JEE Main Chemistry

Sample Paper – 12

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. For an electron in the **3d** orbital ($n = 3$, $l = 2$), which of the following correctly states the number of radial nodes, angular nodes, and total nodes?

(A) 1 radial node, 2 angular nodes, 3 total nodes

(B) 0 radial nodes, 2 angular nodes, 2 total nodes

(C) 2 radial nodes, 0 angular nodes, 2 total nodes

(D) 1 radial node, 1 angular node, 2 total nodes

Q2. In BF_3, the boron atom has an empty p orbital and the fluorine atoms have lone pairs. Which statement **correctly** describes the back bonding ($p\pi$–$p\pi$) present in BF_3 and its consequences?

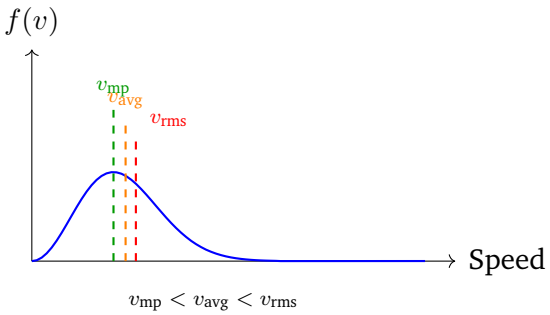
(A) BF_3 is more Lewis acidic than BCl_3 because back bonding is stronger in BF_3.

(B) The B–F bond order is exactly 1 because fluorine is too electronegative to donate lone pairs.

(C) Back bonding in BF_3 increases the B–F bond length compared to a pure single bond.

(D) Lone pairs from F donate into the empty p orbital of B (π back bonding), shortening the B–F bond and reducing the Lewis acidity of BF_3 compared to BCl_3.

Q3. The Maxwell–Boltzmann speed distribution for an ideal gas gives three characteristic speeds. Which of the following correctly orders the most probable speed (v_{mp}), average speed (v_{avg}), and root-mean-square speed (v_{rms})?



(A) $v_{mp} < v_{avg} < v_{rms}$

(B) $v_{rms} < v_{avg} < v_{mp}$

(C) $v_{avg} < v_{mp} < v_{rms}$

(D) $v_{mp} < v_{rms} < v_{avg}$

Q4. The thermal stability of Group 2 metal carbonates (MCO_3) varies across the group. Which of the following **correctly** explains the trend in thermal stability down Group 2?

(A) Thermal stability decreases down the group because larger cations polarize CO_3^{2-} more strongly, weakening the C–O bonds.

(B) $BaCO_3$ is less thermally stable than $MgCO_3$ because Ba^{2+} has a lower charge density.

(C) Thermal stability increases down the group ($BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$) because larger cations have lower charge density and stabilize CO_3^{2-} better.

(D) All Group 2 carbonates have the same thermal stability since the CO_3^{2-} anion is identical in all of them.

Q5. For a sparingly soluble salt AgCl, the solubility product is $K_{sp} = 1.8 \times 10^{-10}$ at 25 °C. If a solution contains $[Ag^+] = 2.0 \times 10^{-4}$ mol/L and $[Cl^-] = 1.0 \times 10^{-6}$ mol/L, what will happen?

(A) No precipitation; the solution is unsaturated since the ionic product is less than K_{sp}.

(B) The solution is at equilibrium with a saturated solution of AgCl.

(C) More AgCl will dissolve until equilibrium is reached.

(D) AgCl precipitates from the solution because the ionic product $[Ag^+][Cl^-]$ exceeds K_{sp}.

Q6. Phosphoric acid (H_3PO_4) is a triprotic acid with $K_{a1} = 7.5 \times 10^{-3}$, $K_{a2} = 6.2 \times 10^{-8}$, and $K_{a3} = 4.8 \times 10^{-13}$. For calculating the pH of a 0.1 M H_3PO_4 solution, which of the following approaches is **most appropriate**?

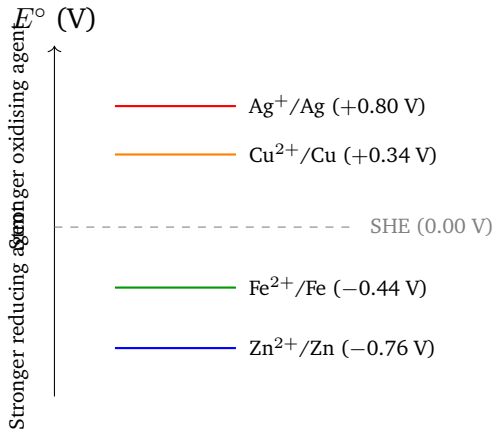
(A) Use all three dissociation constants, as each contributes significantly to the total $[H^+]$.

(B) Use only the first dissociation constant K_{a1}, since K_{a2} and K_{a3} are negligibly small compared to K_{a1}.

(C) Average the three dissociation constants and use the geometric mean K_a.

(D) Use K_{a3} because the third dissociation is rate-determining in a triprotic acid.

Q7. Using the standard electrode potential series (reduction potentials), which statement about the reaction between iron and copper sulfate solution is **correct**?



(A) Fe can displace Cu from $CuSO_4$ solution because $E^\circ(Cu^{2+}/Cu) > E^\circ(Fe^{2+}/Fe)$; the reaction Fe + $CuSO_4 \rightarrow FeSO_4$ + Cu is spontaneous.

(B) Cu can displace Fe from $FeSO_4$ solution because Cu has a higher reduction potential.

(C) Fe cannot displace Cu from $CuSO_4$ because Fe is below Cu in the activity series.

(D) Zn cannot displace Fe from $FeSO_4$ solution because Zn has a lower reduction potential than Fe.

Q8. A first-order reaction has an initial concentration $[A]_0 = 0.100\,M$ and a rate constant $k = 0.0693\,min^{-1}$. What is the concentration of A after 20 minutes, and what percentage of the original reactant remains?

(A) $[A] = 0.050\,M$; 50% of original reactant remains

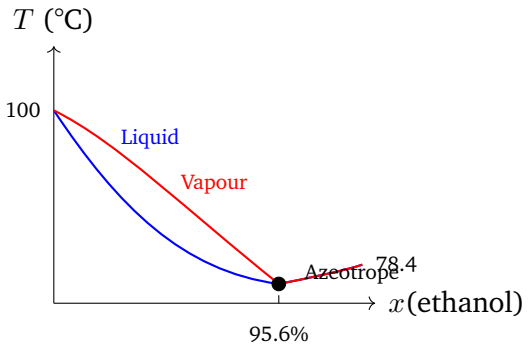
(B) $[A] = 0.010\,M$; 10% of original reactant remains

(C) $[A] = 0.025\,M$; 25% of original reactant remains

(D) $[A] = 0.075\,M$; 75% of original reactant remains

Q9. An azeotrope is formed when a mixture of two liquids cannot be separated by fractional distillation beyond a certain composition. Study the

boiling point–composition (T–x) diagram below and identify the **correct** statement about the ethanol–water system.



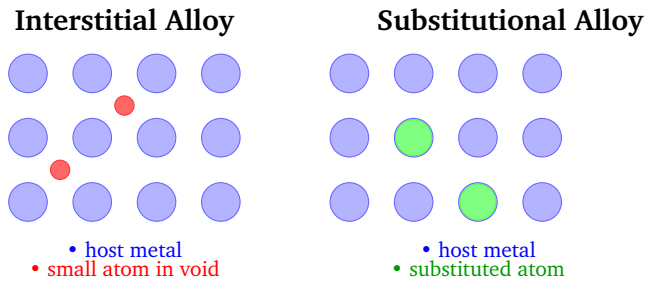
(A) Ethanol–water forms a maximum boiling azeotrope with negative deviation from Raoult's law.

(B) The azeotropic mixture of ethanol–water can be separated by fractional distillation to give pure ethanol.

(C) Ethanol and water are perfectly miscible and form an ideal solution with no azeotrope.

(D) Ethanol–water forms a **minimum** boiling azeotrope at approximately 95.6% ethanol; fractional distillation cannot separate ethanol further beyond this composition.

Q10. Alloys can be classified as **interstitial** or **substitutional** depending on how the alloying atoms are incorporated into the host lattice. Study the diagrams below and choose the statement that **correctly** distinguishes the two types.



(A) In interstitial alloys, atoms of the alloying element replace host metal atoms; in substitutional alloys, smaller atoms fill the voids.

(B) In interstitial alloys, smaller atoms (e.g., C in steel) occupy void spaces in the host metal lattice, making it harder; in substitutional alloys, one metal atom is replaced by a similarly sized atom (e.g., brass = Cu + Zn).

(C) Both interstitial and substitutional alloys require the alloying atom to have the same crystal structure as the host metal.

(D) Interstitial alloys are always more ductile than substitutional alloys.

Q11. Which of the following correctly matches the industrial process with its catalyst used in the manufacture of sulfuric acid by the **Contact process**?

(A) V_2O_5 (vanadium pentoxide) is used in the Contact process: $2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_3$.

(B) Fe (iron) is used as the catalyst in the Contact process to oxidize SO_2 to SO_3.

(C) Pt/Rh gauze is the catalyst used in the Contact process for making H_2SO_4.

(D) MnO_2 (manganese dioxide) catalyzes the oxidation of SO_2 to SO_3 in the Contact process.

Q12. Which of the following **correctly** describes the composition and use of **washing soda**?

(A) Washing soda is $NaHCO_3$ (sodium bicarbonate), used in baking as a leavening agent.

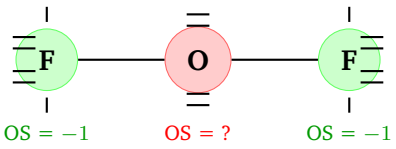
(B) Washing soda is $Ca(OH)_2$ (slaked lime), used in construction and neutralising soil acidity.

(C) Washing soda is $Na_2CO_3 \cdot 10H_2O$ (sodium carbonate decahydrate), used in the manufacture of glass, paper, and for removing permanent hardness of water.

(D) Washing soda is $Na_2SO_4 \cdot 10H_2O$ (Glauber's salt), used as a laxative.

Q13. In most compounds, oxygen has an oxidation state of -2. However, there

is an exception. The Lewis structure of OF_2 is shown below. What is the oxidation state of oxygen in OF_2, and why?



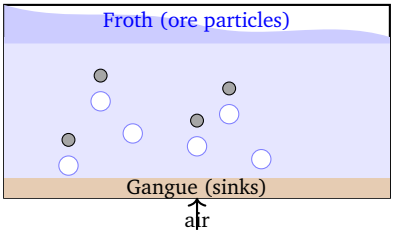
(A) Oxygen has OS $= -2$ in OF_2, and each fluorine has OS $= 0$.

(B) Oxygen has OS $= -1$ in OF_2 because fluorine is only slightly more electronegative.

(C) Oxygen has OS $= 0$ in OF_2 because it is in the elemental-like bonding situation.

(D) Oxygen has OS $= +2$ in OF_2 because fluorine (the most electronegative element) forces oxygen to be the positive partner, with each F having OS $= -1$.

Q14. Froth flotation is used for the concentration of sulfide ores. Study the schematic of a flotation cell below and identify the **correct** statement about the mechanism.



(A) In froth flotation, the gangue particles are made hydrophobic by the collector agent and float with the air bubbles, while ore particles sink.

(B) In froth flotation, a collector (e.g., sodium ethyl xanthate) makes the ore surface hydrophobic; ore particles attach to air bubbles and float as froth while hydrophilic gangue sinks.

(C) Froth flotation works by gravity separation; denser ore particles sink while less dense gangue floats.

(D) Froth flotation is used exclusively for oxide ores and is not effective for sulfide ores.

Q15. The spectrochemical series arranges ligands in order of their ability to split d orbitals. Which of the following **correctly** describes the effect of strong-field versus weak-field ligands on spin state?

(A) I^- and CO are strong-field ligands that cause spin pairing and give low-spin complexes.

(B) CN^- and NH_3 are weak-field ligands that give high-spin complexes with maximum unpaired electrons.

(C) CN^- and CO are strong-field ligands that cause spin pairing (low-spin), while I^- and Br^- are weak-field ligands that give high-spin complexes.

(D) All ligands produce the same spin state regardless of field strength, because the metal ion determines the spin.

Q16. The thiocyanate ion (SCN^-) is an ambidentate ligand that can coordinate through either its sulfur or its nitrogen atom. Which pair of complexes represents **linkage isomers**?

(A) $[Co(NH_3)_5(NCS)]^{2+}$ and $[Co(NH_3)_5(SCN)]^{2+}$

(B) $[Co(NH_3)_5Cl]^{2+}$ and $[Co(NH_3)_4Cl_2]^{+}$

(C) $[Co(en)_3]^{3+}$ and $[Co(NH_3)_6]^{3+}$

(D) cis-$[Co(NH_3)_4Cl_2]^{+}$ and trans-$[Co(NH_3)_4Cl_2]^{+}$

Q17. Clemmensen reduction and Wolff–Kishner reduction both convert a carbonyl group (C=O) to a methylene group (CH_2). Which statement **correctly** distinguishes the two methods and their preferred conditions?

(A) Both Clemmensen and Wolff–Kishner reductions use acidic conditions.

(B) Wolff–Kishner uses Zn–Hg amalgam with concentrated HCl (acidic); Clemmensen uses NH_2NH_2/KOH (basic).

(C) Clemmensen reduction is preferred for base-sensitive substrates because it uses alkaline conditions.

(D) Clemmensen reduction (Zn–Hg/conc. HCl, acidic) is preferred for acid-stable substrates; Wolff–Kishner reduction (NH_2NH_2/KOH, basic) is preferred for base-stable substrates.

Q18. What is the major product when benzonitrile (C_6H_5CN) is heated with dilute H_2SO_4 (aqueous acid hydrolysis)?

(A) Aniline ($C_6H_5NH_2$)

(B) Benzoic acid (C_6H_5COOH)

(C) Benzaldehyde (C_6H_5CHO)

(D) Benzamide ($C_6H_5CONH_2$) only, which does not hydrolyse further under dilute acid

Q19. The Lucas test ($ZnCl_2$ / conc. HCl) is used to distinguish between primary, secondary, and tertiary alcohols. Which of the following **correctly** describes the result for **2-methylpropan-2-ol** (tert-butanol)?

(A) 2-Methylpropan-2-ol gives **immediate** turbidity at room temperature because it forms a stable tertiary carbocation via S_N1 with the Lucas reagent.

(B) 2-Methylpropan-2-ol gives turbidity only after 5 minutes of warming, characteristic of a secondary alcohol.

(C) 2-Methylpropan-2-ol gives no turbidity even on heating, because tertiary alcohols do not react with Lucas reagent.

(D) 2-Methylpropan-2-ol gives turbidity after several hours at room temperature, because tertiary alcohols are slow to react with HCl.

Q20. In **aqueous solution**, the basicity of methylamine derivatives depends on the balance between the electron-donating inductive effect of methyl groups and the solvation of the protonated cation. Which of the following gives the **correct decreasing order of basicity** in aqueous solution?

(A) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(B) $NH_3 > CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N$

(C) $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

(D) $CH_3NH_2 > (CH_3)_2NH > NH_3 > (CH_3)_3N$

Section B — Numerical Value Questions (Q21–Q30) [Attempt Any 5]

Q21. How many moles of N_2 are present in 56 g of nitrogen gas? (Molar mass of $N_2 = 28$ g/mol)

(Enter the exact numerical value as your answer.)

Q22. For Ag_2S, the solubility product expression is $K_{sp} = [Ag^+]^2[S^{2-}]$. If the molar solubility of Ag_2S is s, then $[Ag^+] = 2s$ and $[S^{2-}] = s$, so $K_{sp} = (2s)^2(s) = As^3$. What is the value of A (the numerical coefficient multiplied by s^3)?

(Enter the exact numerical value as your answer.)

Q23. How many P–OH bonds (ionisable hydroxyl groups) does phosphoric acid (H_3PO_4) contain? This number equals the **basicity** (number of replaceable H atoms) of the acid.

(Enter the exact numerical value as your answer.)

Q24. When 10 g of $CaCO_3$ (molar mass $= 100$ g/mol) is heated and completely decomposes according to $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$, a total of 17.8 kJ of heat is absorbed. Calculate the standard enthalpy change ΔH in kJ/mol for the decomposition of **1 mole** of $CaCO_3$.

(Enter the exact numerical value as your answer.)

Q25. What is the mass (in grams) of 0.5 moles of O_2 gas? (Molar mass of $O_2 = 32$ g/mol)

(Enter the exact numerical value as your answer.)

Q26. How many π bonds are present in one molecule of benzene (C_6H_6) according to the Kekulé resonance structure?

(Enter the exact numerical value as your answer.)

Q27. Calculate the oxidation state of sulfur in pyrosulfuric acid, $H_2S_2O_7$ (oleum). [H $= +1$, O $= -2$]

(Enter the exact numerical value as your answer.)

Q28. How many electrons are **shared** (i.e., are bonding electrons) in the nitrogen–nitrogen triple bond of the N_2 molecule?

(Enter the exact numerical value as your answer.)

Q29. What is the oxidation state of xenon in XeO_4 (xenon tetroxide)? [O $= -2$]

(Enter the exact numerical value as your answer.)

Q30. The magnetic moment formula is $\mu = \sqrt{n(n+2)}$ BM, where n = number of unpaired electrons. Fe^{2+} has the electronic configuration [Ar]$3d^6$. In the high-spin free-ion state, calculate the value of $n(n+2)$ for Fe^{2+}.

(Enter the exact numerical value as your answer.)

Detailed Solutions

Q1.

Solution

Concept — Nodes in Atomic Orbitals: For an orbital with principal quantum number n and azimuthal quantum number l:

- Radial (spherical) nodes $= n - l - 1$
- Angular (planar/conical) nodes $= l$
- Total nodes $= n - 1$

Step 1 — Identify quantum numbers for 3d: For the 3d orbital: $n = 3$, $l = 2$.

Step 2 — Calculate nodes:

$$\text{Radial nodes} = n - l - 1 = 3 - 2 - 1 = 0$$

$$\text{Angular nodes} = l = 2$$

$$\text{Total nodes} = n - 1 = 3 - 1 = 2$$

So the 3d orbital has **0 radial nodes**, **2 angular nodes**, and **2 total nodes**.

Why other options are wrong:

- Option A (1 radial, 2 angular, 3 total): Radial nodes $= 0$ for 3d, not 1; total $= n - 1 = 2$, not 3.
- Option C (2 radial, 0 angular): This would be a 3s orbital ($l = 0$: 0 angular nodes; $n - l - 1 = 2$ radial).
- Option D (1 radial, 1 angular): This does not correspond to any valid combination for $n = 3$.

Final Answer: 0 radial nodes, 2 angular nodes, 2 total nodes $\Rightarrow$ Option B

Answer: (B) Go Back to Q#1

Q2.

Solution

Concept — Back Bonding (pπ–pπ) in BF_3: Boron in BF_3 is sp^2 hybridised and has an empty, unhybridised p orbital perpendicular to the molecular plane. Each fluorine atom has lone pairs in p orbitals that can overlap with this empty p orbital on boron.

Step 1 — Nature of back bonding: F lone pairs donate into the empty p orbital of B (pπ–pπ back bonding). This gives the B–F bond partial double bond character.

Step 2 — Consequences:

- B–F bond length is *shorter* than expected for a pure single bond (observed: 130 pm vs. predicted single bond ≈ 152 pm).
- BF_3 is *less* Lewis acidic than BCl_3 or BBr_3 because back bonding partially satisfies the empty orbital of B, reducing its electron deficiency. In BCl_3 and BBr_3, the p–p orbital size mismatch (2p of B vs. 3p of Cl or 4p of Br) makes back bonding less effective.

Why other options are wrong:

- Option A: BF_3 is *less* Lewis acidic than BCl_3 (not more), because back bonding is *more* effective in BF_3.
- Option B: The B–F bond order is between 1 and 2 (partial double bond character), not exactly 1.
- Option C: Back bonding *decreases* the B–F bond length (shortens it), not increases.

Final Answer: F lone pair donates into empty p orbital of B; B–F bond is shorter; BF_3 is less Lewis acidic than $BCl_3 \Rightarrow$ Option D

Answer: (D) Go Back to Q#2

Q3.

Solution

Concept — Maxwell–Boltzmann Speed Distribution: The three characteristic speeds for an ideal gas at temperature T with molar mass M are:

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

Step 1 — Compare magnitudes: The ratio of the coefficients under the square root: $\frac{2RT}{M}$ vs. $\frac{8RT}{\pi M}$ vs. $\frac{3RT}{M}$.

Comparing: $2 < \frac{8}{\pi} \approx 2.546 < 3$.

Step 2 — Conclude ordering:

$$v_{\text{mp}} < v_{\text{avg}} < v_{\text{rms}}$$

Numerically: $v_{\text{mp}} : v_{\text{avg}} : v_{\text{rms}} \approx 1.414 : 1.596 : 1.732$ (in units of $\sqrt{RT/M}$).

The most probable speed is the peak of the Maxwell distribution (the mode), the average speed is the mean, and the rms speed is the square root of the mean-square speed (the highest of the three).

Why other options are wrong:

- Option B: This is the reverse order, which is incorrect.
- Option C: v_{avg} lies between v_{mp} and v_{rms}, not below v_{mp}.
- Option D: $v_{\text{rms}} > v_{\text{avg}}$, so this order is incorrect.

Final Answer: $v_{\text{mp}} < v_{\text{avg}} < v_{\text{rms}} \Rightarrow$ Option A

Answer: (A) Go Back to Q#3

Q4.

Solution

Concept — Thermal Stability of Group 2 Carbonates: The thermal decomposition of MCO_3 (s) $\rightarrow$ MO(s) + CO_2(g) requires breaking the C–O bond in CO_3^{2-}. Smaller, more highly charged cations (e.g., Be^{2+}, Mg^{2+}) have higher charge density and polarize the CO_3^{2-} ion more strongly, weakening the C–O bond and facilitating decomposition. Larger cations (e.g., Ba^{2+}) have lower charge density and stabilize CO_3^{2-} better.

Step 1 — Trend in charge density down Group 2: As we go down Group 2, the ionic radius increases while the charge remains $+2$. Therefore, charge density (charge/size) decreases down the group: $Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$.

Step 2 — Effect on thermal stability: Lower charge density $\Rightarrow$ less polarization of CO_3^{2-} $\Rightarrow$ CO_3^{2-} is more stable $\Rightarrow$ higher thermal stability. So thermal stability increases: $BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$.

Why other options are wrong:

- Option A: Larger cations have *lower* charge density and polarize CO_3^{2-} *less* strongly; thermal stability therefore *increases* (not decreases) down the group.
- Option B: $BaCO_3$ is actually *more* thermally stable than $MgCO_3$ because Ba^{2+} has lower charge density.
- Option D: Thermal stability clearly varies across the group; they are not all equal.

Final Answer: Thermal stability increases down Group 2: $BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3 \Rightarrow$ Option C

Answer: (C) Go Back to Q#4

Q5.

Solution

Concept — Ionic Product and Precipitation: For a sparingly soluble salt, precipitation occurs when the ionic product (IP) exceeds K_{sp}. If IP $< K_{sp}$, the solution is unsaturated; if IP $= K_{sp}$, it is at equilibrium (saturated); if IP $> K_{sp}$, precipitation occurs.

Step 1 — Calculate the ionic product:

$$\text{IP} = [Ag^+][Cl^-] = (2.0 \times 10^{-4})(1.0 \times 10^{-6}) = 2.0 \times 10^{-10}$$

Step 2 — Compare IP with K_{sp}:

$$\text{IP} = 2.0 \times 10^{-10} > K_{sp} = 1.8 \times 10^{-10}$$

Since IP $> K_{sp}$, the solution is supersaturated and AgCl will precipitate.

Why other options are wrong:

- Option A: IP is *greater* than K_{sp}, not less, so the solution is not unsaturated.
- Option B: The solution is not at equilibrium; IP $\neq K_{sp}$.
- Option C: AgCl will precipitate (not dissolve) since IP $> K_{sp}$.

Final Answer: IP $= 2.0 \times 10^{-10} > K_{sp} = 1.8 \times 10^{-10} \Rightarrow$ AgCl precipitates $\Rightarrow$ Option D

Answer: (D) Go Back to Q#5

Q6.

Solution

Concept — pH of Polyprotic Acid: H_3PO_4 undergoes three stepwise dissociations:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-, \quad K_{a1} = 7.5 \times 10^{-3}$$
$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}, \quad K_{a2} = 6.2 \times 10^{-8}$$
$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}, \quad K_{a3} = 4.8 \times 10^{-13}$$

Step 1 — Compare magnitudes: $K_{a1} = 7.5 \times 10^{-3}$ is approximately 10^5 times larger than $K_{a2} = 6.2 \times 10^{-8}$, and K_{a3} is negligibly tiny.

Step 2 — Determine which dissociation dominates: Since $K_{a1} \gg K_{a2} \gg K_{a3}$, virtually all the $[H^+]$ produced comes from the first dissociation. The second and third dissociations contribute negligible $[H^+]$ and can be ignored for pH calculation.

Why other options are wrong:

- Option A: The second and third dissociations contribute negligibly (K_{a2} is $10^5\times$ smaller than K_{a1}).
- Option C: There is no standard practice of averaging dissociation constants.
- Option D: K_{a3} is the smallest; using it alone would vastly underestimate $[H^+]$.

Final Answer: Use only K_{a1} for pH calculation of 0.1 M H_3PO_4 $\Rightarrow$ Option B

Answer: (B) Go Back to Q#6

Q7.

Solution

Concept — Standard Electrode Potential and Reactivity: A metal with a *lower* (more negative) standard reduction potential is a stronger reducing agent and can displace metals with *higher* (more positive) reduction potentials from their salt solutions. The reaction is spontaneous when $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} > 0$.

Step 1 — Check Fe displacing Cu: Fe acts as anode (oxidized): $E^\circ(Fe^{2+}/Fe) = -0.44\,V$
Cu^{2+} reduced (cathode): $E^\circ(Cu^{2+}/Cu) = +0.34\,V$

$$E^\circ_{\text{cell}} = +0.34 - (-0.44) = +0.78\,V > 0 \quad \text{(spontaneous)}$$

Reaction: $\text{Fe}(s) + \text{CuSO}_4(\text{aq}) \rightarrow \text{FeSO}_4(\text{aq}) + \text{Cu}(s)$.

Why other options are wrong:

- Option B: Cu *cannot* displace Fe from FeSO_4 because $E^\circ(\text{Cu}^{2+}/\text{Cu}) > E^\circ(\text{Fe}^{2+}/\text{Fe})$; Cu would need to be oxidised (act as reducing agent), but Cu is below Fe in the activity series for this purpose.
- Option C: Fe *is* above Cu in the activity series (more reactive); it can displace Cu.
- Option D: Zn *can* displace Fe because $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76\,\text{V} < E^\circ(\text{Fe}^{2+}/\text{Fe}) = -0.44\,\text{V}$; $E^\circ_{\text{cell}} > 0$.

Final Answer: Fe displaces Cu from CuSO_4; $E^\circ_{\text{cell}} = +0.78\,\text{V}$ (spontaneous) $\Rightarrow$ Option A

Answer: (A) Go Back to Q#7

Q8.

Solution

Concept — Integrated First-Order Rate Law: For a first-order reaction:

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

Step 1 — Identify the half-life: $k = 0.0693\,\text{min}^{-1}$.

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{0.0693} = 10\,\text{min}$$

Step 2 — Apply at $t = 20$ min (two half-lives):

$$[\text{A}] = [\text{A}]_0 \times e^{-0.0693\times 20} = 0.100 \times e^{-1.386} = 0.100 \times \left(\frac{1}{4}\right) = 0.025\,\text{M}$$

Fraction remaining $= \dfrac{0.025}{0.100} = 0.25 = \mathbf{25}\%$.
(Alternatively: after each half-life, concentration halves. After $t = 10$ min: 0.050 M; after $t = 20$ min: 0.025 M.)

Why other options are wrong:

- Option A (0.050 M, 50%): This corresponds to $t = 10$ min (one half-life), not 20 min.
- Option B (0.010 M, 10%): This would require approximately $3.32 \times t_{1/2} \approx 33$

min.

- Option D (0.075 M, 75%): After 20 min, 75% is *consumed*, not remaining.

Final Answer: $[\mathrm{A}] = 0.025\,\mathrm{M}$; 25% of original reactant remains $\Rightarrow \boxed{0.025\,\mathrm{M}}$

Answer: (C) Go Back to Q#8

Q9.

Solution

Concept — Azeotropes and Raoult's Law: An azeotrope forms when the vapour composition equals the liquid composition at a certain temperature, making separation by fractional distillation impossible beyond that point.

Step 1 — Type of azeotrope for ethanol–water: Ethanol and water show *positive* deviation from Raoult's law (intermolecular forces in the mixture are weaker than in pure components). This gives a *minimum boiling* azeotrope: the boiling point of the mixture passes through a minimum at the azeotropic composition.

Step 2 — Azeotropic composition and consequence: The ethanol–water azeotrope boils at $78.1\,^{\circ}\mathrm{C}$ (compared to pure ethanol at $78.4\,^{\circ}\mathrm{C}$ and water at $100\,^{\circ}\mathrm{C}$) at a composition of approximately 95.6% ethanol by volume (or $\approx 89.4\%$ by mole). Beyond this point, fractional distillation cannot enrich the ethanol further; the distillate always has the azeotropic composition.

Why other options are wrong:

- Option A: Ethanol–water shows *positive* deviation (not negative); it forms a *minimum* (not maximum) boiling azeotrope.
- Option B: The azeotrope *cannot* be separated by fractional distillation; other methods (e.g., addition of benzene as entrainer, molecular sieves) are needed.
- Option C: Ethanol–water is not ideal; it does form an azeotrope.

Final Answer: Ethanol–water forms a minimum boiling azeotrope at $\approx 95.6\%$ ethanol; fractional distillation cannot go beyond this $\Rightarrow \boxed{\text{Option D}}$

Answer: (D) Go Back to Q#9

Q10.

Solution

Concept — Interstitial vs. Substitutional Alloys: The classification of alloys depends on the relative size of the alloying atoms and how they fit in the host lattice.

Step 1 — Interstitial alloys: Formed when *small* atoms (C, N, H, B) occupy the interstitial (void) spaces between the host metal atoms without displacing them. The lattice structure of the host is retained but distorted, making the alloy *harder* and *less ductile*. Example: Steel (Fe + C), where carbon atoms fit in the octahedral voids of the iron lattice.

Step 2 — Substitutional alloys: Formed when host metal atoms are *replaced* by atoms of the alloying metal of *similar size* (within $\sim 15\%$). The lattice structure remains essentially the same. Example: Brass (Cu + Zn), where Zn atoms replace some Cu atoms in the lattice.

Why other options are wrong:

- Option A: This reverses the descriptions of interstitial and substitutional alloys.
- Option C: The same crystal structure is NOT required; interstitial alloys rely on void space, not crystal structure similarity.
- Option D: Interstitial alloys are generally *harder* and *less* ductile (not more ductile) than pure metals.

Final Answer: Interstitial: smaller atoms in voids (e.g., steel); Substitutional: similar-sized atoms replace host (e.g., brass) $\Rightarrow$ Option B

Answer: (B) Go Back to Q#10

Q11.

Solution

Concept — Industrial Catalysts: Different industrial processes use specific catalysts:

- Contact process (H_2SO_4 manufacture): V_2O_5 (vanadium pentoxide)
- Haber process (NH_3 manufacture): Fe (iron) with Mo promoter
- Ostwald process (HNO_3 manufacture): Pt/Rh gauze

Step 1 — The Contact process reaction:

$$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5,\ 450\,^\circ C} 2SO_3(g)$$

SO_3 is then absorbed in concentrated H_2SO_4 to form oleum ($H_2S_2O_7$), which is diluted to give H_2SO_4.

Why other options are wrong:

- Option B: Fe is used in the Haber process (NH_3 synthesis), not the Contact process.
- Option C: Pt/Rh gauze is used in the Ostwald process ($NH_3 \rightarrow NO \rightarrow HNO_3$), not the Contact process.
- Option D: MnO_2 is used in lab preparation of O_2 from $KClO_3$, not in the Contact process.

Final Answer: V_2O_5 is the catalyst in the Contact process $\Rightarrow$ Option A

Answer: (A) Go Back to Q#11

Q12.

Solution

Concept — Important Sodium and Calcium Compounds (s-Block):

- Washing soda: $Na_2CO_3 \cdot 10H_2O$
- Baking soda: $NaHCO_3$
- Slaked lime: $Ca(OH)_2$
- Glauber's salt: $Na_2SO_4 \cdot 10H_2O$

Step 1 — Uses of washing soda ($Na_2CO_3 \cdot 10H_2O$):

- Manufacture of glass (Na_2CO_3 is a flux): combined with SiO_2 and $CaCO_3$ at high temperature.
- Manufacture of paper, soap, and caustic soda.
- Water softening: removes permanent hardness by precipitating Ca^{2+} and Mg^{2+} as their insoluble carbonates.
- Domestic cleaning (laundry soda).

Why other options are wrong:

- Option A: $NaHCO_3$ (baking soda), not washing soda, is used in baking. On heating: $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$.

- Option B: $Ca(OH)_2$ (slaked lime) is used in construction and agriculture, not washing soda.
- Option D: Glauber's salt is $Na_2SO_4 \cdot 10H_2O$, used as a laxative and in dye industry, not $Na_2CO_3 \cdot 10H_2O$.

Final Answer: Washing soda = $Na_2CO_3 \cdot 10H_2O$; used in glass, paper manufacture and water softening $\Rightarrow$ Option C

Answer: (C) Go Back to Q#12

Q13.

Solution

Concept — Oxidation State of Oxygen (Anomalous Cases): Oxygen normally has OS $= -2$, but it can deviate in compounds with fluorine (the only element more electronegative than oxygen). In any O–F compound, fluorine is always -1 and oxygen is forced to be positive.

Step 1 — Determine OS of O in OF_2: OF_2 is electrically neutral. Let OS of O be x; each F has OS $= -1$.

$$x + 2(-1) = 0 \implies x = +2$$

Step 2 — Significance: OS $= +2$ is the *highest known oxidation state* of oxygen. This arises solely because F is the only element more electronegative than O, forcing O to carry the positive partial charge.

Why other options are wrong:

- Option A: OS of O $= -2$ is impossible here if each F is -1; that would give total charge $= -2 + (-2) = -4 \neq 0$.
- Option B: OS of O $= -1$ would require $-1 + 2(-1) = -3 \neq 0$ (not balanced).
- Option C: OS of O $= 0$ would give $0 + 2(-1) = -2 \neq 0$ (not balanced).

Final Answer: Oxygen has OS $= +2$ in OF_2 $\Rightarrow$ $+2$

Answer: (D) Go Back to Q#13

Q14.

Solution

Concept — Froth Flotation for Sulfide Ores: Froth flotation exploits the difference in wettability (hydrophobicity) between ore particles and gangue (unwanted rock).

Step 1 — Mechanism:

(a) Crushed ore is mixed with water and a *collector* agent (e.g., sodium ethyl xanthate or potassium ethyl xanthate for sulfide ores).
(b) The collector adsorbs on the ore surface, making it *hydrophobic* (water-repelling).
(c) Air is blown through the mixture; hydrophobic ore particles adhere to air bubbles and rise to the surface as *froth*.
(d) The hydrophilic gangue (silica, rock) remains wetted and *sinks* to the bottom.
(e) A *frother* (pine oil) stabilizes the froth.
(f) The froth (containing ore) is skimmed off.

Step 2 — Key principle: The process exploits selective hydrophobicity: ore particles float, gangue sinks.

Why other options are wrong:

- Option A: The collector makes the *ore* (not gangue) hydrophobic; it is the ore that floats.
- Option C: Froth flotation is *not* a gravity separation method; it uses surface chemistry and air bubbles.
- Option D: Froth flotation is specifically designed for *sulfide* ores (e.g., PbS, ZnS, $CuFeS_2$); oxide and silicate ores use other methods.

Final Answer: Collector makes ore surface hydrophobic; ore floats as froth; gangue sinks $\Rightarrow$ Option B

Answer: (B) Go Back to Q#14

Q15.

Solution

Concept — Spectrochemical Series and Spin State: Ligands are arranged in the spectrochemical series based on their ability to split the d orbitals of the central metal ion (crystal field splitting energy, Δ_o):

$$I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 < en < CN^- < CO$$

(weak-field $\rightarrow$ strong-field)

Step 1 — Effect on spin state:

- **Strong-field ligands** (CN^-, CO): Large $\Delta_o \Rightarrow$ energy cost of promotion $>$ pairing energy $\Rightarrow$ electrons pair up $\Rightarrow$ *low-spin* complex (fewer unpaired electrons).
- **Weak-field ligands** (I^-, Br^-): Small $\Delta_o \Rightarrow$ electrons spread across all d orbitals $\Rightarrow$ *high-spin* complex (maximum unpaired electrons, Hund's rule).

Why other options are wrong:

- Option A: I^- is a *weak*-field ligand (not strong-field); CO is strong-field. They are opposite.
- Option B: CN^- is a *strong*-field ligand; NH_3 is a moderate-field ligand. Both are not weak-field.
- Option D: The spin state depends critically on the ligand field strength, not just the metal ion.

Final Answer: CN^- and CO are strong-field (low-spin); I^- and Br^- are weak-field (high-spin) $\Rightarrow$ Option C

Answer: (C) Go Back to Q#15

Q16.

Solution

Concept — Linkage Isomerism: Linkage isomers arise when an ambidentate ligand (one that can coordinate through more than one donor atom) is bonded to the metal through different atoms. The overall molecular formula is the same, but the bonding site differs.

Step 1 — SCN^- as ambidentate ligand: SCN^- (thiocyanate) can coordinate through:

- Nitrogen atom: *isothiocyanato* group, written NCS (N-bonded), denoted –NCS in the formula.
- Sulfur atom: *thiocyanato* group, written SCN (S-bonded), denoted –SCN in the formula.

Step 2 — Identify the linkage isomers: $[Co(NH_3)_5(NCS)]^{2+}$: cobalt is bonded to N of SCN^- (N-bonded isothiocyanato).
$[Co(NH_3)_5(SCN)]^{2+}$: cobalt is bonded to S of SCN^- (S-bonded thiocyanato).
Both have the same formula $Co(NH_3)_5(NCS \text{ or } SCN)]^{2+}$. These are **linkage isomers**.

Why other options are wrong:

- Option B: These differ in the number of Cl and NH_3 ligands and their charges $\Rightarrow$ different complexes (not isomers of each other in the linkage sense).
- Option C: $[Co(en)_3]^{3+}$ and $[Co(NH_3)_6]^{3+}$ have different ligands entirely $\Rightarrow$ these are coordination isomers (different ligands), not linkage isomers.
- Option D: cis- and trans-$[Co(NH_3)_4Cl_2]^+$ are *geometric* isomers, not linkage isomers.

Final Answer: $[Co(NH_3)_5(NCS)]^{2+}$ and $[Co(NH_3)_5(SCN)]^{2+}$ are linkage isomers $\Rightarrow$ Option A

Answer: (A) Go Back to Q#16

Q17.

Solution

Concept — Clemmensen vs. Wolff–Kishner Reduction: Both methods reduce carbonyl groups (C=O) to methylene groups (CH_2) in one synthetic step but under completely opposite conditions.

Step 1 — Clemmensen Reduction:

- Reagents: Zn–Hg amalgam (zinc amalgam) + concentrated HCl.
- Conditions: Strongly *acidic*.
- Use: Preferred for substrates that are stable under acidic conditions (acid-stable substrates) but sensitive to base.
- Example: Reduction of ketones to alkanes in Friedel-Crafts acylation products.

Step 2 — Wolff–Kishner Reduction:

- Reagents: Hydrazine (NH_2NH_2) + KOH (or NaOH) in a high-boiling solvent (e.g., ethylene glycol).
- Conditions: Strongly *basic*, high temperature.
- Use: Preferred for acid-sensitive substrates (base-stable substrates).
- Mechanism: Carbonyl $\rightarrow$ hydrazone $\rightarrow$ N_2 + alkane.

Why other options are wrong:

- Option A: Not both acidic; Wolff–Kishner uses strongly basic conditions.
- Option B: This swaps the reagents; Wolff–Kishner uses NH_2NH_2/KOH (basic), and Clemmensen uses Zn–Hg/HCl (acidic).
- Option C: Clemmensen uses acidic (not alkaline) conditions.

Final Answer: Clemmensen = Zn–Hg/conc. HCl (acidic); Wolff–Kishner = NH_2NH_2/KOH (basic) $\Rightarrow$ Option D

Answer: (D) Go Back to Q#17

Q18.

Solution

Concept — Acid Hydrolysis of Nitriles: Nitriles (R–C≡N) undergo stepwise hydrolysis in the presence of acid or base:

$$\text{R–CN} \xrightarrow{H^+/H_2O} \text{RCONH}_2 \xrightarrow{H^+/H_2O} \text{RCOOH} + NH_4^+$$

Under dilute acid conditions with sufficient water and heating, the reaction proceeds all the way to the carboxylic acid.

Step 1 — Apply to benzonitrile:

$$C_6H_5CN \xrightarrow{\text{dil. } H_2SO_4, \Delta} C_6H_5COOH \text{ (benzoic acid)} + NH_4^+$$

Step 2 — Contrast with reduction: If $LiAlH_4$ were used, the nitrile would be *reduced* to the primary amine: $C_6H_5CN \rightarrow C_6H_5CH_2NH_2$. But the question specifies acid hydrolysis, which gives the acid.

Why other options are wrong:

- Option A (aniline, $C_6H_5NH_2$): Aniline is obtained by reduction of nitrobenzene ($C_6H_5NO_2$), not by acid hydrolysis of benzonitrile.
- Option C (benzaldehyde, C_6H_5CHO): Benzaldehyde is not formed by hydrol-

ysis of benzonitrile.

- Option D (benzamide only): Under dilute H_2SO_4 with heating, benzamide is the intermediate; with sufficient time/reflux, it hydrolyses further to benzoic acid.

Final Answer: $C_6H_5CN + \text{dil. } H_2SO_4 \xrightarrow{\Delta} C_6H_5COOH$ (benzoic acid) $\Rightarrow$ $\boxed{C_6H_5COOH}$

Answer: (B) Go Back to Q#18

Q19.

Solution

Concept — Lucas Test for Alcohols: The Lucas test uses Lucas reagent (anhydrous $ZnCl_2$ + conc. HCl) and works by converting the OH group to Cl, generating an alkyl chloride (insoluble in the aqueous reagent), which appears as turbidity.

Step 1 — Mechanism and reactivity: The reaction proceeds via S_N1 (for 3° and 2°) or S_N2 (for 1°):

- **Tertiary alcohols** (e.g., 2-methylpropan-2-ol): Form a stable 3° carbocation instantly $\Rightarrow$ **immediate turbidity at room temperature**.
- **Secondary alcohols**: Turbidity after warming for 5 minutes.
- **Primary alcohols**: No turbidity at room temperature; very slow reaction even on heating (or requires heating for a long time).

Step 2 — Result for 2-methylpropan-2-ol: $(CH_3)_3COH + HCl \xrightarrow{ZnCl_2} (CH_3)_3CCl + H_2O$ (immediate, via stable 3° carbocation).

Why other options are wrong:

- Option B (turbidity after 5 min, warming): This is the result for a secondary alcohol (e.g., 2-butanol), not tertiary.
- Option C (no turbidity): Tertiary alcohols react *immediately*; this response characterizes primary alcohols.
- Option D (turbidity after several hours): Tertiary alcohols react very quickly at room temperature; multi-hour delays are not observed.

Final Answer: 2-Methylpropan-2-ol gives immediate turbidity with Lucas reagent $\Rightarrow$ $\boxed{\text{Option A}}$

Answer: (A) Go Back to Q#19

Q20.

Solution

Concept — Basicity of Amines in Aqueous Solution: The basicity of amines in aqueous solution depends on two competing factors:

(a) **Inductive effect**: More methyl groups $\Rightarrow$ higher electron density on N $\Rightarrow$ stronger base.
(b) **Solvation of cation**: The protonated amine (ammonium cation) must be stabilized by solvation. More alkyl groups $\Rightarrow$ bulkier cation $\Rightarrow$ poorer solvation $\Rightarrow$ lower basicity.

Step 1 — Analyze each amine:

- NH_3 ($pK_b = 4.74$): Weakest base; no inductive donation.
- CH_3NH_2 ($pK_b \approx 3.36$): One methyl group; stronger than NH_3.
- $(CH_3)_2NH$ ($pK_b \approx 3.27$): Two methyl groups; inductive effect stronger; solvation still adequate $\Rightarrow$ **most basic** in water.
- $(CH_3)_3N$ ($pK_b \approx 4.19$): Three methyl groups give maximum inductive effect, but the bulky trimethylammonium ion $(CH_3)_3NH^+$ is poorly solvated by water $\Rightarrow$ basicity drops below $(CH_3)_2NH$.

Step 2 — Decreasing order of basicity in water: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

Why other options are wrong:

- Option A: This is the gas-phase order, not the aqueous order. In gas phase, $(CH_3)_3N$ is most basic because solvation doesn't apply.
- Option B: This is the reverse order, entirely incorrect.
- Option D: Places CH_3NH_2 above $(CH_3)_2NH$, which is not the aqueous basicity order.

Final Answer: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3 \Rightarrow$ Option C

Answer: (C) Go Back to Q#20

Q21.

Solution

Concept — Mole Concept: Number of moles $= \dfrac{\text{mass (g)}}{\text{molar mass (g/mol)}}$.

Step 1 — Calculate moles of N_2:

$$n(\mathrm{N_2}) = \frac{56\ \mathrm{g}}{28\ \mathrm{g/mol}} = \boxed{2}\ \mathrm{mol}$$

Answer: (2) Go Back to Q#21

Q22.

Solution

Concept — Solubility Product Expression: For $Ag_2S \rightleftharpoons 2Ag^+ + S^{2-}$, if molar solubility is s:

$$[\mathrm{Ag^+}] = 2s, \quad [\mathrm{S^{2-}}] = s$$

$$K_{sp} = [\mathrm{Ag^+}]^2[\mathrm{S^{2-}}] = (2s)^2(s) = 4s^2 \times s = 4s^3$$

Step 1 — Identify the coefficient A: $K_{sp} = A \cdot s^3$ where $A = (2)^2 \times 1 = \boxed{4}$

Answer: (4) Go Back to Q#22

Q23.

Solution

Concept — Structure of Phosphoric Acid: H_3PO_4 has the structure where the phosphorus atom is bonded to:

- 3 hydroxyl groups (P–OH), each contributing one ionisable proton.
- 1 P=O (double bond to oxygen, non-ionisable).

Step 1 — Count P–OH bonds: Number of P–OH bonds = 3 (corresponding to the 3 ionisable H atoms, giving basicity = 3).

$$\text{Number of P–OH bonds} = \boxed{3}$$

(Note: Compare with H_3PO_3 (phosphorous acid) which has only 2 P–OH bonds and basicity = 2, and H_3PO_2 (hypophosphorous acid) which has 1 P–OH bond and basicity = 1.)

Answer: (3) Go Back to Q#23

Q24.

Solution

Concept — Enthalpy from Calorimetry: The enthalpy change per mole is scaled up from the measured heat for the given mass.

Step 1 — Calculate moles of $CaCO_3$:

$$n(\text{CaCO}_3) = \frac{10\,\text{g}}{100\,\text{g/mol}} = 0.1\,\text{mol}$$

Step 2 — Calculate ΔH per mole: Heat absorbed for 0.1 mol $= 17.8\,\text{kJ}$.

$$\Delta H = \frac{17.8\,\text{kJ}}{0.1\,\text{mol}} = \boxed{178}\,\text{kJ/mol}$$

The decomposition $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ is endothermic with $\Delta H = +178\,\text{kJ/mol}$.

Answer: (178) Go Back to Q#24

Q25.

Solution

Concept — Mass from Moles: Mass $=$ moles $\times$ molar mass.

Step 1 — Calculate mass of O_2:

$$m(\text{O}_2) = 0.5\,\text{mol} \times 32\,\text{g/mol} = \boxed{16}\,\text{g}$$

Answer: (16) Go Back to Q#25

Q26.

Solution

Concept — π Bonds in Benzene: In the Kekulé structure of benzene, there are 3 C=C double bonds, each containing 1 σ bond and 1 π bond. The 6 C–H bonds and 6 C–C σ bonds are all sigma bonds.

Step 1 — Count π bonds: Benzene (C_6H_6) has 3 C=C double bonds in the Kekulé

structure $\Rightarrow$ 3 π bonds.

$$\text{Number of } \pi \text{ bonds in benzene} = \boxed{3}$$

(In the molecular orbital description, these 3 π bonds are delocalised into a π system, but from the Lewis/Kekulé perspective, there are 3.)

Answer: (3) Go Back to Q#26

Q27.

Solution

Concept — Oxidation State Calculation in Pyrosulfuric Acid: In $H_2S_2O_7$: H $= +1$, O $= -2$, and S $= x$ (unknown).

Step 1 — Apply charge balance: $H_2S_2O_7$ is electrically neutral:

$$2(+1) + 2(x) + 7(-2) = 0$$

$$2 + 2x - 14 = 0 \implies 2x = 12 \implies x = +6$$

Step 2 — Verify with structure: $H_2S_2O_7$ (pyrosulfuric acid / oleum) can be viewed as 2 H_2SO_4 molecules joined by loss of H_2O: structure is HO–SO_2–O–SO_2–OH. In H_2SO_4, S has OS $= +6$. Therefore, S in $H_2S_2O_7$ also has OS $= +6$.

$$\text{Oxidation state of S in } H_2S_2O_7 = \boxed{+6}$$

Answer: (6) Go Back to Q#27

Q28.

Solution

Concept — Electrons in a Triple Bond: A single bond consists of 1 electron pair (2 electrons); a double bond consists of 2 electron pairs (4 electrons); a triple bond consists of 3 electron pairs (6 electrons).

Step 1 — Electrons in N≡N: The N≡N triple bond consists of 1 σ bond + 2 π bonds $= 3$ bonding electron pairs $= 6$ bonding electrons.

$$\text{Shared (bonding) electrons in N} \equiv \text{N} = 3 \times 2 = \boxed{6}$$

(N also has 1 lone pair each, for a total of 10 electrons on each N; but those 2 lone

pairs are *not* shared/bonding.)

Answer: (6) Go Back to Q#28

Q29.

Solution

Concept — Oxidation State of Xenon in XeO_4: In XeO_4, oxygen has its normal OS $= -2$. Let OS of Xe be x.

Step 1 — Apply charge balance (XeO_4 is neutral):

$$x + 4(-2) = 0 \implies x = +8$$

Step 2 — Significance: OS $= +8$ is the *highest known oxidation state* for xenon (and among the highest for any element). Xenon tetroxide (XeO_4) is a very powerful oxidizing agent. Other xenon oxides: XeO (OS $= +2$, if it existed), XeO_2 (OS $= +4$), XeO_3 (OS $= +6$), XeO_4 (OS $= +8$).

$$\text{Oxidation state of Xe in } XeO_4 = \boxed{+8}$$

Answer: (8) Go Back to Q#29

Q30.

Solution

Concept — Magnetic Moment of Fe^{2+}: $\mu = \sqrt{n(n+2)}$ BM, where n = number of unpaired electrons.

Step 1 — Electronic configuration of Fe^{2+}: Fe: [Ar]$3d^6 4s^2$. Remove 2 electrons (from 4s first): Fe^{2+}: [Ar]$3d^6$.

Step 2 — Count unpaired electrons in high-spin $3d^6$: In high-spin free ion (Hund's rule):

$$3d^6: \quad \uparrow\downarrow \quad \uparrow \quad \uparrow \quad \uparrow \quad \uparrow$$

The 6 electrons fill: one pair in the first orbital, then one each in the remaining four orbitals $\Rightarrow$ **4 unpaired electrons** ($n = 4$).

Step 3 — Calculate $n(n+2)$:

$$n(n+2) = 4 \times (4+2) = 4 \times 6 = \boxed{24}$$

(Magnetic moment $\mu = \sqrt{24} \approx 4.90\,\text{BM}$, consistent with the experimental value for high-spin Fe^{2+} complexes.)

Answer: (24) Go Back to Q#30

Answer Key

Section A (MCQ):

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

Section B (Numerical Value):

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
21	2	22	4						
23	3	24	178						
25	16	26	3						
27	6	28	6						
29	8	30	24						