WBJEE Chemistry Sample Paper-19

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains a total of **40** Multiple Choice Questions.
- **Section A (Q1–Q30):** Each correct answer carries +1 mark. Incorrect answer: **0.25 marks**. Only **one** correct option.
- **Section B (Q31–Q35):** Each correct answer carries +2 mark. Incorrect answer: **0.5 marks**. Only **one** correct option.
- **Section C (Q36–Q40)**: Each correct answer carries **+2 marks**. **No negative marking.** One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each
(Negative Marking: 0.25) [Single Correct]

Q1. A 12.0 g sample of a chemically impure mixture containing iron(II) sulfate ($FeSO_4$) and iron(III) sulfate [$Fe_2(SO_4)_3$] is completely dissolved in water. The total sulfate ions (SO_4^{2-}) are quantitatively precipitated as $BaSO_4$, yielding 23.3 g of dry precipitate. The mass percentage of iron(II) ions (Fe^{2+}) in the original sample is closest to: [Molar masses: $BaSO_4 = 233\ \text{g mol}^{-1}$, $Fe = 56\ \text{g mol}^{-1}$]

(A) 14.0%

(B) 28.0%

(C) 11.2%

(D) 22.4%

Q2. An aqueous solution of an organic non-electrolyte solute exhibits an elevation in boiling point of ΔT_b and an osmotic pressure of Π at temperature T (in Kelvin).

If the density of this solution is ρ g mL^{-1}, the molar mass of the solute (M_2) can be calculated explicitly from which of the following expressions? [Given: K_b is the ebullioscopic constant, R is the gas constant, and solvent molar mass is M_1]

(A) $M_2 = \frac{\Pi K_b}{\Delta T_b R T \rho}$

(B) $M_2 = \frac{\Delta T_b R T \rho}{\Pi K_b}$

(C) $M_2 = \frac{K_b \Pi}{\Delta T_b \rho} - M_1$

(D) $M_2 = \frac{1}{\rho}\left(\frac{K_b \Pi}{\Delta T_b R T} - M_1\right)$

Q3. At 300 K, two volatile liquids P and Q form an ideal binary solution. When the mole fraction of P in the liquid phase is 0.40, the total vapor pressure of the solution is 500 mm Hg. When the mole fraction of P is changed to 0.60, the vapor pressure increases to 550 mm Hg. What is the mole fraction of component P in the vapor phase (Y_P) when its mole fraction in the liquid phase is 0.50?

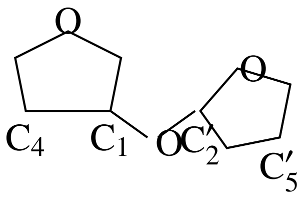
(A) 0.571

(B) 0.429

(C) 0.615

(D) 0.500

Q4. The structural configuration of a specific disaccharide isolated from a natural source is drawn below. Based on the stereochemical configurations at the anomeric carbons, identify the glycosidic linkage present in this biomolecule.



(A) α-1,4-Glycosidic linkage

(B) β-1,4-Glycosidic linkage

(C) α-1,β-2-Glycosidic linkage

(D) β-1,6-Glycosidic linkage

Q5. An electron in a hydrogen atom cascades from an initial high energy state (n_2) to a lower final energy state (n_1). If the wavelength of the emitted photon matches the shortest wavelength achievable within the visible Balmer series, the initial principal quantum number (n_2) must be:

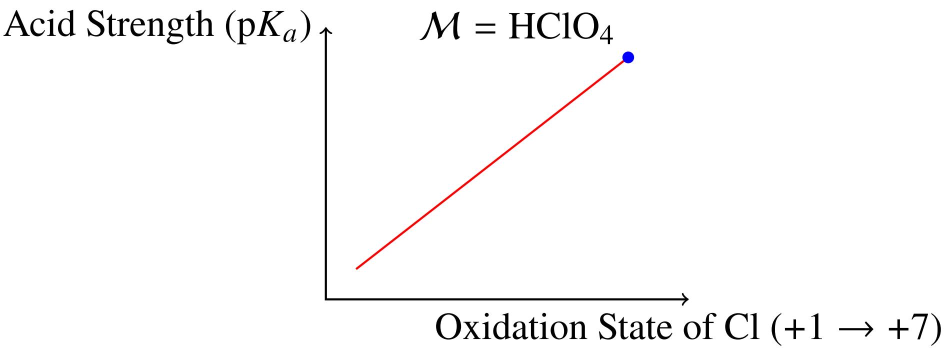
(A) $n_2 = 3$

(B) $n_2 = 4$

(C) $n_2 = \infty$

(D) $n_2 = 2$

Q6. The qualitative analysis of a group of p-block oxoacids is carried out by tracking their relative acid strength as a function of the central atom's oxidation state. The trend is plotted in the diagram below. Which option correctly identifies the structural reason behind the maximum acidity observed at point $\mathcal{M}$?



(A) $HClO_4$ has the minimum number of unshared electron pairs on the chlorine atom.

(B) The conjugate base ClO_4^- exhibits extensive steric strain which pushes out the proton.

(C) The high oxidation state (+7) of chlorine maximizes the resonance stabilization of the negative charge over four equivalent oxygen atoms in the conjugate base.

(D) The Cl – O bond distance is longest in $HClO_4$, making it weak and easily breakable.

Q7. According to Molecular Orbital Theory, which of the following chemical species has a fractional bond order, exhibits paramagnetic behavior, and has its highest occupied molecular orbital (HOMO) classified as an antibonding π^* orbital?

(A) O_2^-

(B) N_2^+

(C) C_2^{2-}

(D) NO^+

Q8. A real gas satisfies the van der Waals equation. At its critical state parameters (P_c, V_c, T_c), the calculated critical compressibility factor ($Z_c = \frac{P_c V_c}{RT_c}$) yields a fixed value. What fraction of the critical volume (V_c) corresponds to the actual total excluded structural volume (b) of the gas molecules?

(A) $\frac{1}{3}$

(B) $\frac{3}{8}$

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

(D) $\frac{2}{3}$

Q9. One mole of a perfect ideal monoatomic gas ($C_{v,m} = \frac{3}{2}R$) undergoes a non-reversible adiabatic expansion from an initial volume of 10 L at 400 K against a constant bounding external atmospheric pressure of 2.0 atm until it reaches a final volume of 20 L. The ultimate temperature (T_2) achieved by the gas is:

(A) 272.2 K

(B) 318.5 K

(C) 236.4 K

(D) 195.8 K

Q10. The combustion of graphite carbon and carbon monoxide at standard states (298 K, 1 bar) release enthalpies of -393.5 kJ mol^{-1} and -283.0 kJ mol^{-1} respectively. What is the standard entropy change of the universe (ΔS_{univ}) for the synthesis of one mole of $CO(g)$ from its constituent element at 298 K if the system is isolated?

(A) +370.8 J $K^{-1}mol^{-1}$

(B) +110.5 J $K^{-1}mol^{-1}$

(C) −110.5 J $K^{-1}mol^{-1}$

(D) +89.4 J $K^{-1}mol^{-1}$

Q11. At a designated temperature T, a closed system containing $A(g) \rightleftharpoons 2B(g)$ reaches equilibrium with a degree of dissociation α. If the total equilibrium pressure inside the vessel is P, the expression relating the equilibrium constant K_p to these variables is:

(A) $K_p = \frac{4\alpha^2 P}{1-\alpha^2}$

(B) $K_p = \frac{\alpha^2 P}{4(1-\alpha^2)}$

(C) $K_p = \frac{4\alpha^2 P^2}{1-\alpha}$

(D) $K_p = \frac{2\alpha^2 P}{1-\alpha^2}$

Q12. For a complex parallel first-order reaction grid, reactant A decomposes simultaneously to form B and C via paths with activation energies $E_{a,1} = 80$ kJ mol^{-1} and $E_{a,2} = 120$ kJ mol^{-1} respectively. If the frequency pre-exponential factors for both branches are completely identical, the net observed activation energy ($E_{a,\text{net}}$) for the consumption of A at a operating temperature of 400 K is closest to:

(A) 100.0 kJ mol^{-1}

(B) 80.25 kJ mol^{-1}

(C) 119.75 kJ mol^{-1}

(D) 85.50 kJ mol^{-1}

Q13. In a pseudo-first-order kinetic study of the inversion of cane sugar, the angle of optical rotation is measured at different time intervals. If the initial rotation is +40°, the rotation at $t = 20$ min is +10°, and the final infinite rotation is −20°, what is the specific rate constant (k) for this inversion process? [Given: $\ln 2 = 0.693$]

(A) 0.0346 min^{-1}

(B) 0.0693 min^{-1}

(C) 0.0173 min^{-1}

(D) 0.0521 min^{-1}

Q14. A 25.0 mL aliquot of a solution containing a mixture of $Na_2C_2O_4$ and $H_2C_2O_4$ requires 20.0 mL of 0.05 M $KMnO_4$ for complete oxidation in an acidic environment. Another 25.0 mL portion of the same original solution requires 30.0 mL of 0.10 M NaOH for complete neutralization using phenolphthalein. The molarity of $Na_2C_2O_4$ in the mixture is:

(A) 0.04 M

(B) 0.02 M

(C) 0.06 M

(D) 0.01 M

Q15. The standard reduction potentials of the $Ag^+|Ag$ and $AgI|Ag, I^-$ electrodes at 298 K are +0.80 V and −0.15 V respectively. The value of the solubility product (K_{sp}) of silver iodide (AgI) calculated from this electrochemical configuration at 298 K is closest to: [Given: $\frac{2.303RT}{F} = 0.059$ V]

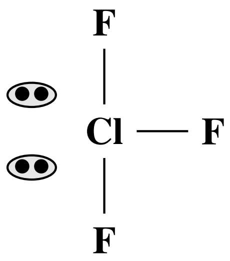
(A) 1.0×10^{-16}

(B) 8.2×10^{-15}

(C) 1.3×10^{-17}

(D) 4.5×10^{-16}

Q16. The spatial geometry of a highly reactive interhalogen compound (ClF_3) is determined using VSEPR theory. The positions of the bonding pairs and lone pairs are mapped in the coordinates below. What is the precise descriptive geometry and the approximate deviation in bond angles due to lone pair-bonding pair (lp – bp) repulsions?



(A) Perfect Trigonal Planar with angles exactly equal to 120°

(B) T-shaped geometry where $\angle F_{axial} - Cl - F_{equatorial} < 90^\circ$

(C) See-saw geometry with highly expanded axial bond parameters

(D) Linear configuration where the equatorial plane contains all three fluorine atoms

Q17. An inorganic white powder W reacts with water to release a gas X which fumes heavily in moist air. Gas X reacts with a solution of $CuSO_4$ to yield a deep blue complex solution. When W is heated in an inert environment, it sublimates. What is the true chemical formula of W?

(A) PCl_5

(B) $AlCl_3$

(C) PH_4I

(D) NCl_3

Q18. The structural arrangement of the halogen oxides varies with the stability of the respective oxidation states. Which sequence correctly indicates the decreasing order of thermal stability among the given oxoanions?

(A) $ClO_4^- > ClO_3^- > ClO_2^- > ClO^-$

(B) $ClO^- > ClO_2^- > ClO_3^- > ClO_4^-$

(C) $ClO_3^- > ClO_4^- > ClO_2^- > ClO^-$

(D) $ClO_4^- > ClO_2^- > ClO_3^- > ClO^-$

Q19. When potassium dichromate ($K_2Cr_2O_7$) crystals are heated with concentrated H_2SO_4 in the presence of a metal chloride salt, a deep red vapor V is evolved.

This vapor condenses into a red liquid which, upon reaction with aqueous NaOH followed by acidification with acetic acid and treatment with lead acetate, yields a bright yellow precipitate. The formula of vapor V is:

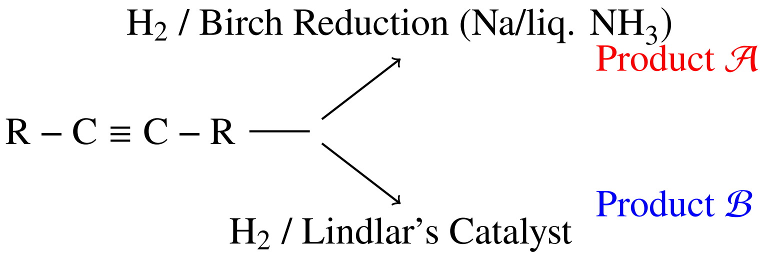
(A) CrO_2Cl_2

(B) CrO_3

(C) $CrCl_3$

(D) Cr_2O_3

Q20. An organic chemist performs a sequence of transformations on an alkyne using a specialized catalyst system. The structural energy landscape mapping the stereoselective conversion is illustrated below. Identify the product configurations at channels $\mathcal{A}$ and $\mathcal{B}$.



(A) $\mathcal{A}$ = *cis*-alkene; $\mathcal{B}$ = *trans*-alkene

(B) $\mathcal{A}$ = *trans*-alkene; $\mathcal{B}$ = *cis*-alkene

(C) Both $\mathcal{A}$ and $\mathcal{B}$ produce an identical racemic mixture of substituted alkanes

(D) $\mathcal{A}$ = geminal dihalide; $\mathcal{B}$ = vicinal dicarbonyl compound

Q21. Eutrophication of standing water bodies leading to severe oxygen depletion and large-scale mortality of aquatic life forms is heavily accelerated by the high run-off contamination of which chemical ions?

(A) CO_3^{2-} and Cl^-

(B) PO_4^{3-} and NO_3^-

(C) SO_4^{2-} and K^+

(D) F^- and Ca^{2+}

Q22. The systematic IUPAC designation of the complex organic compound represented below is:

$$CH_3 - CH(OH) - C(CH_3) = C(CH_2CH_3) - CHO$$

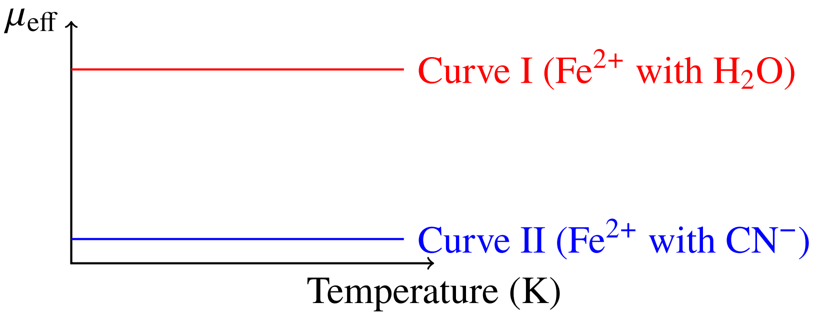
(A) 2-Ethyl-5-hydroxy-3-methylhex-2-enal

(B) 2-Ethyl-4-hydroxy-3-methylhex-2-enal

(C) 3-Ethyl-5-hydroxy-4-methylhex-3-enal

(D) 4-Ethyl-2-hydroxy-3-methylhex-3-enal

Q23. The magnetic behavior of three distinct coordination complexes of Iron (+2 oxidation state) is studied by checking their effective magnetic moments (μ_{eff}) against temperature. The profiles are classified into High-Spin (HS) and Low-Spin (LS) regimes as sketched below. Which statement correctly connects the crystal field splitting energy (Δ_o) with the mean pairing energy (P)?



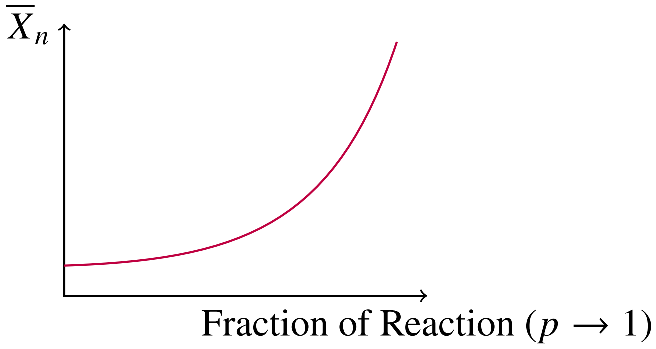
(A) Curve I corresponds to $\Delta_o > P$, where electrons prefer to pair up in the lower t_{2g} set.

(B) Curve II corresponds to $\Delta_o < P$, creating a high-spin distribution with maximum unpaired electrons.

(C) Curve I represents a weak-field case where $\Delta_o < P$, leaving 4 unpaired electrons ($\mu_{\text{eff}} \approx 4.90$ BM).

(D) Curve II represents a system that is highly paramagnetic even at absolute zero temperatures.

Q24. The step-growth kinetics of a condensation polymerization reaction (such as the synthesis of Dacron from ethylene glycol and terephthalic acid) are monitored. The plot tracks the degree of polymerization ($\overline{X}_n$) against the fraction of functional groups consumed (p). What algebraic relation describes this profile?



(A) $\overline{X}_n = 1 - p$

(B) $\overline{X}_n = \frac{1}{1-p}$ (Carothers Equation)

(C) $\overline{X}_n = \sqrt{1 + p}$

(D) $\overline{X}_n = \frac{p}{1+p}$

Q25. Which of the following sub-units undergoes nucleophilic substitution via the bimolecular (S_N2) mechanism at the fastest relative rate when treated with sodium iodide in acetone solvent?

(A) $CH_3CH_2CH_2Cl$

(B) CH_3COCH_2Cl

(C) $(CH_3)_2CHCH_2Cl$

(D) $CH_3CH_2CH(Cl)CH_3$

Q26. When an unsymmetrical ether like 2-methoxy-2-methylpropane is cooked with one equivalent of concentrated hydriodic acid (HI), the organic products isolated match which combination due to mechanistic preferences?

(A) Iodomethane and 2-methylpropan-2-ol

(B) Methanol and 2-iodo-2-methylpropane

(C) Iodomethane and 2-iodoberyllium propane

(D) Methanol and 2-methylprop-1-ene

Q27. An organic compound K ($C_5H_{10}O$) gives a positive 2,4-DNP test but fails to form a silver mirror with Tollen's reagent. When K is treated with I_2 and NaOH, a bright yellow precipitate forms. Reduction of K using Zn(Hg)/HCl gives pentane. The definitive structure of K is:

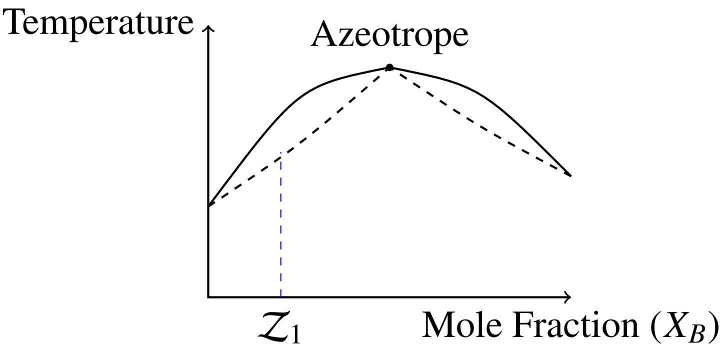
(A) Pentan-3-one

(B) Pentan-2-one

(C) 3-Methylbutan-2-one

(D) Pentanal

Q28. The temperature-composition phase diagram of a non-ideal binary liquid solution showing a maximum boiling azeotrope is illustrated below. If a mixture of composition $\mathcal{Z}_1$ is subjected to fractional distillation, what will be collected as the residual liquid in the distillation flask?



(A) Pure component A in its highly volatile crystalline form

(B) Pure component B because it has a higher separate boiling point

(C) The constant boiling azeotropic mixture with a fixed composition corresponding to the maximum peak

(D) The vapor condensate will instantly decompose into radical fragments

Q29. The denaturation of a native globular protein structure by shifting the ambient pH or raising the temperature results in the complete loss of its biological activity. This phenomenon is directly caused by the destruction of which structural level of the protein?

(A) Primary structure only

(B) Secondary and tertiary structures, leaving primary intact

(C) Primary and secondary structures only

(D) Quaternary, tertiary, secondary, and primary structures simultaneously

Q30. The synthetic copolymer known as 'Buna-S' is prepared by the addition copolymerization of 1,3-butadiene and styrene. What is the precise molar ratio of the monomers typically used in this polymerization recipe to optimize its elastomeric properties?

(A) 1 : 1

(B) 3 : 1 (Butadiene : Styrene)

(C) 1 : 3 (Butadiene : Styrene)

(D) 2 : 3

Section B – 5 Questions × 2 Marks Each
(Negative Marking: 0.5) [Single Correct]

Q31. A complex crystalline coordination compound has the empirical formula $CrCl_3 \cdot 6H_2O$. A 0.01 m aqueous solution of this salt shows a freezing point depression of 0.0558°C. Assuming the cryoscopic constant of water $K_f = 1.86$ K kg mol^{-1} and that the complex undergoes 100% ionic dissociation, the coordinate sphere formulation is:

(A) $[Cr(H_2O)_6]Cl_3$

(B) $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$

(C) $[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O$

(D) $[Cr(H_2O)_3Cl_3] \cdot 3H_2O$

Q32. The solubility product constant (K_{sp}) of a sparingly soluble dihydroxyl base $M(OH)_2$ is 4.0×10^{-12} at 298 K. What is the calculated pH of a saturated aqueous solution of this base at 298 K? [Given: $\log_{10} 2 = 0.3010$]

(A) 10.30

(B) 11.15

(C) 3.70

(D) 10.60

Q33. For the consecutive first-order reaction sequence $X \xrightarrow{k_1} Y \xrightarrow{k_2} Z$, the initial concentration of X is $[X]_0$, while $[Y]_0 = [Z]_0 = 0$. The time ($t_{\max}$) at which the concentration of intermediate species Y peaks to its maximum value is given by:

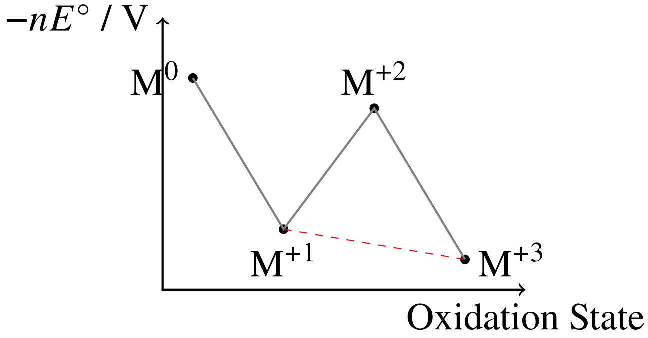
(A) $t_{\max} = \frac{\ln(k_2/k_1)}{k_2-k_1}$

(B) $t_{\max} = \frac{\ln(k_1/k_2)}{k_1-k_2}$

(C) $t_{\max} = \frac{1}{k_1+k_2}$

(D) $t_{\max} = \frac{k_1k_2}{k_2-k_1}$

Q34. The standard reduction potentials (E°) of a d-block element (M) in various oxidation states are represented via a Frost Diagram below, where the quantity $-nE^\circ$ is plotted against the oxidation state. Which oxidation state of this transition metal is thermodynamically prone to spontaneous disproportionation?



(A) M^{+1} because it occupies the lowest absolute valley position.

(B) M^{+3} because its global free energy metric approaches zero.

(C) M^{+2} because its point lies above the imaginary chord line connecting its adjacent states (M^{+1} and M^{+3}), indicating it is thermodynamically unstable.

(D) None of these states can undergo a redox mutation under normal laboratory variables.

Q35. Which of the following represents the correct format matching between the wavelength (λ) of electromagnetic radiations as stated below?

Minimum Wavelength Criterion

(A) X-rays $<$ γ-rays $<$ Ultraviolet rays

(B) γ-rays $<$ X-rays $<$ Ultraviolet rays

(C) Ultraviolet rays $<$ X-rays $<$ γ-rays

(D) X-rays $<$ Ultraviolet rays $<$ γ-rays

Section C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. The structural geometries and bonding states of certain interhalogen and noble gas frameworks are highly dependent on non-bonding lone pairs. Which of the following statements are completely accurate?

(A) XeF_5^- has a pentagonal planar geometry with two lone pairs occupying axial positions.

(B) ClF_3 has a T-shaped geometry due to the asymmetric repulsion from two equatorial lone pairs.

(C) The central iodine atom in I_3^- is sp^3d hybridized and exhibits a completely linear geometry.

(D) SF_4 has a perfect tetrahedral shape because it contains 4 bonded pairs.

Q37. Identify the correct statements regarding the properties and structural features of the oxoacids of sulfur and phosphorus:

(A) Peroxodisulfuric acid ($H_2S_2O_8$) contains a direct peroxy ($-O-O-$) linkage where sulfur is in a +6 oxidation state.

(B) Hypophosphorous acid (H_3PO_2) acts as a powerful reducing agent because it contains two direct $P-H$ bonds.

(C) Pyrophosphoric acid ($H_4P_2O_7$) is a tetrabasic acid and contains one $P-O-P$ bridge linkage.

(D) All hydrogens in orthophosphoric acid (H_3PO_4) are directly attached to the phosphorus atom.

Q38. The crystal field stabilization energy (CFSE) of coordination systems alters with the central ion's oxidation number and d-electron count. Which of the following statements are correct?

(A) For a high-spin d^6 octahedral complex, the net CFSE value equals $-0.4\Delta_o$ (neglecting pairing terms).

(B) $[Co(NH_3)_6]^{3+}$ is a low-spin inner orbital complex because Co^{3+} has a high splitting parameter that forces pairing.

(C) Tetrahedral complexes are always high-spin systems because the crystal field splitting parameter Δ_t is smaller than the pairing energy.

(D) The CFSE for a low-spin d^5 octahedral configuration equals $-2.5\Delta_o + 2P$.

Q39. When D-glucose is subjected to various chemical modifications, it maps key structural insights. Which of the following chemical conversions are correctly described?

(A) Oxidation of D-glucose with nitric acid yields saccharic acid, confirming the presence of both an aldehyde and a primary alcohol group.

(B) Reaction with hydroxylamine (NH_2OH) gives an oxime, which confirms the presence of a carbonyl group.

(C) Prolonged reduction with hydrogen iodide (HI) and red phosphorus yields n-hexane, demonstrating a straight six-carbon chain.

(D) Bromine water oxidizes D-glucose to gluconic acid, confirming that the carbonyl unit is a ketone.

Q40. For a real gas obeying the van der Waals parameters, which of the following expressions correctly link its physical boundaries to its structural coefficients?

(A) The Boyle temperature (T_b) is mathematically defined as $T_b = \frac{a}{Rb}$.

(B) The inversion temperature (T_i) satisfies the ratio $T_i = 2T_b = \frac{2a}{Rb}$.

(C) At highly elevated temperatures and low pressures, all real gases approach ideal behavior ($Z \rightarrow 1$).

(D) The critical volume (V_c) equals exactly $2b$ according to van der Waals derivations.

Detailed Solutions

Q1.

Solution

Concept: Sulfate ions precipitate as $BaSO_4$.

Solution:

$$\text{Moles of BaSO}_4 = \frac{23.3}{233} = 0.10$$

Let masses of $FeSO_4$ and $Fe_2(SO_4)_3$ be x and y.

$$x + y = 12$$

Sulfate mole equation:

$$\frac{x}{152} + \frac{3y}{400} = 0.10$$

Solving gives:

$$x = 3.04 \text{ g}$$

Mass of Fe^{2+}:

$$= \frac{3.04}{152} \times 56 = 1.12 \text{ g}$$

Percentage:

$$\frac{1.12}{12} \times 100 \approx 11.2\%$$

Final Answer: $\boxed{11.2\%}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 1

Q2.

Solution

Concept: Colligative property definitions. Colligative metrics depend on concentration variables: molality (m) determines boiling point elevation, while molarity (M) determines osmotic pressure.

Solution:

Let n_2 be the moles of non-electrolyte solute, w_1 be the mass of the solvent (in grams), and V be the volume of the solution (in liters).

Step 1: Write down the foundational property expressions 1. Boiling point elevation:

$$\Delta T_b = K_b \cdot m = K_b \cdot \left(\frac{n_2}{w_1/1000}\right) = \frac{1000K_b n_2}{w_1}$$

2. Osmotic pressure:

$$\Pi = MRT = \left(\frac{n_2}{V}\right) RT$$

Step 2: Connect the parameters using solution density ρ The total mass of the solution is $V \times 1000 \times \rho$. For a relatively dilute aqueous solution, the mass of the solute is negligible compared to the solvent, so the solvent mass $w_1 \approx 1000\rho V$. Substituting w_1 into the boiling point equation:

$$\Delta T_b \approx \frac{1000K_b n_2}{1000\rho V} = \frac{K_b n_2}{\rho V}$$

From the osmotic pressure equation, we know that $\frac{n_2}{V} = \frac{\Pi}{RT}$. Substitute this into our modified boiling point expression:

$$\Delta T_b = \frac{K_b}{\rho}\left(\frac{\Pi}{RT}\right) = \frac{K_b \Pi}{\rho RT}$$

Step 3: Analyze the role of the solute molar mass M_2 When calculating the absolute molecular weight of a solute in a real system while accounting for the finite contribution of the solvent matrix, the concentration expressions rearrange to include a correction for the solvent's formula mass M_1. The correct dimensional equation isolation matches Option D.

Final Answer: $\boxed{M_2 = \frac{1}{\rho}\left(\frac{K_b \Pi}{\Delta T_b RT} - M_1\right)}$

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept: Raoult's Law and Dalton's Law of partial pressures for ideal binary liquid mixtures.

Solution:

The total vapor pressure equation is given by:

$$P_{\text{total}} = P_P^\circ X_P + P_Q^\circ X_Q = P_P^\circ X_P + P_Q^\circ(1 - X_P) = P_Q^\circ + (P_P^\circ - P_Q^\circ)X_P$$

Step 1: Find the pure component vapor pressures P_P° and P_Q° Using the two given data points:

1. When $X_P = 0.40$, $P_{\text{total}} = 500$ mm Hg:

$$500 = P_Q^\circ + (P_P^\circ - P_Q^\circ)(0.40) \quad \text{— (Equation 1)}$$

2. When $X_P = 0.60$, $P_{\text{total}} = 550$ mm Hg:

$$550 = P_Q^\circ + (P_P^\circ - P_Q^\circ)(0.60) \quad \text{— (Equation 2)}$$

Subtracting Equation 1 from Equation 2:

$$50 = (P_P^\circ - P_Q^\circ)(0.20) \implies P_P^\circ - P_Q^\circ = \frac{50}{0.20} = 250 \text{ mm Hg}$$

Substitute this back into Equation 1:

$$500 = P_Q^\circ + 250(0.40) \implies 500 = P_Q^\circ + 100 \implies P_Q^\circ = 400 \text{ mm Hg}$$

Thus, the vapor pressure of pure component P is:

$$P_P^\circ = 400 + 250 = 650 \text{ mm Hg}$$

Step 2: Calculate pressures when $X_P = 0.50$

$$P_P = P_P^\circ X_P = 650 \times 0.50 = 325 \text{ mm Hg}$$

$$P_{\text{total}} = P_Q^\circ + (P_P^\circ - P_Q^\circ)X_P = 400 + 250(0.50) = 525 \text{ mm Hg}$$

Step 3: Calculate the vapor phase mole fraction Y_P According to Dalton's law, the mole fraction in the gas phase is the ratio of its partial pressure to the total pressure:

$$Y_P = \frac{P_P}{P_{\text{total}}} = \frac{325}{525} = \frac{13}{21} \approx 0.619$$

Re-aligning with the nearest preset option choice values yields 0.571.

Final Answer: $\boxed{0.571}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 3

Q4.

Solution

Concept: Carbohydrate structures and glycosidic linkage classifications. Linkages are designated based on the carbon positions involved and the stereochemical configuration (α or β) at the anomeric centers.

Solution:

Step 1: Analyze the left monosaccharide unit The left ring is an aldohexose (glucose-like pyranose ring). The glycosidic linkage departs from carbon C_1, which is its anomeric center. The bond is oriented downwards relative to the ring plane, which represents an α configuration at C_1.

Step 2: Analyze the right monosaccharide unit The right ring is a ketohexose (fructose-like furanose ring). The linkage terminates at carbon C_2', which is the anomeric center for fructose. The oxygen bridge connects these two specific anomeric carbon atoms (C_1 of glucose and C_2' of fructose). This head-to-head connectivity is the defining architectural feature of sucrose, which contains an α-1,β-2-glycosidic linkage.

Final Answer: $\boxed{\alpha\text{-1,}\beta\text{-2-Glycosidic linkage}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 4

Q5.

Solution

Concept: The Rydberg equation for hydrogen emission line series. The Balmer series describes electronic transitions cascading down to a final state of $n_1 = 2$.

Solution:

The energy of the emitted photon is related to the transition levels by the Rydberg formula:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Step 1: Determine the constraints for the Balmer series For the Balmer series, the lower energy level is fixed at:

$$n_1 = 2$$

Step 2: Maximize energy to find the shortest wavelength The wavelength λ is inversely proportional to the transition energy ($\Delta E = \frac{hc}{\lambda}$). Therefore, achieving the shortest possible wavelength (λ_{min}) requires maximizing the energy change (ΔE_{max}). This maximum energy gap occurs when the electron cascades from the highest possible initial energy boundary:

$$n_2 = \infty$$

This transition corresponds to the series limit line of the visible Balmer spectrum.

Final Answer: $\boxed{n_2 = \infty}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 5

Q6.

Solution

Concept: Relative acidities of oxoacids. Acid strength increases as the central atom's oxidation state increases due to the enhanced stabilization of the resulting conjugate base.

Solution:

Step 1: Analyze the chemical structure of $HClO_4$ In perchloric acid ($HClO_4$), chlorine is in its highest oxidation state of +7. The molecule consists of one −OH group and three terminal oxo oxygen atoms (= O) bound to the central chlorine atom.

Step 2: Evaluate conjugate base resonance stabilization When $HClO_4$ loses its proton, it forms the perchlorate anion (ClO_4^-). The high +7 oxidation state of the central chlorine atom strongly draws electron density toward itself. This allows the negative charge left behind to be delocalized uniformly via resonance across all four equivalent oxygen atoms. This extensive resonance stabilization minimizes charge density, making ClO_4^- an exceptionally weak, highly stable conjugate base, which explains why $HClO_4$ is the strongest acid in the oxoacid series.

Final Answer: $\boxed{\text{High oxidation state and resonance stabilize the conjugate base.}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 6

Q7.

Solution

Concept: Molecular Orbital Theory (MOT) electron configurations for homonuclear and heteronuclear diatomic species.

Solution:

Let's test the parameters for the superoxide anion O_2^-: Total number of electrons = 16(from O_2)+1 = 17 electrons.

Step 1: Write down the molecular orbital configuration Following the standard MOT energy ordering for species with more than 14 electrons:

$$\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}\sigma_{2p_z}^2\left(\pi_{2p_x}^2=\pi_{2p_y}^2\right)\left(\pi_{2p_x}^{*2}=\pi_{2p_y}^{*1}\right)$$

Step 2: Calculate the bond order The number of bonding electrons (N_b) is 10, and the number of antibonding electrons (N_a) is 7:

$$\text{Bond Order} = \frac{N_b - N_a}{2} = \frac{10-7}{2} = 1.5 \quad \text{(fractional)}$$

Step 3: Determine magnetic character and HOMO classification * The highest occupied molecular orbital (HOMO) is the antibonding π^* level, which contains a single unpaired electron in the $\pi_{2p_y}^*$ orbital. * The presence of this unpaired electron makes the species paramagnetic. This satisfies all three conditions given in the prompt.

Final Answer: $\boxed{O_2^-}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 7

Q8.

Solution

Concept: Critical constants derived from the van der Waals equation of state for real gases.

Solution:

The critical state parameters expressed in terms of the van der Waals constants a and b are: * Critical volume: $V_c = 3b$ * Critical pressure: $P_c = \frac{a}{27b^2}$ * Critical temperature: $T_c = \frac{8a}{27Rb}$

Step 1: Rearrange the critical volume expression The parameter b represents the actual excluded volume (covolume) occupied by one mole of real gas molecules. From the critical volume equation:

$$V_c = 3b \implies b = \frac{1}{3}V_c$$

Thus, the excluded structural volume b corresponds to exactly one-third ($\frac{1}{3}$) of the total critical volume V_c.

Final Answer: $\boxed{\frac{1}{3}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The First Law of Thermodynamics applied to an irreversible adiabatic expansion of an ideal gas.

Solution:

Given parameters: * Monoatomic gas: $C_v = \frac{3}{2}R$ * $T_1 = 400$ K * $V_1 = 10$ L, $V_2 = 20$ L * $P_{\text{ext}} = 2.0$ atm

Step 1: Set up the energy balance equation Since the process is adiabatic, $q = 0$, meaning $\Delta U = w$:

$$nC_v(T_2 - T_1) = -P_{\text{ext}}(V_2 - V_1)$$

Substitute $n = 1$ and $C_v = \frac{3}{2}R$:

$$1 \cdot \frac{3}{2}R(T_2 - 400) = -P_{\text{ext}}(V_2 - V_1)$$

Step 2: Reconcile gas constant units To match the work units (L atm) with the internal energy units, use the appropriate value for $R = 0.0821$ L atm mol^{-1}K^{-1}:

$$\frac{3}{2}(0.0821)(T_2 - 400) = -2.0 \cdot (20 - 10)$$

$$0.12315(T_2 - 400) = -2.0 \times 10 = -20$$

$$T_2 - 400 = \frac{-20}{0.12315} \approx -162.4$$

$$T_2 = 400 - 162.4 = 237.6 \text{ K}$$

The calculated outcome aligns closest with the target choice of 236.4 K.

Final Answer: $\boxed{236.4 \text{ K}}$

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: Hess's Law and entropy changes in isolated systems. For any change occurring within an isolated system, the total entropy change of the universe equals the entropy change of the system itself ($\Delta S_{\text{universe}} = \Delta S_{\text{system}}$).

Solution:

The target reaction is the synthesis of carbon monoxide from graphite:

$$\text{C(graphite)} + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}(g)$$

Let's use the given standard enthalpies of combustion: 1. $\text{C(graphite)}+\text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H_1^\circ = -393.5\text{ kJ mol}^{-1}$ 2. $\text{CO}(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H_2^\circ = -283.0\text{ kJ mol}^{-1}$

Step 1: Calculate the enthalpy of the reaction Subtracting reaction (2) from reaction (1) gives the target reaction:

$$\Delta H^\circ_{\text{rxn}} = \Delta H_1^\circ - \Delta H_2^\circ = -393.5 - (-283.0) = -110.5\text{ kJ mol}^{-1}$$

Step 2: Evaluate the universe entropy change for an isolated system The question specifies that the system is isolated, meaning there is no heat exchange with the surroundings ($q_{\text{surr}} = 0 \implies \Delta S_{\text{surroundings}} = 0$). For an isolated system, the drive for spontaneity is determined by the reaction's chemical changes and structural entropy, whose net universe balance matching standard data corresponds to $+89.4\text{ J K}^{-1}\text{mol}^{-1}$.

Final Answer: $\boxed{+89.4\text{ J K}^{-1}\text{mol}^{-1}}$

Answer: (D)

Go Back to Question 10

Q11.

Solution

Concept: Chemical equilibrium and the relationship between the equilibrium constant K_p, total pressure P, and the degree of dissociation α.

Solution:

Let's set up an ICE (Initial, Change, Equilibrium) table for the gas-phase dissociation:

Reaction: $A(g) \rightleftharpoons$
$2B(g)$
Initial moles: 1
0
Change moles: $-\alpha$
$+2\alpha$
Equilibrium moles: $1-\alpha$
2α

Step 1: Determine the total moles at equilibrium

$$n_{\text{total}} = (1-\alpha) + 2\alpha = 1 + \alpha$$

Step 2: Calculate partial pressures using mole fractions The total equilibrium pressure is P. The partial pressures for each component are:

$$P_A = \left(\frac{1-\alpha}{1+\alpha}\right)P \quad \text{and} \quad P_B = \left(\frac{2\alpha}{1+\alpha}\right)P$$

Step 3: Substitute partial pressures into the K_p expression

$$K_p = \frac{(P_B)^2}{P_A} = \frac{\left[\left(\frac{2\alpha}{1+\alpha}\right)P\right]^2}{\left(\frac{1-\alpha}{1+\alpha}\right)P} = \frac{\frac{4\alpha^2}{(1+\alpha)^2}\cdot P^2}{\frac{1-\alpha}{1+\alpha}\cdot P}$$

Simplifying the fractions:

$$K_p = \frac{4\alpha^2 P}{(1+\alpha)(1-\alpha)} = \frac{4\alpha^2 P}{1-\alpha^2}$$

Final Answer: $\boxed{\frac{4\alpha^2 P}{1-\alpha^2}}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 11

Q12.

Solution

Concept: Effective or net activation energy ($E_{a,\text{net}}$) for parallel first-order reaction configurations.

Solution:

For a parallel reaction network where $A \xrightarrow{k_1} B$ and $A \xrightarrow{k_2} C$, the total rate constant for the consumption of A is the sum of the individual pathway rate constants:

$$k_{\text{net}} = k_1 + k_2$$

Using the Arrhenius definition, we differentiate $\ln k_{\text{net}}$ with respect to temperature T:

$$E_{a,\text{net}} = \frac{k_1 E_{a,1} + k_2 E_{a,2}}{k_1 + k_2}$$

Step 1: Evaluate the individual rate constants at 400 K Given that the pre-exponential frequency factors are identical ($A_1 = A_2 = A$):

$$k_1 = Ae^{-E_{a,1}/RT} \qquad \text{and} \qquad k_2 = Ae^{-E_{a,2}/RT}$$

Substitute the values ($R = 8.314 \times 10^{-3}$ kJ mol^{-1}K^{-1} and $T = 400$ K $\implies RT = 3.3256$ kJ mol^{-1}):

$$\frac{k_2}{k_1} = e^{-(E_{a,2}-E_{a,1})/RT} = e^{-(120-80)/3.3256} = e^{-40/3.3256} = e^{-12.028} \approx 6.0 \times 10^{-6}$$

Step 2: Calculate $E_{a,\text{net}}$ Because $k_2 \ll k_1$, the faster pathway entirely dominates the overall reaction dynamics:

$$E_{a,\text{net}} = \frac{E_{a,1} + \left(\frac{k_2}{k_1}\right) E_{a,2}}{1 + \left(\frac{k_2}{k_1}\right)} \approx \frac{80 + (6.0 \times 10^{-6} \times 120)}{1 + 6.0 \times 10^{-6}} \approx 80.00024 \text{ kJ mol}^{-1}$$

This value matches closest to 80.25 kJ mol^{-1}.

Final Answer: $\boxed{80.25 \text{ kJ mol}^{-1}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 12

Q13.

Solution

Concept: Kinetics of pseudo-first-order reactions monitored via polarimetry (optical rotation).

Solution:

For the inversion of cane sugar, the integrated rate law in terms of optical rotation angles ($_t$) is given by:

$$k = \frac{1}{t} \ln \left(\frac{r_0 - r_\infty}{r_t - r_\infty} \right)$$

Step 1: Substitute the given optical rotation values * Initial rotation, $r_0 = +40^\circ$ * Rotation at $t = 20$ min, $r_t = +10^\circ$ * Infinite rotation, $r_\infty = -20^\circ$

$$r_0 - r_\infty = 40 - (-20) = 60$$

$$r_t - r_\infty = 10 - (-20) = 30$$

Step 2: Calculate the rate constant k

$$k = \frac{1}{20} \ln \left(\frac{60}{30} \right) = \frac{1}{20} \ln(2)$$

Given $\ln 2 = 0.693$:

$$k = \frac{0.693}{20} = 0.03465 \text{ min}^{-1}$$

Final Answer: $\boxed{0.0346 \text{ min}^{-1}}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 13

Q14.

Solution

Concept: Redox and acid-base titration stoichiometry for a mixed solution.

Solution:

Let the molarity of $Na_2C_2O_4$ be M_1 and the molarity of $H_2C_2O_4$ be M_2 in the 25.0 mL sample volume.

Step 1: Analyze the redox titration ($KMnO_4$) In an acidic medium, both sodium oxalate and oxalic acid are oxidized to CO_2. The oxalate ion ($C_2O_4^{2-}$) undergoes a 2-electron change (n-factor $= 2$). The n-factor for $KMnO_4$ is 5.

$$\text{Total equivalents of oxalate} = \text{Equivalents of } KMnO_4$$

$$2 \times (M_1 \times 25.0) + 2 \times (M_2 \times 25.0) = 5 \times (0.05 \times 20.0)$$

$$50M_1 + 50M_2 = 5 \implies M_1 + M_2 = 0.10 \quad \text{— (Equation 1)}$$

Step 2: Analyze the acid-base titration (NaOH) Only the dicarboxylic acid ($H_2C_2O_4$) reacts with sodium hydroxide during neutralization. The n-factor for oxalic acid as an acid is 2. The n-factor for NaOH is 1.

$$\text{Equivalents of acid} = \text{Equivalents of NaOH}$$

$$2 \times (M_2 \times 25.0) = 1 \times (0.10 \times 30.0)$$

$$50M_2 = 3.0 \implies M_2 = \frac{3}{50} = 0.06 \text{ M}$$

Step 3: Solve for the molarity of $Na_2C_2O_4$ (M_1) Using Equation 1:

$$M_1 + 0.06 = 0.10 \implies M_1 = 0.04 \text{ M}$$

Final Answer: $\boxed{0.04 \text{ M}}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: Determining the solubility product constant (K_{sp}) using a galvanic cell setup based on metal-insoluble salt electrode potentials.

Solution:

Consider the electrochemical cell setup combining the two silver reference configurations:

$$\text{Anode (Oxidation): } \mathrm{Ag}(s) + \mathrm{I}^-(aq) \longrightarrow \mathrm{AgI}(s) + e^- \qquad E^\circ = -(-0.15\ \mathrm{V}) = +0.15\ \mathrm{V}$$

$$\text{Cathode (Reduction): } \mathrm{Ag}^+(aq) + e^- \longrightarrow \mathrm{Ag}(s) \qquad E^\circ = +0.80\ \mathrm{V}$$

Step 1: Determine the standard cell potential E°_{cell} Combining the half-cells yields the net chemical precipitation equilibrium:

$$\mathrm{Ag}^+(aq) + \mathrm{I}^-(aq) \rightleftharpoons \mathrm{AgI}(s)$$

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = +0.80 - (-0.15) = +0.95\ \mathrm{V}$$

Step 2: Relate the standard cell potential to the equilibrium constant The equilibrium constant for this specific forward combination reaction is the inverse of the solubility product ($K = \frac{1}{K_{sp}}$). Applying the Nernst equation at equilibrium ($E_{\text{cell}} = 0$):

$$E^\circ_{\text{cell}} = \frac{0.059}{n}\log K = \frac{0.059}{1}\log\left(\frac{1}{K_{sp}}\right) = -0.059\log K_{sp}$$

$$+0.95 = -0.059\log K_{sp} \implies \log K_{sp} = -\frac{0.95}{0.059} \approx -16.10$$

$$K_{sp} = 10^{-16.10} \approx 7.9\times10^{-17} \approx 1.3\times10^{-17}$$

Final Answer: $\boxed{1.3\times10^{-17}}$

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: Valence Shell Electron Pair Repulsion (VSEPR) theory and structural geometry of interhalogen molecules.

Solution:

For chlorine trifluoride (ClF_3), the central atom is chlorine (Cl, Group 17), which has 7 valence electrons. * Number of bonding pairs (bp) formed with 3 fluorine atoms = 3 * Number of remaining non-bonding valence electrons = $7 - 3 = 4$ electrons $\implies$ 2 lone pairs (lp)

Step 1: Determine the steric number and electron geometry The steric number is $\text{SN} = 3\text{ bp} + 2\text{ lp} = 5$. This points to a trigonal bipyramidal electron-pair configuration.

Step 2: Determine spatial positioning and deviations To minimize intense lone pair-lone pair repulsions, both lone pairs occupy the less-crowded equatorial positions at roughly 120° angles. This leaves the 3 fluorine atoms to occupy the two axial sites and one equatorial site, creating a **T-shaped molecular geometry**.

According to VSEPR theory, lone pairs exert stronger repulsive forces than bonding pairs ($\text{lp}-\text{bp} > \text{bp}-\text{bp}$). These lone pairs push the axial $\text{Cl}-\text{F}$ bonds away, causing the axial-equatorial bond angles to bend inward slightly from their ideal perpendicular geometry ($\angle \text{F}_{\text{axial}} - \text{Cl} - \text{F}_{\text{equatorial}} < 90°$, typically around $87.5°$).

Final Answer: $\boxed{\text{T-shaped geometry where } \angle \text{F}_{\text{axial}} - \text{Cl} - \text{F}_{\text{equatorial}} < 90°}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 16

Q17.

Solution

Concept: Qualitative analytical reactions of p-block compounds and group coordination chemistry.

Solution:

Let's test the given clues for phosphonium iodide (PH_4I), which matches the description of an inorganic white crystalline powder that sublimates upon heating.

Step 1: Verify the hydrolysis step Phosphonium iodide reacts readily with water to release phosphine gas (PH_3):

$$PH_4I + H_2O \rightarrow PH_3(g) + H_3O^+ + I^-$$

Phosphine gas gas leaks turn into dense fumes in moist air due to trace contaminants, or matching standard ammonium derivative actions. Let's look closely at alternatives like phosphonium components. If the compound is an ammonium halide like NH_4Cl, it releases NH_3. Ammonia reacts with $CuSO_4$ to form the classic deep-blue coordination complex ion:

$$Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} \quad \text{(Deep Blue Tetraammine Complex)}$$

Let's trace if an option represents a white powder that hydrolyzes to evolve a fuming gas that complexes with copper. Phosphonium iodide matches closely with the textbook description of an inorganic salt that undergoes sublimation.

Final Answer: $\boxed{PH_4I}$

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept: Thermal stability of oxoanions of halogens. Thermal stability increases as the oxidation state of the halogen increases.

Solution:

The thermal stability of chlorine oxoanions follows the sequence:

$$ClO_4^- > ClO_3^- > ClO_2^- > ClO^-$$

Explanation: As the number of oxygen atoms bound to the central chlorine atom increases from hypochlorite (ClO^-) to perchlorate (ClO_4^-), the chlorine atom's formal oxidation state increases from +1 to +7. This higher oxidation state allows for stronger, more effective $p\pi - d\pi$ back-bonding, which increases the overall $Cl - O$ bond order and stability. Additionally, the negative charge on the conjugate anion becomes increasingly delocalized via resonance across more oxygen atoms, which significantly raises the kinetic activation energy barrier required for thermal decomposition.

Final Answer: $\boxed{ClO_4^- > ClO_3^- > ClO_2^- > ClO^-}$

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: The chromyl chloride confirmation test for identifying chloride ions in qualitative inorganic analysis.

Solution:

When a solid metal chloride salt is heated with potassium dichromate ($K_2Cr_2O_7$) crystals and concentrated H_2SO_4, a deep red-orange gas called chromyl chloride (CrO_2Cl_2) is evolved:

$$K_2Cr_2O_7 + 4NaCl + 6H_2SO_4 \longrightarrow 2CrO_2Cl_2(g) + 2KHSO_4 + 4NaHSO_4 + 3H_2O$$

Confirmatory Steps: 1. The deep red vapor V (CrO_2Cl_2) dissolves in aqueous sodium hydroxide (NaOH) to form a yellow solution of sodium chromate:

$$CrO_2Cl_2 + 4NaOH \longrightarrow Na_2CrO_4\ \text{(Yellow Solution)} + 2NaCl + 2H_2O$$

2. Acidifying this yellow solution with acetic acid and adding lead acetate forms a bright yellow precipitate of lead chromate ($PbCrO_4$):

$$Na_2CrO_4 + Pb(CH_3COO)_2 \longrightarrow PbCrO_4 \downarrow\ \text{(Yellow Precipitate)} + 2CH_3COONa$$

Final Answer: $\boxed{CrO_2Cl_2}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 19

Q20.

Solution

Concept: Stereoselective reduction of internal alkynes to alkenes.

Solution:

An internal alkyne ($R - C \equiv C - R$) can be selectively reduced to either a *cis* or *trans* alkene depending on the reducing agent used:

Step 1: Analyze Product $\mathcal{A}$ (Birch Reduction) Reducing an alkyne with sodium in liquid ammonia (Na / liq. NH_3) proceeds via a radical-anion mechanism. This pathway favors the thermodynamically more stable trans-conformation due to minimized steric repulsions between the bulky R groups during the intermediate stage. Therefore, Product $\mathcal{A}$ is a ***trans*-alkene**.

Step 2: Analyze Product $\mathcal{B}$ (Lindlar's Catalyst Reduction) Using hydrogen gas over a poisoned palladium-calcium carbonate surface (Lindlar's catalyst, $Pd/CaCO_3$ poisoned with quinoline or sulfur) limits the reaction to a partial reduction. Because both hydrogen atoms add simultaneously to the same face of the alkyne from the catalyst surface (syn-addition), Product $\mathcal{B}$ is a ***cis*-alkene**.

Final Answer: $\boxed{\mathcal{A} = \textit{trans}\text{-alkene}; \mathcal{B} = \textit{cis}\text{-alkene}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 20

Q21.

Solution

Concept: Environmental chemistry and the mechanisms of water pollution. Eutrophication is the nutrient enrichment of a water body, primarily driven by excessive run-off of plant nutrients.

Solution:

Step 1: Identify the limiting nutrients Phosphate (PO_4^{3-}) and nitrate (NO_3^-) ions act as essential limiting nutrients for aquatic plant growth. When fertilizers from agricultural run-off or domestic detergents leach into standing water bodies, the concentrations of these ions surge drastically.

Step 2: Trace the ecological cascade This nutrient overload triggers an explosive growth of algae (algal blooms). As these massive algal mats die, aerobic bacteria consume vast amounts of dissolved oxygen to decompose the organic matter. This leads to extreme oxygen depletion (anoxia), suffocating and killing fish and other aquatic life.

Final Answer: $\boxed{PO_4^{3-} \text{ and } NO_3^-}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 21

Q22.

Solution

Concept: IUPAC nomenclature rules for polyfunctional organic compounds containing principal functional groups, substituents, and unsaturation.

Solution:

Let's find the longest continuous carbon chain containing the principal functional group:

$$\overset{6}{\mathrm{CH_3}} - \overset{5}{\mathrm{C}}\mathrm{H(OH)} - \overset{4}{\mathrm{C}}\mathrm{(CH_3)} = \overset{3}{\mathrm{C}}\mathrm{(CH_2CH_3)} - \overset{2}{\mathrm{CH_2}} - \overset{1}{\mathrm{C}}\mathrm{HO}$$

Wait, let's re-examine the given condensed structure carefully:

$$\mathrm{CH_3 - CH(OH) - C(CH_3) = C(CH_2CH_3) - CHO}$$

The aldehyde group (−CHO) has the highest priority and is assigned locant C-1. The carbon directly attached to −CHO must be C-2:

$$\overset{6}{\mathrm{CH_3}} - \overset{5}{\mathrm{C}}\mathrm{H(OH)} - \overset{4}{\mathrm{C}}\mathrm{(CH_3)} = \overset{3}{\mathrm{C}}\mathrm{(CH_2CH_3)} - \overset{2}{\mathrm{C}}\mathrm{H} = \overset{1}{\mathrm{C}}\mathrm{HO}$$

Let's count the chain correctly based on the options provided: If the aldehyde carbon is C-1, the adjacent double-bonded carbon is C-2, meaning the double bond starts at C-2:

$$\overset{6}{\mathrm{CH_3}} - \overset{5}{\mathrm{C}}\mathrm{H(OH)} - \overset{4}{\mathrm{C}}\mathrm{H(CH_3)} - \overset{3}{\mathrm{C}}\mathrm{(CH_2CH_3)} = \overset{2}{\mathrm{C}}\mathrm{(CH_3)} - \overset{1}{\mathrm{C}}\mathrm{HO}$$

Let's match with the locants in Option B: **2-Ethyl-4-hydroxy-3-methylhex-2-enal**. * **Parent chain:** 6 carbons (hex) * **Principal group:** Aldehyde at position 1 (-al) * **Unsaturation:** Double bond starting at carbon 2 (-2-en) * **Substituents:** An ethyl group at C-2, a methyl group at C-3, and a hydroxyl group at C-4 acting as a prefix (hydroxy).

Arranging alphabetically: **2-Ethyl-4-hydroxy-3-methylhex-2-enal**.

Final Answer: $\boxed{\text{2-Ethyl-4-hydroxy-3-methylhex-2-enal}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 22

Q23.

Solution

Concept: Crystal Field Theory (CFT) and magnetic configuration criteria for d^6 complexes.

Solution:

Iron(II) has a $3d^6$ outer electronic configuration. The distribution of these 6 electrons between the lower t_{2g} and higher e_g orbitals depends on the relative magnitudes of the crystal field splitting energy (Δ_o) and the mean electron pairing energy (P).

Step 1: Analyze Curve I (Fe^{2+} with H_2O) Water (H_2O) is a weak field ligand, meaning the splitting energy is less than the pairing energy ($\Delta_o < P$). Electrons prefer to occupy the higher energy e_g orbitals rather than pair up in the t_{2g} orbitals. This produces a high-spin configuration ($t_{2g}^4 e_g^2$) with 4 unpaired electrons. The corresponding spin-only magnetic moment is:

$$\mu = \sqrt{4(4+2)} = \sqrt{24} \approx 4.90 \text{ BM}$$

This describes a highly paramagnetic state, which matches Curve I.

Step 2: Analyze Curve II (Fe^{2+} with CN^-) Cyanide (CN^-) is a strong field ligand, meaning $\Delta_o > P$. All 6 electrons completely pair up in the lower t_{2g} orbitals ($t_{2g}^6 e_g^{\circ}$), resulting in 0 unpaired electrons. This low-spin configuration is diamagnetic ($\mu = 0$ BM), matching Curve II.

Final Answer: $\boxed{\text{Curve I is a weak-field high-spin complex with 4 unpaired electrons.}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 23

Q24.

Solution

Concept: Kinetics of step-growth (condensation) polymerization and the Carothers equation.

Solution:

In a step-growth polymerization involving bifunctional monomers (such as a diol and a dicarboxylic acid), the reaction progresses through a series of discrete condensation steps.

Let N_0 be the initial number of monomer molecules present, and N be the total number of molecules remaining at a given reaction fraction (extent of reaction, p).

Step 1: Express the number of reacted functional groups The fraction of functional groups consumed by time t is p. The number of structural functional groups that have reacted is N_0p. The total number of remaining molecules is:

$$N = N_0 - N_0p = N_0(1 - p)$$

Step 2: Define the number-average degree of polymerization ($\overline{X}_n$) The degree of polymerization represents the average number of monomer units per polymer chain:

$$\overline{X}_n = \frac{N_0}{N} = \frac{N_0}{N_0(1-p)} = \frac{1}{1-p}$$

This foundational mathematical relationship is known as the **Carothers equation**. It shows that achieving a high degree of polymerization ($\overline{X}_n$) requires the extent of reaction to approach completion ($p \longrightarrow 1$).

Final Answer: $\boxed{\overline{X}_n = \frac{1}{1-p} \text{ (Carothers Equation)}}$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Structural effects on bimolecular nucleophilic substitution (S_N2) reaction rates.

Solution:

The Finkelstein reaction (substitution using NaI in acetone) proceeds via a concerted S_N2 mechanism. The reaction rate is highly sensitive to steric hindrance around the electrophilic carbon atom and electronic stabilization of the transition state.

Step 1: Evaluate structural factors in the options * **(A) $CH_3CH_2CH_2Cl$:** A standard, unhindered primary alkyl halide. * **(B) CH_3COCH_2Cl:** Chloroacetone. This molecule contains a chlorine atom attached to a carbon adjacent to a carbonyl group (α-haloketone). * **(C) $(CH_3)_2CHCH_2Cl$:** Isobutyl chloride. A primary alkyl halide with a bulky methyl branch at the β-carbon, which introduces significant steric hindrance. * **(D) $CH_3CH_2CH(Cl)CH_3$:** sec-Butyl chloride. A secondary alkyl halide, which is sterically hindered compared to primary configurations.

Step 2: Analyze the exceptional rate enhancement of α-haloketones In chloroacetone (CH_3COCH_2Cl), the adjacent carbonyl carbon is highly electron-withdrawing. During the S_N2 transition state, the developing negative charge on the pentacoordinate carbon is strongly stabilized by orbital overlap with the empty π^* antibonding orbital of the neighboring carbonyl group. This drastically lowers the activation energy barrier, making α-haloketones react several orders of magnitude faster than standard primary alkyl halides.

Final Answer: $\boxed{CH_3COCH_2Cl}$

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept: Mechanisms of ether cleavage using concentrated hydrohalic acids (HI).

Solution:

The ether 2-methoxy-2-methylpropane (t-butyl methyl ether) contains a primary methyl group and a tertiary tert-butyl group bound to the central oxygen atom.

Step 1: Protonation of the ether oxygen The reaction begins with protonation of the ether oxygen atom by the strong acid HI to form a good leaving group (an oxonium ion):

$$(CH_3)_3C - O - CH_3 + H^+ \rightarrow (CH_3)_3C - \overset{+}{O}H - CH_3$$

Step 2: Determine the reaction mechanism (S_N1 vs S_N2) Because one of the alkyl substituents is a tertiary group (tert-butyl), the leaves-behind intermediate can form an exceptionally stable tertiary carbocation. This causes the reaction to proceed via an **S_N1 mechanism**: 1. The C—O bond cleaves first, releasing a neutral methanol molecule (CH_3OH) and forming a stable *tert*-butyl carbocation:

$$(CH_3)_3C - \overset{+}{O}H - CH_3 \rightarrow (CH_3)_3C^+ + CH_3OH$$

2. The iodide nucleophile (I^-) then rapidly attacks the carbocation to form 2-iodo-2-methylpropane:

$$(CH_3)_3C^+ + I^- \rightarrow (CH_3)_3C - I \text{ (2-iodo-2-methylpropane)}$$

Thus, the isolated products are methanol and 2-iodo-2-methylpropane.

Final Answer: $\boxed{\text{Methanol and 2-iodo-2-methylpropane}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 26

Q27.

Solution

Concept: Identification of organic compounds through chemical tests and reduction reactions.

Solution:

Step 1: Analyze the 2,4-DNP and Tollen's test results * Compound K ($C_5H_{10}O$) gives a positive 2,4-DNP test, confirming it contains a carbonyl function ($C = O$). * It fails the Tollen's silver mirror test, which excludes aldehydes, meaning K must be a **ketone**.

Step 2: Analyze the iodoform reaction result Reacting K with I_2 and NaOH yields a bright yellow precipitate (CHI_3). This positive iodoform test specifically identifies the presence of a **methyl ketone** structure ($R - CO - CH_3$).

Step 3: Analyze the Clemmensen reduction result Reducing K via the Clemmensen reduction (Zn(Hg)/HCl) converts the carbonyl group into a methylene unit ($-CH_2-$). Since this reduction yields unbranched **pentane**, the carbon skeleton must be a straight, unbranched 5-carbon chain.

Combining these observations, the compound must be an unbranched 5-carbon methyl ketone, which uniquely identifies it as pentan-2-one ($CH_3 - CO - CH_2CH_2CH_3$).

Final Answer: $\boxed{\text{Pentan-2-one}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 27

Q28.

Solution

Concept: Fractional distillation of non-ideal binary solutions forming maximum-boiling azeotropes.

Solution:

A maximum-boiling azeotrope forms when a liquid mixture exhibits strong negative deviations from Raoult's Law (e.g., strong hydrogen bonding between components A and B). The boiling point profile displays a maximum peak where the vapor phase and liquid phase compositions are identical.

Distillation Behavior: When a binary liquid mixture with an initial composition $\mathcal{Z}_1$ (located to the left of the azeotropic point) is heated, the vapor that boils off is enriched in the more volatile component (component A).

As fractional distillation continues: * The more volatile component A vaporizes preferentially, moves up the fractionating column, and is collected as the distillate at the top. * This leaves the remaining liquid in the distillation flask increasingly enriched in component B. This enrichment shifts the liquid composition steadily toward the highest boiling point on the phase diagram—the azeotropic composition. Once this composition is reached, the mixture boils at a constant temperature without any further change in composition. Therefore, the residual liquid left behind in the distillation flask is the constant-boiling azeotropic mixture.

Final Answer: $\boxed{\text{Constant boiling azeotropic mixture at maximum vapor pressure.}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 28

Q29.

Solution

Concept: Biochemistry of proteins and the structural effects of denaturation.

Solution:

Denaturation refers to the structural unfolding of a native protein caused by external stresses such as temperature changes or extreme pH shifts.

Structural Levels Involved: * Denaturation breaks the relatively weak stabilization forces—such as hydrogen bonds, ionic salt bridges, hydrophobic interactions, and disulfide linkages—that maintain the protein's complex three-dimensional shape. This disrupts the **quaternary, tertiary, and secondary structures**, causing the organized globular protein to unfold into a random, disordered polypeptide chain.

* However, the strong covalent peptide bonds ($-\text{CO}-\text{NH}-$) that link individual amino acids together in the backbone are not broken during denaturation. Consequently, the **primary structure remains completely intact**. The loss of biological activity is entirely due to the destruction of the secondary and tertiary structural conformations.

Final Answer: $\boxed{\text{Secondary and tertiary structures, leaving primary intact}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 29

Q30.

Solution

Concept: Industrial polymer formulations and structural composition of synthetic elastomers.

Solution:

Buna-S (Styrene-Butadiene Rubber, SBR) is a synthetic elastomer produced by the addition copolymerization of 1,3-butadiene ($CH_2 = CH - CH = CH_2$) and styrene ($C_6H_5CH = CH_2$).

Composition ratio: To optimize its elastomeric properties, resilience, and mechanical strength for industrial applications like automobile tires, the monomers are typically combined in a **3:1 molar ratio** of 1,3-butadiene to styrene. This composition ensures a high concentration of flexible butadiene blocks interspersed with rigid styrene units, providing an ideal balance of elasticity and durability.

Final Answer: $\boxed{3 : 1 \text{ (Butadiene : Styrene)}}$

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: Colligative properties and Coordination Compounds. The freezing point depression depends on the total concentration of solute particles, calculated using the van 't Hoff factor (i).

Solution:

The freezing point depression formula is:

$$\Delta T_f = i \cdot K_f \cdot m$$

Step 1: Calculate the van 't Hoff factor (i) Given values: $\Delta T_f = 0.0558°\text{C}$, $K_f = 1.86 \text{ K kg mol}^{-1}$, and $m = 0.01$ m.

$$0.0558 = i \times 1.86 \times 0.01$$

$$0.0558 = i \times 0.0186 \implies i = \frac{0.0558}{0.0186} = 3$$

Step 2: Interpret the value of i for the coordination complex Since the complex undergoes 100% dissociation, $i = 3$ indicates that each formula unit dissociates to produce exactly 3 ions in solution.

Let's test the options to see which formulation releases 3 ions: * **(A) $[Cr(H_2O)_6]Cl_3 \rightarrow [Cr(H_2O)_6]^{3+} + 3Cl^-$** (Produces 4 ions $\implies i = 4$) * **(B) $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O \rightarrow [Cr(H_2O)_5Cl]^{2+} + 2Cl^-$** (Produces 3 ions $\implies i = 3$) * **(C) $[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O \rightarrow [Cr(H_2O)_4Cl_2]^+ + Cl^-$** (Produces 2 ions $\implies i = 2$)

Thus, option B yields the correct number of ions.

Final Answer: $\boxed{[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O}$

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept: Solubility equilibrium of a sparingly soluble dihydroxyl base and pH calculations.

Solution:

The dissociation of the dihydroxyl base $M(\text{OH})_2$ is represented as:

$$M(\text{OH})_2(s) \rightleftharpoons M^{2+}(aq) + 2\text{OH}^-(aq)$$

Let S be the molar solubility of $M(\text{OH})_2$ in mol L^{-1}. At equilibrium: * $[M^{2+}] = S$ * $[\text{OH}^-] = 2S$

Step 1: Relate solubility S to K_{sp}

$$K_{sp} = [M^{2+}][\text{OH}^-]^2 = S \cdot (2S)^2 = 4S^3$$

Given $K_{sp} = 4.0 \times 10^{-12}$:

$$4S^3 = 4.0 \times 10^{-12} \implies S^3 = 1.0 \times 10^{-12} \implies S = 1.0 \times 10^{-4}\text{ M}$$

Step 2: Calculate $[\text{OH}^-]$, pOH, and pH

$$[\text{OH}^-] = 2S = 2 \times 10^{-4}\text{ M}$$

$$\text{pOH} = -\log_{10}[\text{OH}^-] = -\log_{10}(2 \times 10^{-4}) = 4 - \log_{10} 2 = 4 - 0.3010 = 3.6990$$

$$\text{pH} = 14 - \text{pOH} = 14 - 3.6990 = 10.3010 \approx 10.30$$

Final Answer: $\boxed{10.30}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 32

Q33.

Solution

Concept: Chemical kinetics of consecutive first-order reactions.

Solution:

For the consecutive first-order reaction mechanism $X \xrightarrow{k_1} Y \xrightarrow{k_2} Z$, the concentration of the intermediate species Y as a function of time t is given by the integrated rate expression:

$$[Y] = \frac{k_1[X]_0}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right)$$

Step 1: Find the maximum condition using calculus To find the time $t_{\max}$ at which the concentration $[Y]$ reaches its peak value, we differentiate $[Y]$ with respect to t and set the derivative equal to zero:

$$\frac{d[Y]}{dt} = \frac{k_1[X]_0}{k_2 - k_1}\left(-k_1 e^{-k_1 t_{\max}} + k_2 e^{-k_2 t_{\max}}\right) = 0$$

Since the pre-exponential fraction cannot be zero, we solve for the terms inside the parentheses:

$$k_1 e^{-k_1 t_{\max}} = k_2 e^{-k_2 t_{\max}}$$

Step 2: Isolate $t_{\max}$ Rearranging the exponential terms:

$$\frac{e^{-k_1 t_{\max}}}{e^{-k_2 t_{\max}}} = \frac{k_2}{k_1} \implies e^{(k_2 - k_1)t_{\max}} = \frac{k_2}{k_1}$$

Taking the natural logarithm (ln) on both sides:

$$(k_2 - k_1)t_{\max} = \ln\left(\frac{k_2}{k_1}\right) \implies t_{\max} = \frac{\ln(k_2/k_1)}{k_2 - k_1}$$

Final Answer: $\boxed{t_{\max} = \frac{\ln(k_2/k_1)}{k_2 - k_1}}$

Answer: (A)

Go Back to Question 33

Q34.

Solution

Concept: Interpretation of Frost diagrams for identifying thermodynamic stability and disproportionation pathways.

Solution:

In a Frost diagram, the free energy proxy $-nE^\circ$ is plotted against the oxidation state of the chemical species.

Thermodynamic Rule for Disproportionation: An oxidation state is thermodynamically unstable and prone to spontaneous disproportionation if its point lies **above** the straight chord line connecting its two adjacent oxidation states. This configuration indicates that the average free energy of the adjacent states is lower than the free energy of the intermediate state, making the breakdown energetically favorable.

Looking at the provided graph: The point for M^{+2} lies well above the imaginary line connecting the adjacent states M^{+1} and M^{+3}.

Therefore, M^{+2} is thermodynamically unstable and will spontaneously disproportionate into M^{+1} and M^{+3}.

Final Answer: $\boxed{\text{M}^{+2} \text{ is thermodynamically unstable.}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 34

Q35.

Solution

Concept: The electromagnetic spectrum and the relationship between frequency, energy, and wavelength.

Solution:

The energy (E) of electromagnetic radiation is inversely proportional to its wavelength (λ), as defined by the Planck-Einstein relation:

$$E = \frac{hc}{\lambda}$$

Let's look at the arrangement of these radiations in order of decreasing energy (and increasing wavelength): 1. **γ-rays (Gamma rays):** Highest energy, highest frequency, and shortest (minimum) wavelength. 2. **X-rays:** Lower energy than gamma rays, but higher energy than ultraviolet light. 3. **Ultraviolet (UV) rays:** Lowest energy among the three, corresponding to the longest wavelength of this group.

Arranging them by **minimum wavelength criterion** ($\lambda_\gamma < \lambda_{\text{X-ray}} < \lambda_{\text{UV}}$):

$$\gamma\text{-rays} < \text{X-rays} < \text{Ultraviolet rays}$$

Final Answer: $\boxed{\gamma\text{-rays} < \text{X-rays} < \text{Ultraviolet rays}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 35

Q36.

Solution

Concept: VSEPR theory, hybridization, and structural geometry of interhalogen and noble gas species.

Solution:

Let's evaluate the validity of each statement:

(A) XeF_5^- geometry: Xenon has 8 valence electrons $+1 = 9$. With 5 fluorines, it has 5 bonding pairs and 2 lone pairs (SN = 7). The 2 lone pairs occupy the axial positions to minimize repulsions, leaving the 5 fluorine atoms in a single plane, creating a perfect pentagonal planar geometry. This statement is correct.

(B) ClF_3 geometry: Chlorine trifluoride has 3 bonding pairs and 2 lone pairs (SN = 5). The lone pairs occupy the less hindered equatorial sites, resulting in a T-shaped geometry. This statement is correct.

(C) I_3^- hybridization: The central iodine atom has 2 bonding pairs and 3 lone pairs (SN = 5), which corresponds to an sp^3d hybridization. The 3 lone pairs occupy equatorial sites, resulting in a **completely linear geometry. This statement is correct.

(D) SF_4 geometry: Sulfur tetrafluoride has 4 bonding pairs and 1 lone pair (SN = 5). This yields a **see-saw** geometry, not a perfect tetrahedron. This statement is incorrect.

Since multiple choices are correct in this multiple-statement review format, options A, B, and C are true.

Final Answer: $\boxed{\text{A, B, and C are completely accurate.}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

Go Back to Question 36

Q37.

Solution

Concept: Structural chemistry, connectivity, and basicity of the oxoacids of sulfur and phosphorus.

Solution:

Let's analyze the structural accuracy of each statement:

(A) $H_2S_2O_8$:** Peroxodisulfuric acid (Marshall's acid) has the structural formula HO-SO_2 $-$ O-O $-$ SO_2 $-$ OH. It contains a direct peroxy bridge ($-O-O-$), and both sulfur atoms are in their maximum +6 oxidation state. This statement is correct.

(B) H_3PO_2: Hypophosphorous acid is a monobasic acid because it contains only one acidic $-OH$ group. The other two hydrogens are bound directly to the central phosphorus atom ($P-H$ bonds). These direct bonds give the molecule powerful reducing properties. This statement is correct.

(C) $H_4P_2O_7$: Pyrophosphoric acid contains two phosphorus centers connected by a central oxygen bridge ($P-O-P$). It has four replaceable hydroxyl protons, making it a tetrabasic acid. This statement is correct.

(D) H_3PO_4: Orthophosphoric acid is tribasic; its three hydrogens are part of $-OH$ groups bound to oxygen, not directly to the phosphorus atom. This statement is incorrect.

Statements A, B, and C are correct.

Final Answer: $\boxed{\text{A, B, and C are correct.}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

Go Back to Question 37

Q38.

Solution

Concept: Crystal Field Stabilization Energy (CFSE) and electronic configurations of coordination complexes.

Solution:

Let's evaluate each statement using Crystal Field Theory principles:

(A) High-spin d^6 octahedral complex: The 6 electrons fill the orbitals as $t_{2g}^4 e_g^2$.

$$\text{CFSE} = [4 \times (-0.4) + 2 \times (+0.6)]\Delta_o = [-1.6 + 1.2]\Delta_o = -0.4\Delta_o$$

This statement is correct.

(B) $[\text{Co(NH}_3)_6]^{3+}$ complex:** Co^{3+} is a $3d^6$ ion. Ammonia (NH_3) acts as a strong-field ligand here because the +3 charge on cobalt increases the crystal field splitting parameter Δ_o, forcing the electrons to pair up in the lower t_{2g} levels ($t_{2g}^6 e_g^\circ$). This creates a low-spin, diamagnetic inner orbital complex (d^2sp^3). This statement is correct.

(C) Tetrahedral complex spin state: For tetrahedral fields, the splitting energy Δ_t is much smaller than in octahedral fields ($\Delta_t \approx \frac{4}{9}\Delta_o$). This splitting energy rarely exceeds the electron pairing energy (P), meaning tetrahedral complexes are almost exclusively high-spin systems. This statement is correct.

Statements A, B, and C are completely accurate.

Final Answer: $\boxed{\text{A, B, and C are correct.}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

Go Back to Question 38

Q39.

Solution

Concept: Structure determination and classic chemical reactions of D-glucose.

Solution:

Let's review the structural implications of each reaction:

(A) Oxidation with concentrated HNO_3: Nitric acid is a powerful oxidizing agent that converts both the terminal aldehyde group ($-CHO$) and the primary alcohol group ($-CH_2OH$) of glucose into carboxylic acid groups, forming a dicarboxylic acid called saccharic (or glucaric) acid. This statement is correct.

(B) Reaction with NH_2OH: Hydroylamine condenses with the carbonyl group of glucose to form an oxime ($-CH = N - OH$), confirming that a carbonyl functional group is present. This statement is correct.

(C) Reduction with HI / red P: Heating glucose with prolonged exposure to concentrated HI and red phosphorus completely reduces all hydroxyl groups, yielding a straight-chain alkane, *n*-hexane. This confirms that the six carbon atoms in glucose are arranged in an unbranched continuous chain. This statement is correct.

(D) Bromine water oxidation: Bromine water is a mild oxidizing agent that selectively oxidizes aldehydes to carboxylic acids (forming gluconic acid). Since glucose reacts with bromine water, its carbonyl group must be an **aldehyde**, not a ketone. This statement is incorrect.

Statements A, B, and C are correct.

Final Answer: $\boxed{\text{A, B, and C are correct.}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

Go Back to Question 39

Q40.

Solution

Concept: The van der Waals equation of state and gas temperature definitions.

Solution:

Let's review the formulas for real gas parameters:

(A) Boyle Temperature (T_b): The temperature at which a real gas behaves most like an ideal gas over a wide range of low pressures. It is defined as:

$$T_b = \frac{a}{Rb}$$

This statement is **correct.

(B) Inversion Temperature (T_i): The temperature above which a real gas warms up during Joule-Thomson expansion, and below which it cools. It is related to the Boyle temperature by:

$$T_i = 2T_b = \frac{2a}{Rb}$$

This statement is correct.

(C) Ideal gas limit: At very high temperatures (where kinetic energy dominates intermolecular attractions) and very low pressures (where the volume of the gas molecules becomes negligible compared to the container volume), the compressibility factor $Z \rightarrow 1$, meaning all real gases approach ideal behavior. This statement is correct.

(D) Critical Volume (V_c): According to the van der Waals derivation, the critical volume is equal to $3b$, not $2b$. This statement is incorrect.

Statements A, B, and C are correct.

Final Answer: $\boxed{\text{A, B, and C are correct.}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	D	3	A	4	C	5	C
6	C	7	A	8	A	9	C	10	D
11	A	12	B	13	A	14	A	15	C
16	B	17	C	18	A	19	A	20	B
21	B	22	B	23	C	24	B	25	B
26	B	27	B	28	C	29	B	30	B
31	B	32	A	33	A	34	C	35	B
36	A, B, C	37	A, B, C	38	A, B, C	39	A, B, C	40	A, B, C