):

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

Section B — Numerical (Q21–Q30):

21	6	22	10
23	108	24	16
25	6	26	3
27	36	28	50
29	2	30	0