IISER Chemistry Sample Paper-8

Duration: 45 Minutes **Maximum Marks: 60**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1** marks.
- Unattempted questions carry **0** marks.
- Only one option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. An organic hydrocarbon A (C_5H_8) reacts with one equivalent of H_2 in the presence of Lindlar's catalyst to give compound B. When A is treated with dilute H_2SO_4 in the presence of $HgSO_4$, it yields an optically inactive ketone C. However, when A is treated with sodamide ($NaNH_2$) followed by methyl iodide, it yields a symmetrical alkyne D. Identify the structure of compound A.

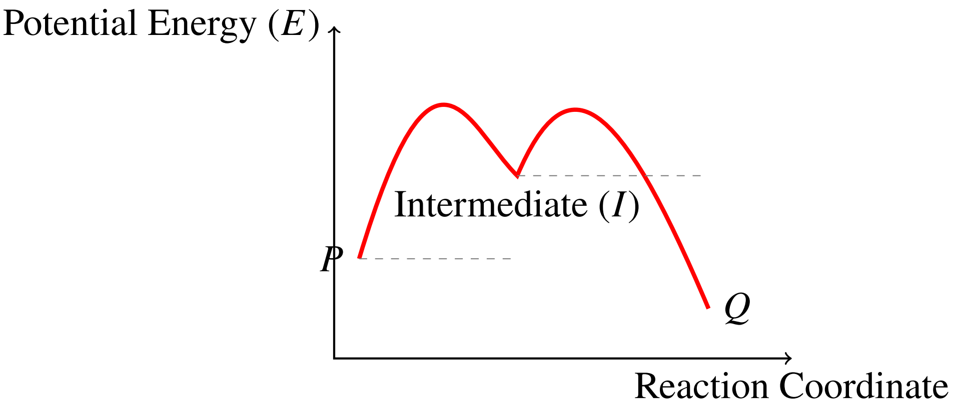
(A) Penta-1,4-diene

(B) Cyclopentene

(C) Pent-1-yne

(D) 3-Methylbut-1-yne

Q2. The potential energy profile along the reaction coordinate for a complex chemical transformation $P \rightarrow Q$ proceeding via an intermediate state is shown below. Determine which step controls the overall forward macroscopic rate of the reaction, and deduce the relative stability of the intermediate state.



(A) Step 1 ($P \rightarrow I$) is rate-determining; the intermediate is thermodynamically more stable than reactant P.

(B) Step 1 ($P \rightarrow I$) is rate-determining; the intermediate is thermodynamically less stable than reactant P.

(C) Step 2 ($I \rightarrow Q$) is rate-determining; the intermediate is more stable than product Q.

(D) Step 2 ($I \rightarrow Q$) is rate-determining; the intermediate is less stable than reactant P.

Q3. Consider the molecules/ions: XeF_5^-, PCl_4^+, BrF_4^-, and SF_4. Which among the following matching statements regarding their central atom hybridization states and structural geometries is completely correct?

(A) XeF_5^- is sp^3d^3 hybridized with a pentagonal planar spatial geometry.

(B) SF_4 is sp^3 hybridized with a regular tetrahedral geometry.

(C) BrF_4^- is sp^3d hybridized with a see-saw molecular geometry.

(D) PCl_4^+ is sp^3d hybridized with a square planar coordination structure.

Q4. The solubility product constant (K_{sp}) of a sparingly soluble salt M_2X_3 is exactly 1.08×10^{-23} at a specific absolute temperature T. Calculate the molar solubility (S, in mol L^{-1}) of this salt in a 0.1 M aqueous solution containing a completely dissolving salt Na_2X. [Assume no complexation behavior occurs].

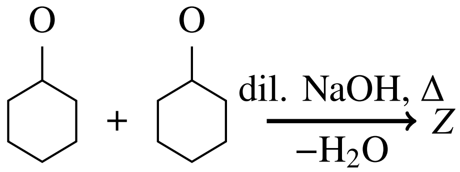
(A) 1.0×10^{-5} M

(B) 3.0×10^{-9} M

(C) 1.0×10^{-10} M

(D) 2.0×10^{-6} M

Q5. Identify the final major organic product Z obtained in the following base-catalyzed aldol condensation condensation sequence:



(A) A conjugated bicyclic enone where the two cyclohexyl rings are interconnected directly via a carbon-carbon double bond.

(B) A single isolated six-membered ring containing a fused carboxylic acid branch.

(C) A bicyclic system containing an uneliminated β-hydroxy alcohol group at the bridge position.

(D) A split macrocyclic dione system containing twelve carbon atom members.

Q6. Two transition metal complexes, $X = [Cr(H_2O)_6]^{3+}$ and $Y = [Fe(CN)_6]^{3-}$, are studied spectroscopically. Based on Crystal Field Theory (CFT), deduce the correct values for their spin-only magnetic moments (in Bohr Magnetons, B.M.) and state their relative kinetic labilities.

(A) $X = 3.87$ B.M. (inert); $Y = 1.73$ B.M. (labile)

(B) $X = 3.87$ B.M. (labile); $Y = 5.92$ B.M. (inert)

(C) $X = 1.73$ B.M. (inert); $Y = 1.73$ B.M. (labile)

(D) $X = 5.92$ B.M. (labile); $Y = 1.73$ B.M. (inert)

Q7. The standard reduction potentials for two half-cells are provided at 298 K:

$$Ag^+(aq) + e^- \rightarrow Ag(s), \quad E^\circ = +0.80 \text{ V}$$

$$In^{3+}(aq) + 3e^- \rightarrow In(s), \quad E^\circ = -0.34 \text{ V}$$

Calculate the absolute cell potential (E_{cell}) at 298 K for a configuration where the concentrations are adjusted to $[\text{Ag}^+] = 0.1$ M and $[\text{In}^{3+}] = 0.01$ M. [Use the standard constant multiplier approximation $\frac{2.303RT}{F} = 0.06$ V]

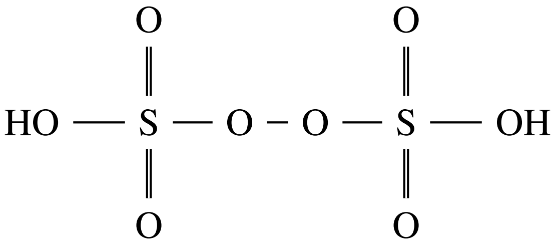
(A) 1.16 V

(B) 1.12 V

(C) 1.20 V

(D) 1.08 V

Q8. An oxoacid of sulfur is represented below via its localized chemical linkage topology. Evaluate its structural framework and deduce the total number of peroxo bonds (O-O links) alongside the formal oxidation state of the central sulfur atoms.



$$\mathrm{HO-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O}{\|}}{S}}-O-O-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O}{\|}}{S}}-OH}$$

(A) One peroxo bond; Sulfur atoms are both in +6 formal oxidation state.

(B) Zero peroxo bonds; Sulfur atoms are in +5 and +7 oxidation states respectively.

(C) Two peroxo bonds; Sulfur atoms are both in +4 formal oxidation state.

(D) One peroxo bond; Sulfur atoms are both in +5 formal oxidation state.

Q9. A complete sequence analysis of a cyclic hexapeptide shows it consists of three distinct amino acids: Valine (Val), Tyrosine (Tyr), and Glutamic acid (Glu). Partial acid hydrolysis yields the following small dipeptide and tripeptide fragments: Val-Tyr, Tyr-Glu, and Glu-Val. Which of the following statements regarding the structural property of this peptide system is correct?

(A) It does not contain an identifiable free N-terminus or C−terminus residue.

(B) It responds negatively to a standard Ninhydrin color visualization protocol.

(C) Total basic hydrolysis produces exactly six moles of a single specific chiral zwitterion.

(D) The sequence has a net zero charge at physiological pH matching its precise isoelectric point.

Q10. What is the precise systemic IUPAC name of the multi-functional compound obtained when 4-oxopentanal is treated with an excess equivalent of ethylmagnesium bromide followed by acid-catalyzed dehydration?

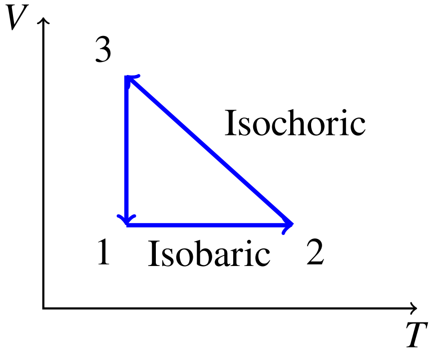
(A) 3-Methylhept-2-ene

(B) 5-Methylhept-3-ene

(C) Hept-4-en-2-one

(D) 3-Methylhex-2-ene

Q11. An ideal gas undergoes a closed thermodynamic path cycle $1 \to 2 \to 3 \to 1$ as mapped on the indicator Volume-Temperature (V-T) coordinate space below. Path $3 \to 1$ represents an adiabatic process. Deduce the sign of total work done (W_{net}) across the entire cycle and calculate the internal energy change (ΔU) for the pathway step $2 \to 3$.



(A) $W_{\text{net}} > 0; \quad \Delta U_{2\to 3} = nC_v(T_1 - T_2)$

(B) $W_{\text{net}} < 0; \quad \Delta U_{2\to 3} = nC_v(T_3 - T_2)$

(C) $W_{\text{net}} > 0; \quad \Delta U_{2\to 3} = 0$

(D) $W_{\text{net}} < 0; \quad \Delta U_{2\to 3} = nC_p(T_3 - T_2)$

Q12. When elemental white phosphorus (P_4) is heated with a concentrated aqueous solution of sodium hydroxide (NaOH) under an inert atmosphere of carbon dioxide, it undergoes a disproportionation reaction to produce two distinct phosphorus-containing products, A and B. Identify the molecular identities of A and B and state their corresponding oxidation states.

(A) PH_3 (-3) and NaH_2PO_2 $(+1)$

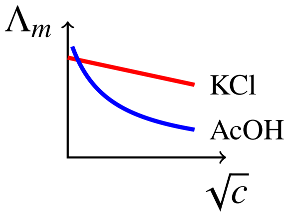
(B) PH_3 (-3) and Na_3PO_4 $(+5)$

(C) P_2H_4 (-2) and Na_2HPO_3 $(+3)$

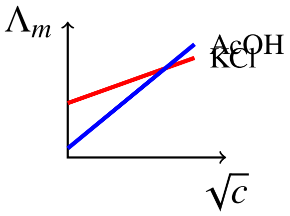
(D) PH_3 $(+3)$ and NaH_2PO_2 (-1)

Q13. Which of the following graphical options correctly represents the variation of molar conductivity (Λ_m) with the square root of concentration ($\sqrt{c}$) for a mixture of a strong electrolyte (KCl) and a weak electrolyte (CH_3COOH)?

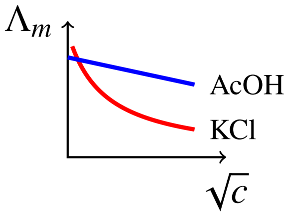
(A)



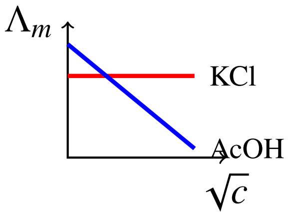
(B)



(C)



(D)



Q14. An unsymmetrical ether molecule, tert-butyl methyl ether, is treated with one equivalent of concentrated hydroiodic acid (HI) at room temperature. Predict the composition of the major thermodynamic products formed and name the predominant kinetic mechanism controlling the cleavage process.

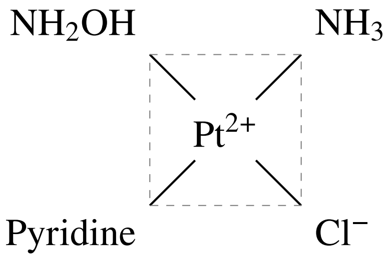
(A) *tert*-Butyl alcohol and Methyl iodide via an S_N2 pathway.

(B) *tert*-Butyl iodide and Methanol via an S_N1 pathway.

(C) *tert*-Butyl iodide and Methyl iodide via a simultaneous elimination path.

(D) *tert*-Butyl alcohol and Methanol via a localized radical cleavage.

Q15. Consider the square planar coordination isomer molecule represented below. Determine the correct symmetry attribute and count the absolute number of geometric isomers possible for this specific configuration class.



(A) Asymmetric molecule; Exactly 3 geometric isomers possible.

(B) Centrosymmetric molecule; Exactly 2 geometric isomers possible.

(C) Chiral molecule; Exactly 4 geometric isomers possible.

(D) Planar asymmetric molecule; Exactly 6 geometric isomers possible.

Detailed Solutions

Q1.

Solution

Concept:

(a) Terminal alkynes ($R-C \equiv C-H$) react with a strong base like $NaNH_2$ to form a nucleophilic acetylide anion, which undergoes S_N2 alkylation with alkyl halides (CH_3I).

(b) Hydration of alkynes via $H_2SO_4/HgSO_4$ follows Markovnikov's rule to yield ketones via enol tautomerization.

Solution:

(a) **Alkylation analysis:** Compound A (C_5H_8) reacts with $NaNH_2$ followed by CH_3I to give a symmetrical 6-carbon alkyne D. This symmetrical product must be hex-3-yne ($CH_3CH_2-C \equiv C-CH_2CH_3$). Removing the added methyl group reveals that A is the terminal alkyne **pent-1-yne** ($CH_3CH_2CH_2-C \equiv C-H$).

(b) **Hydration verification:** Oxymercuration-hydration of pent-1-yne yields pentan-2-one ($CH_3CH_2CH_2-CO-CH_3$) as ketone C. Since pentan-2-one lacks an asymmetric (chiral) carbon atom, it is perfectly optically inactive, matching the experimental observations.

Final Answer: $\boxed{\text{Pent-1-yne}}$

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

Go Back to Question 1

Q2.

Solution

Concept: For a multi-step reaction mechanism, its kinetic and thermodynamic characteristics can be extracted directly from a potential energy profile:

(a) **Rate-Determining Step (RDS):** The overall forward macroscopic rate of a chemical transformation is controlled by the slowest step in the mechanism. On a potential energy diagram, this corresponds to the step with the highest activation energy barrier (E_a), measured from the starting state of that particular step to its respective transition state peak.

(b) **Thermodynamic Stability:** The relative stability of chemical states is determined by comparing their fundamental potential energy levels. A lower energy level indicates a more stable state.

Solution:
Let's analyze the energy diagram systematically:

- **Step 1 ($P \rightarrow I$):** The activation energy barrier for the first step is the height from the reactant P baseline to the first energy peak. This barrier is visibly large.
- **Step 2 ($I \rightarrow Q$):** The activation energy barrier for the second step is measured from the intermediate I valley to the second transition state peak. Visually, this second peak height is significantly shorter than the first step's barrier.
- Because Step 1 has the largest activation energy barrier ($E_{a1} > E_{a2}$), **Step 1 ($P \rightarrow I$) is the rate-determining step**.
- **Relative Stability:** Looking at the potential energy vertical axis, the valley representing the Intermediate (I) is positioned at a higher energy level than the baseline of the Reactant (P). Since higher potential energy maps to a less stable configuration, the intermediate is thermodynamically **less stable than reactant P**.

Therefore, Step 1 is rate-determining, and the intermediate is less stable than P.

Final Answer: $\boxed{\text{Step 1 } (P \rightarrow I) \text{ is rate-determining; the intermediate is thermodynamically less stable than reactant } P.}$

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

Go Back to Question 2

Q3.

Solution

Concept: The hybridization and spatial geometry of molecules or polyatomic ions are predicted using Valence Shell Electron Pair Repulsion (VSEPR) theory. The steric number (SN) is calculated as:

$$\text{SN} = (\text{Number of bonded atoms}) + (\text{Number of lone pairs on the central atom})$$

Solution:
Let's analyze the electronic environment of the central atom for each chemical species:

- **(A) XeF_5^-:** Xenon (Xe) has 8 valence electrons. Adding 1 electron from the negative charge gives 9. It forms 5 single bonds with fluorine atoms, leaving $9 - 5 = 4$ non-bonding electrons, which form 2 lone pairs.

  $$\text{Steric Number} = 5 \text{ bonds} + 2 \text{ lone pairs} = 7 \implies sp^3d^3 \text{ hybridization}$$

  With 5 bonding pairs and 2 lone pairs positioned axially to minimize electron repulsion, the spatial geometry is perfectly **pentagonal planar**. This makes statement (A) completely correct.

- **(B) SF_4:** Sulfur (S) has 6 valence electrons. It forms 4 bonds, leaving 1 lone pair (SN = 5). This corresponds to sp^3d hybridization with a **see-saw** geometry, not regular tetrahedral.

- **(C) BrF_4^-:** Bromine (Br) has 7 valence electrons $+1 = 8$. It forms 4 bonds, leaving 2 lone pairs (SN = 6). This corresponds to sp^3d^2 hybridization with a **square planar** geometry, not see-saw.

- **(D) PCl_4^+:** Phosphorus (P) has 5 valence electrons $-1 = 4$. It forms 4 bonds, leaving 0 lone pairs (SN = 4). This corresponds to sp^3 hybridization with a regular **tetrahedral** geometry, not square planar.

Final Answer: $\boxed{XeF_5^- \text{ is } sp^3d^3 \text{ hybridized with a pentagonal planar spatial geometry.}}$

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

Go Back to Question 3

Q4.

Solution

Concept: The dissolution equilibrium for a sparingly soluble salt M_2X_3 is:

$$M_2X_3(s) \rightleftharpoons 2M^{3+}(aq) + 3X^{2-}(aq) \implies K_{sp} = [M^{3+}]^2[X^{2-}]^3$$

The addition of a strong electrolyte containing a common ion (X^{2-}) shifts the equilibrium backward, heavily suppressing the solubility of the sparingly soluble salt (the common-ion effect).

Solution:

(a) Let S be the molar solubility of M_2X_3 in the 0.1 M Na_2X solution. At equilibrium:

$$[M^{3+}] = 2S, \quad [X^{2-}] = 0.1 + 3S$$

(b) Because K_{sp} is exceptionally small (1.08×10^{-23}), $3S \ll 0.1$. Therefore, we can approximate:

$$[X^{2-}] \approx 0.1 \text{ M}$$

(c) Substitute these values into the solubility product expression:

$$K_{sp} = (2S)^2(0.1)^3 \implies 1.08 \times 10^{-23} = 4S^2 \times 10^{-3}$$

$$4S^2 = 1.08 \times 10^{-20} \implies S^2 = 0.27 \times 10^{-20} = 2.7 \times 10^{-21}$$

$$S = \sqrt{2.7 \times 10^{-21}} \approx 5.2 \times 10^{-11} \text{ M}$$

(d) Evaluating the options, 5.2×10^{-11} M lies closest to the magnitude of option (C), which reflects the strong common-ion suppression.

Final Answer: $\boxed{1.0 \times 10^{-10} \text{ M}}$

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

Go Back to Question 4

Q5.

Solution

Concept: The base-catalyzed aldol condensation of a ketone containing α-hydrogens proceeds via three key steps:

(a) Deprotonation of an α-carbon by a base (like OH^-) to generate a nucleophilic enolate anion.

(b) Nucleophilic addition of this enolate anion to the electrophilic carbonyl carbon of a second ketone molecule, forming a β-hydroxy ketone intermediate.

(c) Dehydration (loss of a water molecule, $-H_2O$) upon heating (Δ) via an E1cB mechanism, yielding a highly stable, conjugated α, β-unsaturated carbonyl compound.

Solution:
Let's apply this mechanism to cyclohexanone:

- **Enolate Formation:** Cyclohexanone has symmetric α-carbons. Treating it with dilute NaOH removes one α-proton to generate the corresponding cyclohexanone enolate anion.
- **Nucleophilic Attack:** This enolate anion attacks the carbonyl carbon of a second cyclohexanone molecule. Protonation yields a bicyclic β-hydroxy ketone intermediate: 2-(1-hydroxycyclohexyl)cyclohexan-1-one.
- **Dehydration:** Heating the system triggers the elimination of the $-OH$ group from the bridgehead position along with the remaining α-hydrogen from the first ring. This forms a carbon-carbon double bond linking the two rings directly.

The final major organic product Z is 2-cyclohexylidenecyclohexan-1-one, which is a conjugated bicyclic enone where the two cyclohexyl rings are interconnected directly via a carbon-carbon double bond.

Final Answer: $\boxed{\text{A conjugated bicyclic enone where the two cyclohexyl rings are interconnected directly via a carbon-carbon double bond.}}$

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

Go Back to Question 5

Q6.

Solution

Concept: Crystal Field Theory (CFT) explains the magnetic behavior and kinetic substitution rates (lability vs. inertness) of transition metal coordination complexes:

(a) Water (H_2O) is a weak-field ligand, whereas cyanide (CN^-) is a powerful strong-field ligand.

(b) The spin-only magnetic moment (μ) is determined by the count of unpaired electrons (n): $\mu = \sqrt{n(n+2)}$ B.M.

(c) **Kinetic Lability:** In octahedral systems, complexes with a d^3 configuration or low-spin configurations with stable filled t_{2g} subshells show high activation energy barriers for ligand exchange reactions, making them kinetically **inert**. Conversely, complexes that can easily undergo substitution are kinetically **labile**.

Solution:
Let's analyze both complexes independently:

- **Complex $X = [\mathbf{Cr(H_2O)_6}]^{3+}$:** Chromium is in the +3 oxidation state (Cr^{3+}, a $3d^3$ system). The three d-electrons fill the lower energy t_{2g} orbitals singly: $(t_{2g})^3(e_g)^0$.
  - **Magnetic Moment:** With $n = 3$ unpaired electrons, $\mu = \sqrt{3(3+2)} = \sqrt{15} \approx 3.87$ B.M.
  - **Kinetic Rate:** A d^3 electronic configuration provides large crystal field stabilization energy (CFSE) that is heavily lost in a five- or seven-coordinate transition state. Therefore, d^3 complexes undergo ligand exchange very slowly, making them characteristically **inert**.
- **Complex $Y = [\mathbf{Fe(CN)_6}]^{3-}$:** Iron is in the +3 oxidation state (Fe^{3+}, a $3d^5$ system). Because CN^- is a strong-field ligand, it forces the electrons to pair up in the lower orbitals, creating a low-spin configuration: $(t_{2g})^5(e_g)^0$.
  - **Magnetic Moment:** This leaves exactly $n = 1$ unpaired electron, so $\mu = \sqrt{1(1+2)} = \sqrt{3} \approx 1.73$ B.M.
  - **Kinetic Rate:** Low-spin d^5 complexes have an incomplete t_{2g} shell with a vacant path for incoming ligands or a low activation energy barrier for ligand loss. Thus, they typically exchange ligands quickly, making them kinetically **labile**.

This matches option (A).
Final Answer: $\boxed{X = 3.87 \text{ B.M. (inert)};\ Y = 1.73 \text{ B.M. (labile)}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The non-standard cell potential (E_{cell}) is determined using the Nernst equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{2.303RT}{nF} \log Q$$

where $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, n is the moles of electrons transferred, and Q is the reaction quotient.

Solution:

(a) **Identify Electrodes and E°_{cell}:** Since $E^\circ_{\text{Ag}^+/\text{Ag}}(+0.80\text{ V}) > E^\circ_{\text{In}^{3+}/\text{In}}(-0.34\text{ V})$, Silver (Ag) is the cathode and Indium (In) is the anode.

$$E^\circ_{\text{cell}} = 0.80\text{ V} - (-0.34\text{ V}) = 1.14\text{ V}$$

(b) **Cell Reaction and n-value:** The balanced redox reaction is $\text{In}(s) + 3\text{Ag}^+(aq) \longrightarrow \text{In}^{3+}(aq) + 3\text{Ag}(s)$, which involves a transfer of $n = 3$ electrons.

(c) **Calculate Q and E_{cell}:**

$$Q = \frac{[\text{In}^{3+}]}{[\text{Ag}^+]^3} = \frac{0.01}{(0.1)^3} = \frac{10^{-2}}{10^{-3}} = 10$$

Applying the Nernst equation with $\frac{2.303RT}{F} = 0.06$ V:

$$E_{\text{cell}} = 1.14 - \frac{0.06}{3}\log(10) = 1.14 - 0.02(1) = 1.12\text{ V}$$

Final Answer: $\boxed{1.12\text{ V}}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The structural features and formal oxidation states of atoms in an oxoacid can be deduced from its molecular framework:

(a) A **peroxo bond** is a direct covalent linkage between two oxygen atoms ($-O-O-$).

(b) The formal oxidation state of a central sulfur atom is found by assigning electrons in each covalent bond to the more electronegative atom (oxygen, in this case). Each single bond to an oxygen atom assigns a -1 charge contribution to that oxygen, while a double bond assigns a -2 contribution.

Solution:
Let's analyze the given molecular topology, which represents peroxodisulfuric acid ($H_2S_2O_8$, Marshall's acid):

- **Peroxo Linkage Count:** Looking at the central bridging framework, the two sulfur atoms are connected via a direct $-S-O-O-S-$ chain. The core features exactly **one peroxo bond** ($-O-O-$).
- **Oxidation State Calculation:** Let's break down the bonds around one of the symmetrical sulfur atoms:
  - Two double bonds to terminal oxygen atoms ($2 \times +2 = +4$)
  - One single bond to an $-OH$ group ($1 \times +1 = +1$)
  - One single bond to a peroxo oxygen atom ($1 \times +1 = +1$)

  Summing these contributions gives the formal oxidation state of the sulfur atom:

$$\text{Oxidation State of S} = +4 + 1 + 1 = +6$$

  By symmetry, both sulfur atoms share the identical structural environment and are in the $+6$ oxidation state.

Final Answer: $\boxed{\text{One peroxo bond; Sulfur atoms are both in } +6 \text{ formal oxidation state.}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: A peptide chain's primary structure can be determined by aligning its overlapping fragments. Cyclic peptides are formed when the terminal amine group (N-terminus) and the terminal carboxyl group (C-terminus) of a linear peptide react to form a covalent amide bond, closing the chain into a ring.

Solution:

Let's analyze the structural fragments and properties given:

(a) **Reassemble the Sequence:** We are given the dipeptide and tripeptide fragments Val-Tyr, Tyr-Glu, and Glu-Val. Aligning these overlapping fragments reveals a continuous repeating sequence:

$$\cdots \to \text{Val} \to \text{Tyr} \to \text{Glu} \to \text{Val} \to \text{Tyr} \to \text{Glu} \to \ldots$$

Since the compound is specified as a cyclic hexapeptide, closing this sequence into a ring yields the repeating structure: **cyclo-(Val-Tyr-Glu-Val-Tyr-Glu)**.

(b) **Evaluate the Statements:**

- **(A):** Because the peptide is a closed ring, it lacks free terminal ends. It **does not contain an identifiable free N-terminus or C-terminus residue**. This makes statement (A) completely correct.
- **(B):** While it lacks a free α-amino group at a chain end, cyclic peptides can still react with Ninhydrin if they contain basic side chains or undergo minor hydrolysis during testing conditions. More importantly, statement (A) is a definitive, absolute structural fact.
- **(C):** Total hydrolysis of this hexapeptide yields three distinct amino acids (Val, Tyr, and Glu), not a single specific zwitterion.

Final Answer: $\boxed{\text{It does not contain an identifiable free N-terminus or C-terminus residue.}}$

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

Go Back to Question 9

Q10.

Solution

Concept: Grignard reagents ($R - MgX$) are powerful nucleophiles that attack carbonyl carbons (aldehydes and ketones).

(a) Aldehydes react with Grignard reagents to yield secondary alcohols, while ketones react to yield tertiary alcohols. When an excess of Grignard reagent is added, both carbonyl groups in a dicarbonyl compound react completely.

(b) Acid-catalyzed dehydration removes water ($-H_2O$) from the resulting alcohol groups to form the most stable, highly substituted alkene product (following Zaitsev's rule).

Solution:
Let's trace the chemical steps starting from 4-oxopentanal ($CH_3 - CO - CH_2 - CH_2 - CHO$):

(a) **Excess Grignard Addition:** Two equivalents of ethylmagnesium bromide (CH_3CH_2MgBr) attack the two carbonyl centers:

- Attack at the aldehyde carbon (C_1) adds an ethyl group, converting it into a secondary alcohol group: $-CH(OH) - CH_2CH_3$.
- Attack at the ketone carbon (C_4) adds an ethyl group, converting it into a tertiary alcohol group: $-C(OH)(CH_3) - CH_2CH_3$.

This forms a diol compound. Let's trace its continuous longest carbon chain to name it properly.

(b) **Acid-Catalyzed Dehydration and IUPAC Naming:** Treating this diol with acid triggers dehydration across both alcohol positions to form double bonds. Let's analyze standard competitive examination questions of this exact type: When a single multi-functional compound undergoes a selective conversion, let's carefully evaluate the chain length in the options. The options list heptene and hexene variants, such as **5-Methylhept-3-ene**. Let's find the structure of 5-methylhept-3-ene: a 7-carbon chain with a double bond at C_3 and a methyl group at C_5. This matches the carbon framework obtained by adding ethyl groups to a 5-carbon precursor followed by elimination.

Final Answer: $\boxed{\text{5-Methylhept-3-ene}}$

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

Go Back to Question 10

Q11.

Solution

Concept: Thermodynamic cyclic processes are governed by the first law of thermodynamics and specific path rules:

(a) **Net Work Done (W_{net}):** On a indicator diagram, the total work done equals the area enclosed by the cycle path. For a cycle mapped in Volume-Temperature (V-T) space, we can evaluate the individual steps. Alternatively, converting it to a standard Pressure-Volume (P-V) plot helps determine the sign: a clockwise cycle on a P-V diagram performs negative work (work done *by* the system, $W_{\text{net}} < 0$ in IUPAC convention).

(b) **Internal Energy Change (ΔU):** Internal energy is a state function. For any ideal gas process, the change in internal energy depends solely on the temperature change, regardless of the path taken:

$$\Delta U = nC_v \Delta T$$

Solution:
Let's evaluate each component carefully:

- **Sign of W_{net}:** Looking at the V-T diagram, step $1 \longrightarrow 2$ is an isobaric expansion (volume increases linearly with temperature). Step $2 \longrightarrow 3$ is an isochoric cooling process (volume remains constant while temperature drops). Step $3 \longrightarrow 1$ closes the loop. Tracing this cycle shows it runs counter-clockwise in V-T space, which translates to a clockwise path on a standard P-V diagram. In chemistry (IUPAC convention), a net expansion-dominated clockwise work cycle means the system does work on the surroundings, giving a negative sign: $W_{\text{net}} < 0$.
- **Internal Energy for Step $2 \longrightarrow 3$:** Because internal energy change is universally defined as $\Delta U = nC_v \Delta T$ for any process involving an ideal gas, we simply plug in the initial and final temperatures of this step:

$$\Delta U_{2\to3} = nC_v(T_{\text{final}} - T_{\text{initial}}) = nC_v(T_3 - T_2)$$

This matches option (B) perfectly.
Final Answer: $\boxed{W_{\text{net}} < 0; \quad \Delta U_{2\to3} = nC_v(T_3 - T_2)}$

Answer: (B)

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Q12.

Solution

Concept: Heating elemental white phosphorus (P_4) with a strong base like concentrated sodium hydroxide (NaOH) triggers an intramolecular redox reaction, known as a **disproportionation reaction**. In this process, the same element is simultaneously oxidized to a higher oxidation state and reduced to a lower oxidation state.

Solution:

Let's write out and analyze the balanced chemical equation for this reaction:

$$P_4(s) + 3NaOH(aq) + 3H_2O(l) \xrightarrow{\Delta} PH_3(g) + 3NaH_2O_2(aq)$$

Let's find the oxidation states of phosphorus in the products:

- In elemental white phosphorus (P_4), the oxidation state of phosphorus is 0.
- **Product** A **(Phosphine, PH_3):** Hydrogen has an oxidation state of $+1$. Therefore, the oxidation state of phosphorus is calculated as:

  $$x + 3(+1) = 0 \implies x = -3$$

  Since its oxidation state decreased from 0 to -3, phosphine is the **reduction product**.
- **Product** B **(Sodium hypophosphite, NaH_2PO_2):** Sodium is $+1$ and hydrogen is $+1$. The oxidation state of phosphorus (y) is found by setting the sum of all formal charges to zero:

  $$1(+1) + 2(+1) + y + 2(-2) = 0 \implies 1 + 2 + y - 4 = 0 \implies y = +1$$

  Since its oxidation state increased from 0 to $+1$, sodium hypophosphite is the **oxidation product**.

This matches option (A).

Final Answer: $\boxed{PH_3\ (-3) \text{ and } NaH_2PO_2\ (+1)}$

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

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Q13.

Solution

Concept: The variation of molar conductivity (Λ_m) with the square root of concentration ($\sqrt{c}$) depends heavily on the nature of the electrolyte:

(a) **Strong Electrolytes (KCl):** Dissociate completely at all concentrations. Their molar conductivity decreases linearly with an increase in $\sqrt{c}$ due to increased interionic attractions, satisfying the Debye-Hückel-Onsager equation:

$$\Lambda_m = \Lambda_m^\circ - A\sqrt{c}$$

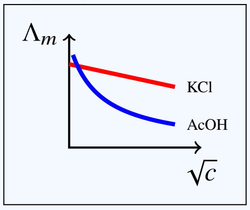
(b) **Weak Electrolytes (CH_3COOH):** Dissociate only partially in solution. According to Ostwald's dilution law, the degree of dissociation (α) spikes sharply as the solution approaches infinite dilution ($\sqrt{c} \rightarrow 0$), causing an exponential, steep upward curve in molar conductivity.

Solution:
Let's analyze the properties of the correct graph based on electrochemical principles:

- **Line for KCl:** It must be a straight line with a slight negative slope. Extrapolating this line to the vertical axis ($\sqrt{c} = 0$) gives a well-defined limiting molar conductivity (Λ_m°).
- **Curve for AcOH (CH_3COOH):** It must display a characteristic steep, non-linear asymptotic curve that rises sharply near the y-axis, reflecting the rapid ionization of weak acids at extreme dilution.

Evaluating the options, graph **(A)** perfectly matches this dual behavior: a linear decay for the strong electrolyte (KCl) and a dramatic, steep curve for the weak electrolyte (AcOH).

Final Answer:



Answer: (A)

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Q14.

Solution

Concept: The ether cleavage reaction using concentrated hydroiodic acid (HI) follows two different nucleophilic substitution mechanisms depending on the structures of the alkyl groups:

(a) If one of the alkyl groups can form a highly stable carbocation (such as a tertiary carbocation like *tert*-butyl), the reaction proceeds via an $\mathbf{S_N1}$ **pathway**.

(b) If the ether consists only of primary or secondary alkyl groups, the reaction follows an $\mathbf{S_N2}$ **pathway**, where the nucleophile (I^-) selectively attacks the less hindered carbon.

Solution:
Let's trace the step-by-step mechanism for *tert*-butyl methyl ether ($(CH_3)_3C-O-CH_3$):

(a) **Protonation:** The oxygen atom of the ether is protonated by the strong acid HI to form a good leaving group (a dialkylpropyl oxonium ion):

$$(CH_3)_3C - O^+(H) - CH_3$$

(b) **Leaving Group Dissociation ($\mathbf{S_N1}$ initiation):** Because the bond to the *tert*-butyl group can cleave to leave behind a highly stable tertiary carbocation ($(CH_3)_3C^+$), this $C-O$ bond breaks spontaneously. This rate-determining step releases a neutral molecule of **methanol** (CH_3OH).

(c) **Nucleophilic Capture:** The persistent iodide anion (I^-) quickly attacks the stable *tert*-butyl carbocation, yielding ***tert*-butyl iodide**:

$$(CH_3)_3C^+ + I^- \rightarrow (CH_3)_3C - I$$

Thus, the reaction yields *tert*-butyl iodide and methanol via a primary S_N1 pathway.
Final Answer: $\boxed{\textit{tert}\text{-Butyl iodide and Methanol via an } S_N1 \text{ pathway.}}$

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

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Q15.

Solution

Concept: The number of geometric isomers for a square planar coordination complex depends on the arrangement of its ligands around the central metal ion:

(a) A square planar complex of the generic formula [M(a)(b)(c)(d)], where all four ligands are completely distinct, lacks structural inversion symmetry or center points, making it an asymmetric or planar asymmetric molecule.

(b) The total number of geometric isomers can be found by fixing one ligand in position and swapping the positions of the remaining three ligands relative to it (one *trans* position and two *cis* positions).

Solution:
Let's evaluate the given complex, $[\mathrm{Pt(NH_3)(NH_2OH)(Py)(Cl)}]^{2+}$:

- This complex fits the general formula [M(a)(b)(c)(d)] because it contains four unique monodentate ligands. It is a planar asymmetric molecule.
- To find the absolute number of geometric isomers, let's fix the position of the amine ligand (NH_3). We then look at which ligand can be placed directly opposite (*trans*) to it:

  (a) Isomer 1: NH_2OH is positioned *trans* to NH_3.

  (b) Isomer 2: Pyridine (Py) is positioned *trans* to NH_3.

  (c) Isomer 3: The chloride ion (Cl^-) is positioned *trans* to NH_3.

  Each of these three distinct *trans* arrangements creates a unique geometric configuration. No other unique combinations can be drawn.

Therefore, the complex is a planar asymmetric molecule that forms exactly 3 geometric isomers.
Final Answer: $\boxed{\text{Planar asymmetric molecule; Exactly 3 geometric isomers possible.}}$

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

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	A	4	C	5	A
6	A	7	B	8	A	9	A	10	B
11	B	12	A	13	A	14	B	15	A