Odisha CPET 2025 Chemistry (Pilot Q1-10) Question Paper with Solutions

General Instructions

(i) This booklet contains 10 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 10 single-correct multiple-choice questions.

(iii) Attempt each question on your own before reviewing the given solution.

1. How many lines are produced when an electron jumps from the fifth to the second orbit for a hydrogen atom?

(A) 8

(B) 10

(C) 15

(D) 6

Correct Answer: (D) 6

Solution:

Step 1: When an electron falls from a higher orbit to a lower orbit, it does not have to jump in one shot. It can also stop at any orbit lying in between, on its way down to the final orbit. So we must count every orbit that lies between the starting orbit and the final orbit, both included. Here the electron starts at $n_2 = 5$ and ends at $n_1 = 2$. The orbits involved are $n = 2, 3, 4, 5$, which is 4 orbits in total.

Step 2: Every pair of these orbits gives one spectral line, since a line is produced for every possible jump between two levels. The number of ways to choose 2 orbits out of n orbits is

$$\frac{n(n-1)}{2}$$

Step 3: Put $n = 4$:

$$\frac{4 \times 3}{2} = \frac{12}{2} = 6$$

So the electron cascading from the 5th orbit down to the 2nd orbit produces 6 spectral lines.

$$\boxed{6 \text{ spectral lines}}$$

Quick Tip: Count all the orbits between the start and end level, then work out how many pairs of orbits that gives.

2. How many electrons in an atom have the following quantum numbers? $N = 3, l = 0$

(A) 4

(B) 2

(C) 6

(D) 8

Correct Answer: (B) 2

Solution:

Step 1: The principal quantum number $n = 3$ tells us we are looking at the third shell. The azimuthal quantum number $l = 0$ tells us we are looking only at the s subshell of that shell, which is the 3s subshell.

Step 2: For a given value of l, the number of orbitals is $2l + 1$. For l $= 0$:

$$2(0) + 1 = 1$$

So the 3s subshell has just 1 orbital.

Step 3: By the Pauli exclusion principle, each orbital can hold a maximum of 2 electrons, with opposite spins. So the maximum number of electrons with $n = 3, l = 0$ is

$$1 \times 2 = 2$$

$$\boxed{2 \text{ electrons}}$$

Quick Tip: l = 0 means the s subshell, and an s subshell has only one orbital.

3. What is the hybridization of copper in $[Cu(NH_3)_4]^{2+}$?

(A) sp^3

(B) sp^2d

(C) dsp^2

(D) sp^3d

Correct Answer: (C) dsp^2

Solution:

Step 1: Find the oxidation state of copper. The complex ion carries an overall charge of 2+, and ammonia is a neutral ligand, so all four NH_3

molecules together contribute zero charge. This means copper itself must carry the +2 charge, so we are dealing with Cu^{2+}.

Step 2: Write the electron configuration of Cu^{2+}. Neutral copper is $[Ar]3d^{10}4s^1$. To form Cu^{2+}, we remove 2 electrons, first the single 4s electron and then one 3d electron, giving

$$Cu^{2+} : [Ar]3d^9$$

Step 3: With a d^9 configuration, one of the five 3d orbitals is singly occupied. In forming this four coordinate ammine complex, copper uses one empty (or vacated) 3d orbital along with the 4s orbital and two 4p orbitals to accept the four lone pairs from the nitrogen atoms of ammonia. This combination of one d, one s and two p orbitals is dsp^2 hybridization, which gives a square planar arrangement of the four ligands around copper.

$$\boxed{dsp^2 \text{ hybridization, square planar shape}}$$

Quick Tip: First work out the oxidation state and d-electron count of copper, then see how many and which orbitals are needed for 4 ligands.

4. What is the bond order of O_2^{2-}?

(A) 1

(B) 2

(C) 2.5

(D) 1.5

Correct Answer: (A) 1

Solution:

Step 1: Count the total number of electrons in O_2^{2-}. A neutral oxygen atom has 8 electrons, so neutral O_2 has $8 \times 2 = 16$ electrons. The peroxide ion O_2^{2-} carries 2 extra electrons, giving a total of

$$16 + 2 = 18 \text{ electrons}$$

Step 2: Fill these 18 electrons into the molecular orbitals of oxygen in order of increasing energy:

$$\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^*2p_x^2\ \pi^*2p_y^2$$

Adding these up: $2 + 2 + 2 + 2 + 2 + 2 + 2 + 2 + 2 = 18$ electrons, which checks out.

Step 3: Count bonding and antibonding electrons. Bonding electrons: $\sigma 1s(2) + \sigma 2s(2) + \sigma 2p_z(2) + \pi 2p_x(2) + \pi 2p_y(2) = 10$. Antibonding electrons: $\sigma^*1s(2) + \sigma^*2s(2) + \pi^*2p_x(2) + \pi^*2p_y(2) = 8$.

Step 4: Bond order is given by

$$\text{Bond order} = \frac{N_b - N_a}{2} = \frac{10 - 8}{2} = \frac{2}{2} = 1$$

$$\boxed{\text{Bond order} = 1}$$

Quick Tip: Work out how many extra electrons the 2- charge adds, and where they land in the molecular orbital diagram.

5. What is the shape of XeF_6?

(A) Square pyramidal

(B) Octahedral

(C) Pentagonal bipyramidal

(D) Distorted octahedral

Correct Answer: (D) Distorted octahedral

Solution:

Step 1: Count the valence electrons around xenon in XeF_6. Xenon contributes 8 valence electrons, and each of the 6 fluorine atoms is singly bonded, using 1 electron from xenon per bond, so 6 electrons are used for the 6 Xe-F bonds. The electrons left on xenon are

$$8 - 6 = 2 \text{ electrons} = 1 \text{ lone pair}$$

Step 2: So xenon has 6 bonding pairs and 1 lone pair around it, a total of 7 electron domains. This is described as an AX_6E_1 system in VSEPR theory.

Step 3: With 7 electron domains, the ideal parent geometry for the electron pairs would be pentagonal bipyramidal. However, one of these 7 positions is occupied by a lone pair, not a bonded fluorine, so the actual molecular shape traced out by only the 6 fluorine atoms is not a clean, ideal octahedron. The lone pair pushes into the octahedral framework of the 6 F atoms and distorts it, and this distortion is also known to make XeF_6 fluxional (its exact shape keeps interconverting).

Step 4: So the molecular shape of XeF_6, based on the positions of the 6 fluorine atoms once the lone pair's distorting effect is included, is best described as a distorted octahedron.

Distorted octahedral

Quick Tip: Count Xe's lone pairs first, then think about how a lone pair affects a 6 bond-pair octahedral arrangement.

6. What is the order of the covalent character of $CaCl_2$, CaF_2, $CaBr_2$, and CaI_2?

(A) $CaCl_2 > CaF_2 > CaBr_2 > CaI_2$

(B) $CaF_2 > CaCl_2 > CaBr_2 > CaI_2$

(C) $CaF_2 < CaCl_2 < CaBr_2 < CaI_2$

(D) $CaCl_2 > CaBr_2 > CaI_2 > CaF_2$

Correct Answer: (C) $CaF_2 < CaCl_2 < CaBr_2 < CaI_2$

Solution:

Step 1: Covalent character in an ionic compound is explained by Fajans' rule. It depends on the polarizing power of the cation and the polarizability of the anion. A bigger, softer anion is polarized more easily, so the bond gains more covalent character.

Step 2: In all four compounds the cation is the same, Ca^{2+}. So the covalent character depends only on the anion. Anion size increases as $F^- < Cl^- < Br^- < I^-$, and polarizability increases in the same order.

Step 3: Since I^- is the largest and most easily polarized halide ion, CaI_2 has the highest covalent character. CaF_2, with the smallest and least polarizable F^-, has the lowest covalent character.

So the order of covalent character is:

$$CaF_2 < CaCl_2 < CaBr_2 < CaI_2$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: Think about which halide ion is largest and most polarizable.

7. A monobasic acid with a concentration of 0.04 M is dissociated to the extent of 0.5% in an aqueous solution. What is the dissociation constant of the acid?

(A) 10^{-6}

(B) 10^{-5}

(C) 10^{-4}

(D) 10^{-7}

Correct Answer: (A) 10^{-6}

Solution:

Step 1: The degree of dissociation is given as a percentage. So $\alpha = 0.5\% = 0.005$.

Step 2: For a weak monobasic acid $HA \rightleftharpoons H^+ + A^-$, the dissociation constant is $K_a = \frac{C\alpha^2}{1-\alpha}$, where C is the initial concentration.

Step 3: Since α is very small, $1 - \alpha \approx 1$, so $K_a \approx C\alpha^2$.

Step 4: Substitute the values: $K_a = 0.04 \times (0.005)^2 = 0.04 \times 0.000025 = 1 \times 10^{-6}$.

$$\boxed{K_a = 10^{-6}}$$

Quick Tip: Use $K_a = C\alpha^2$ since α is small here.

8. The solubility product of $Fe(OH)_3$ is 1.1×10^{-36} at 25 C. What is the solubility of ferric hydroxide?

(A) 3.7×10^{-8} g L^{-1}

(B) 4.8×10^{-9} g L^{-1}

(C) 4.8×10^{-8} g L^{-1}

(D) 3.7×10^{-9} g L^{-1}

Correct Answer: (C) 4.8×10^{-8} g L^{-1}

Solution:

Step 1: Fe(OH)3 dissociates as $Fe(OH)_3 \rightleftharpoons Fe^{3+} + 3OH^-$. If the molar solubility is s mol/L, then $[Fe^{3+}] = s$ and $[OH^-] = 3s$.

Step 2: $K_{sp} = [Fe^{3+}][OH^-]^3 = s(3s)^3 = 27s^4$.

Step 3: $27s^4 = 1.1 \times 10^{-36}$, so $s^4 = \dfrac{1.1 \times 10^{-36}}{27} = 4.074 \times 10^{-38}$.

Step 4: Take the fourth root by taking the square root twice. $\sqrt{4.074 \times 10^{-38}} = 2.018 \times 10^{-19}$, and $\sqrt{2.018 \times 10^{-19}} = 4.49 \times 10^{-10}$ mol/L.

Step 5: Molar mass of Fe(OH)3 = 56 + 3(17) = 56 + 51 = 107 g/mol (Fe = 56, O = 16, H = 1).

Step 6: Solubility in g/L = $4.49 \times 10^{-10} \times 107 = 4.8 \times 10^{-8}$ g/L.

$$\boxed{s = 4.8 \times 10^{-8} \text{ g L}^{-1}}$$

Quick Tip: Write the Ksp expression for Fe(OH)3 in terms of solubility s, then convert mol/L to g/L.

9. Calculate the amount of oxalic acid required to prepare 250 mL of 0.35 M solution of oxalic acid.

(A) 8.735 g

(B) 7.875 g

(C) 8.175 g

(D) 8.375 g

Correct Answer: (B) 7.875 g

Solution:

Step 1: Moles required = Molarity x Volume in litres = $0.35 \times 0.250 = 0.0875$ mol.

Step 2: Molar mass of oxalic acid, $H_2C_2O_4$, is $2(1) + 2(12) + 4(16) = 2 + 24 + 64 = 90$ g/mol.

Step 3: Mass required = moles x molar mass = $0.0875 \times 90 = 7.875$ g.

$$\boxed{7.875 \text{ g}}$$

Quick Tip: First find the moles needed, then multiply by the molar mass of oxalic acid.

10. Which indicator is used to titrate sodium bicarbonate with hydrochloric acid?

(A) Starch

(B) Phenolphthalein

(C) EBT

(D) Methyl orange

Correct Answer: (D) Methyl orange

Solution:

Step 1: Sodium bicarbonate, $NaHCO_3$, is the salt of a weak acid (H_2CO_3) and a strong base. When titrated with HCl, a strong acid, the reaction is $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$.

Step 2: At the equivalence point, the solution holds dissolved CO2 and carbonic acid, so the pH is acidic, around 3.5 to 4.

Step 3: The indicator must change color in this acidic range. Methyl orange changes color between pH 3.1 and 4.4, which matches the equivalence point.

Step 4: Phenolphthalein changes color between pH 8.2 and 10, so it would turn colorless well before the true endpoint and is not suitable here.

$$\boxed{\text{Methyl orange}}$$

Quick Tip: Think about the pH of the solution at the equivalence point of this titration.