IISER Chemistry Sample Paper-10

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: $-\mathbf{1}$ 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. Consider the solvolysis of the following substrates in aqueous ethanol at $25°C$:

$$(CH_3)_3CCl, \quad PhCH_2Cl, \quad CH_2 = CHCH_2Cl, \quad Ph_3CCl$$

Assuming an S_N1 mechanism is operative wherever possible and neglecting steric effects in the solvent, the correct order of rate of solvolysis is:

(A) $Ph_3CCl > (CH_3)_3CCl > PhCH_2Cl > CH_2 = CHCH_2Cl$

(B) $Ph_3CCl > PhCH_2Cl > CH_2 = CHCH_2Cl > (CH_3)_3CCl$

(C) $(CH_3)_3CCl > Ph_3CCl > PhCH_2Cl > CH_2 = CHCH_2Cl$

(D) $PhCH_2Cl > CH_2 = CHCH_2Cl > (CH_3)_3CCl > Ph_3CCl$

Q2. An organic compound X has molecular formula C_8H_8O. It gives a positive 2,4-DNP test but does not reduce Tollens' reagent. Its ^1H-NMR spectrum contains:

- A singlet integrating to 3H near $\delta = 2.6$
- A multiplet integrating to 5H in the aromatic region

The compound X is:

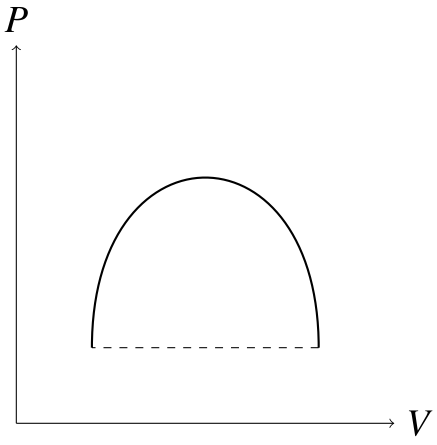
(A) Acetophenone

(B) Benzaldehyde

(C) Phenylacetaldehyde

(D) Ethyl benzoate

Q3. One mole of an ideal gas undergoes the cyclic process shown.



Which statement is necessarily true?

(A) Net work done is zero

(B) Internal energy change over one cycle is positive

(C) Net heat absorbed equals net work done

(D) Entropy change of the gas over one cycle is positive

Q4. For the reaction

$$A + B \longrightarrow Products$$

the experimentally determined rate law is

$$r = k[A]^{3/2}[B]$$

If both concentrations are doubled simultaneously, the rate increases by a factor of:

(A) 4

(B) $2^{3/2}$

(C) $4\sqrt{2}$

(D) 8

Q5. A galvanic cell is constructed as

$$\mathrm{Pt|Fe^{3+}(0.01M), Fe^{2+}(1M)||Ce^{4+}(1M), Ce^{3+}(0.01M)|Pt}$$

Given

$$E^\circ_{Fe^{3+}/Fe^{2+}} = 0.77V$$

$$E^\circ_{Ce^{4+}/Ce^{3+}} = 1.61V$$

The cell emf at $298K$ is closest to:

(A) 0.84 V

(B) 1.08 V

(C) 1.31 V

(D) 1.62 V

Q6. A diprotic acid H_2A has

$$K_{a1} = 10^{-3}, \qquad K_{a2} = 10^{-8}$$

For a $0.1M$ solution, the dominant species at pH = 5 is:

(A) H_2A

(B) HA^-

(C) A^{2-}

(D) Equal amounts of all three

Q7. The complex

$$[Co(NH_3)_4Cl_2]^+$$

is treated with excess $AgNO_3$. One mole of the complex liberates exactly one mole of $AgCl$.

The geometry of the complex is:

(A) Tetrahedral

(B) Square planar

(C) Octahedral

(D) Trigonal bipyramidal

Q8. A high-spin octahedral d^5 complex is expected to have:

(A) One unpaired electron

(B) Two unpaired electrons

(C) Three unpaired electrons

(D) Five unpaired electrons

Q9. Among the following species, which has the highest bond order?

(A) O_2

(B) O_2^+

(C) O_2^-

(D) O_2^{2-}

Q10. The anomalous behavior of fluorine compared to other halogens is primarily attributed to:

(A) High electronegativity only

(B) Small size only

(C) Absence of d-orbitals only

(D) Combined effect of small size, high electronegativity and low bond dissociation energy of $F - F$

Q11. The bond angle order is:

(A) $NH_3 > H_2O > CH_4$

(B) $CH_4 > NH_3 > H_2O$

(C) $H_2O > CH_4 > NH_3$

(D) $NH_3 > CH_4 > H_2O$

Q12. The cycloheptatrienyl cation (tropylium ion) contains:

(A) 6 π-electrons and is aromatic

(B) 8 π-electrons and is antiaromatic

(C) 7 π-electrons and is aromatic

(D) 4 π-electrons and is non-aromatic

Q13. Which of the following amino acids contains sulfur but does not participate directly in disulfide bond formation?

(A) Cysteine

(B) Methionine

(C) Serine

(D) Tyrosine

Q14. The de Broglie wavelength of an electron accelerated through a potential difference V is proportional to:

(A) V

(B) $1/V$

(C) $\sqrt{V}$

(D) $1/\sqrt{V}$

Q15. A gaseous equilibrium

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

is established in a sealed container.

A student simultaneously:

(a) decreases temperature,
(b) increases pressure,
(c) adds a catalyst.

Assuming dimerization is exothermic, the final equilibrium mixture will contain:

(A) More NO_2
(B) More N_2O_4
(C) Same composition as initially
(D) Insufficient information

Detailed Solutions

Q1.

Solution

Concept: Under S_N1 conditions (such as solvolysis in polar protic solvents), the reaction proceeds via a two-step mechanism. The first, rate-determining step is the heterolytic cleavage of the carbon–halogen bond to form a carbocation intermediate. Consequently, the rate of solvolysis is directly proportional to the thermodynamic stability of the resulting carbocation.

Solution: Step 1: Write the ionization step for each substrate to identify the corresponding carbocation formed:

$$\begin{aligned} Ph_3CCl &\xrightarrow{\text{ionization}} Ph_3C^+ \text{ (Triphenylmethyl carbocation)} \\ (CH_3)_3CCl &\xrightarrow{\text{ionization}} (CH_3)_3C^+ \text{ (tert-Butyl carbocation)} \\ PhCH_2Cl &\xrightarrow{\text{ionization}} PhCH_2^+ \text{ (Benzyl carbocation)} \\ CH_2=CHCH_2Cl &\xrightarrow{\text{ionization}} CH_2=CHCH_2^+ \text{ (Allyl carbocation)} \end{aligned}$$

Step 2: Evaluate and compare the stabilities of these carbocations:

- **Triphenylmethyl carbocation (Ph_3C^+):** The positive charge is highly delocalized via resonance over three phenyl rings, resulting in exceptional stability.
- **tert-Butyl carbocation ($(CH_3)_3C^+$):** This is a tertiary alkyl carbocation stabilized by the strong $+I$ inductive effect of three methyl groups and 9 hyperconjugation structures. In solution, the tertiary alkyl cation is energetically more stable than the primary benzyl cation.
- **Benzyl carbocation ($PhCH_2^+$):** This primary benzylic cation is resonance-stabilized with 4 canonical structures where the positive charge is shared with the aromatic ring.
- **Allyl carbocation ($CH_2=CHCH_2^+$):** This allylic cation is stabilized by resonance over two equivalent canonical structures.

Step 3: Arrange the carbocations in order of decreasing stability:

$$Ph_3C^+ > (CH_3)_3C^+ > PhCH_2^+ > CH_2=CHCH_2^+$$

Since the rate of solvolysis matches the stability order of the carbocations, the correct rate order is:

$$Ph_3CCl > (CH_3)_3CCl > PhCH_2Cl > CH_2=CHCH_2Cl$$

This corresponds to Option A.

Final Answer: $\boxed{Ph_3CCl > (CH_3)_3CCl > PhCH_2Cl > CH_2=CHCH_2Cl}$

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: Spectroscopic data along with classic functional group tests are used to determine the structure of organic molecules. The 2,4-DNP test identifies carbonyl groups, while Tollens' test distinguishes between aldehydes and ketones. ^{1}H-NMR spectroscopy provides the local electronic environment of the protons.

Solution: Step 1: Analyze the functional group tests.

- A positive 2,4-DNP test indicates the presence of a carbonyl group ($C = O$), which can belong to either an aldehyde or a ketone.
- A negative Tollens' test (does not reduce Tollens' reagent) shows that the compound is not an aldehyde. This eliminates Benzaldehyde (Option B) and Phenylacetaldehyde (Option C).
- Ethyl benzoate (Option D) is an ester ($C_9H_{10}O_2$), which does not give a positive 2,4-DNP test, leaving ketones like acetophenone as the primary candidates.

Step 2: Analyze the molecular formula and ^{1}H-NMR data:

- The molecular formula is C_8H_8O.
- A singlet integrating to 3H near $\delta = 2.6$ is characteristic of a methyl group adjacent to an electron-withdrawing carbonyl group ($-CO - CH_3$).
- A multiplet integrating to 5H in the aromatic region ($\delta = 7.2 - 8.1$) indicates a monosubstituted benzene ring ($-C_6H_5$).

Step 3: Combine these features. A monosubstituted benzene ring ($-C_6H_5$, 5H) bonded to an acetyl group ($-COCH_3$, 3H) gives acetophenone ($C_6H_5COCH_3$):

$$C_6H_5COCH_3 \implies \text{Formula: } C_8H_8O$$

This matches all of the chemical and spectral observations.

Final Answer: $\boxed{\text{Acetophenone}}$

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

Go Back to Question 2

Q3.

Solution

Concept: For any thermodynamic system undergoing a cyclic process, the change in any state function (such as internal energy U or entropy S) over a complete, closed cycle is precisely zero because the initial and final states are identical. The relationship between heat and work is governed by the First Law of Thermodynamics.

Solution: Step 1: Evaluate the state functions over the complete cycle. Because the system returns to its initial state, we have:

- Net change in internal energy, $\Delta U_{\text{net}} = 0$ (making Option B false).
- Net change in entropy, $\Delta S_{\text{net}} = 0$ (making Option D false).

Step 2: Apply the First Law of Thermodynamics for the cycle:

$$\Delta U_{\text{net}} = Q_{\text{net}} - W_{\text{net}}$$

Step 3: Since $\Delta U_{\text{net}} = 0$, we find:

$$0 = Q_{\text{net}} - W_{\text{net}} \implies Q_{\text{net}} = W_{\text{net}}$$

This shows that the net heat absorbed by the gas (Q_{net}) must equal the net work done by the gas (W_{net}) over one complete cycle. Thus, Option C is necessarily true.

Step 4: Analyze work. The cycle encloses a non-zero area in the P-V plane, which means the net work done by the gas is non-zero (making Option A false).

Final Answer: $\boxed{\text{Net heat absorbed equals net work done}}$

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

Go Back to Question 3

Q4.

Solution

Concept: The rate of a chemical reaction depends on the concentrations of the reactants raised to the powers of their respective reaction orders, as defined by the experimental rate law.

Solution: Step 1: Write down the initial rate expression:

$$r_1 = k[A]^{3/2}[B]$$

Step 2: Define the new concentrations when both are doubled simultaneously:

$$[A'] = 2[A]$$

$$[B'] = 2[B]$$

Step 3: Substitute the new concentrations into the rate law to find the new rate r_2:

$$r_2 = k[A']^{3/2}[B']$$

$$r_2 = k(2[A])^{3/2}(2[B])$$

Step 4: Simplify the expression by factoring out the constants:

$$r_2 = 2^{3/2} \cdot 2^1 \cdot k[A]^{3/2}[B]$$

$$r_2 = 2^{3/2+1} \cdot r_1 = 2^{5/2} \cdot r_1$$

Step 5: Calculate the value of $2^{5/2}$:

$$2^{5/2} = \sqrt{2^5} = \sqrt{32} = \sqrt{16 \times 2} = 4\sqrt{2}$$

Thus, the rate increases by a factor of $4\sqrt{2}$.

Final Answer: $\boxed{4\sqrt{2}}$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: The cell potential (E_{cell}) is determined using the standard half-cell potentials and the concentrations of the reactants and products in the Nernst equation:

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

Solution: Step 1: Identify the anode and cathode reactions from the cell representation:

$$\text{Anode (oxidation): } \mathrm{Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-} \quad E^\circ_{\text{anode, red}} = 0.77\ \text{V}$$

$$\text{Cathode (reduction): } \mathrm{Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)} \quad E^\circ_{\text{cathode, red}} = 1.61\ \text{V}$$

Step 2: Calculate the standard cell potential E°_{cell}:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = 1.61\ \text{V} - 0.77\ \text{V} = 0.84\ \text{V}$$

Step 3: Write the overall cell reaction:

$$\mathrm{Fe^{2+}(aq) + Ce^{4+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ce^{3+}(aq)}$$

Here, the number of transferred electrons is $n = 1$.

Step 4: Set up the reaction quotient Q:

$$Q = \frac{[\mathrm{Fe^{3+}}][\mathrm{Ce^{3+}}]}{[\mathrm{Fe^{2+}}][\mathrm{Ce^{4+}}]} = \frac{(0.01)(0.01)}{(1)(1)} = 10^{-4}$$

Step 5: Apply the Nernst equation at 298 K:

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

$$E_{\text{cell}} = 0.84 - \frac{0.0592}{1}\log(10^{-4})$$

$$E_{\text{cell}} = 0.84 - 0.0592 \times (-4)$$

$$E_{\text{cell}} = 0.84 + 0.2368 = 1.0768\ \text{V} \approx 1.08\ \text{V}$$

Thus, the cell potential is closest to 1.08 V.

Final Answer: $\boxed{1.08\ \text{V}}$

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

Go Back to Question 5

Q6.

Solution

Concept: The distribution of species for a polyprotic acid as a function of pH is dictated by its acid dissociation constants (K_a). Comparing the pH of the solution with the pK_a values identifies the dominant species at equilibrium.

Solution: Step 1: Calculate the pK_a values for the diprotic acid H_2A:

$$\mathrm{p}K_{a1} = -\log K_{a1} = -\log(10^{-3}) = 3$$

$$\mathrm{p}K_{a2} = -\log K_{a2} = -\log(10^{-8}) = 8$$

Step 2: Relate the relative concentrations of the species using the Henderson-Hasselbalch relations:

$$\mathrm{pH} = \mathrm{p}K_{a1} + \log\left(\frac{[\mathrm{HA}^-]}{[\mathrm{H_2A}]}\right) \implies \log\left(\frac{[\mathrm{HA}^-]}{[\mathrm{H_2A}]}\right) = \mathrm{pH} - \mathrm{p}K_{a1}$$

$$\mathrm{pH} = \mathrm{p}K_{a2} + \log\left(\frac{[\mathrm{A}^{2-}]}{[\mathrm{HA}^-]}\right) \implies \log\left(\frac{[\mathrm{A}^{2-}]}{[\mathrm{HA}^-]}\right) = \mathrm{pH} - \mathrm{p}K_{a2}$$

Step 3: Evaluate the ratios at pH = 5:

- For the first dissociation:

  $$\log\left(\frac{[\mathrm{HA}^-]}{[\mathrm{H_2A}]}\right) = 5 - 3 = 2 \implies \frac{[\mathrm{HA}^-]}{[\mathrm{H_2A}]} = 10^2 = 100$$

  This shows that $[\mathrm{HA}^-] \gg [\mathrm{H_2A}]$.

- For the second dissociation:

  $$\log\left(\frac{[\mathrm{A}^{2-}]}{[\mathrm{HA}^-]}\right) = 5 - 8 = -3 \implies \frac{[\mathrm{A}^{2-}]}{[\mathrm{HA}^-]} = 10^{-3} = 0.001$$

  This shows that $[\mathrm{HA}^-] \gg [\mathrm{A}^{2-}]$.

Step 4: Since $[\mathrm{HA}^-]$ is significantly larger than both $[\mathrm{H_2A}]$ and $[\mathrm{A}^{2-}]$, the dominant species in solution at pH = 5 is HA^-.

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

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The reactivity of coordination complexes with silver nitrate ($AgNO_3$) reveals the number of free halide ions in the outer coordination sphere (ionization sphere). The ligands inside the square brackets (coordination sphere) are covalently bound to the metal and do not ionize in solution.

Solution: Step 1: Analyze the chemical formula of the complex ion: $[Co(NH_3)_4Cl_2]^+$. The central cobalt ion is bound to four neutral ammonia ligands (NH_3) and two anionic chloride ligands (Cl^-).

Step 2: Determine the coordination number. Since both ammonia and chloride are monodentate ligands:

$$\text{Coordination Number} = 4\ (NH_3) + 2\ (Cl^-) = 6$$

Step 3: Relate coordination number to geometry. In transition metal complexes, a coordination number of 6 corresponds to an octahedral geometry.

Step 4: Explain the precipitation reaction. The complex exists as a salt with a counter-anion (for example, chloride: $[Co(NH_3)_4Cl_2]Cl$). When dissolved in water, the salt dissociates:

$$[Co(NH_3)_4Cl_2]Cl(aq) \rightarrow [Co(NH_3)_4Cl_2]^+(aq) + Cl^-(aq)$$

The free chloride ion in the outer sphere reacts with $AgNO_3$ to form silver chloride precipitate:

$$Cl^-(aq) + Ag^+(aq) \rightarrow AgCl(s) \downarrow$$

Because only the outer sphere chloride undergoes ionization, exactly one mole of AgCl is liberated per mole of the complex salt. The octahedral geometry of the core coordination complex $[Co(NH_3)_4Cl_2]^+$ remains intact.

Final Answer: $\boxed{\text{Octahedral}}$

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

Go Back to Question 7

Q8.

Solution

Concept: Under Crystal Field Theory (CFT), the five d-orbitals of a metal ion in an octahedral ligand field split into two sets: three lower-energy t_{2g} orbitals and two higher-energy e_g orbitals. The distribution of electrons in these orbitals depends on the spin state of the complex.

Solution: Step 1: Identify the d-electron count. The complex has a d^5 electronic configuration, meaning there are 5 valence d-electrons on the central metal ion.

Step 2: Determine the electronic distribution for high-spin. In a high-spin complex, the crystal field splitting energy (Δ_o) is less than the spin pairing energy (P). According to Hund's rule, electrons fill all five split d-orbitals singly before any orbital receives a second electron:

$$\text{Configuration: } (t_{2g})^3(e_g)^2$$

Step 3: Count the unpaired electrons.

- There are 3 electrons in the t_{2g} subshell, each occupying one of the three degenerate orbitals singly.
- There are 2 electrons in the e_g subshell, each occupying one of the two degenerate orbitals singly.

All 5 electrons are unpaired.

Final Answer: $\boxed{\text{Five unpaired electrons}}$

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

Go Back to Question 8

Q9.

Solution

Concept: The bond order of homonuclear diatomic species is calculated using Molecular Orbital (MO) theory:

$$\text{Bond Order} = \frac{N_b - N_a}{2}$$

where N_b is the number of bonding electrons and N_a is the number of antibonding electrons.

Solution: Step 1: Write down the valence molecular orbital electronic configuration for neutral O_2 (16 electrons):

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

Here, $N_b = 10$ and $N_a = 6$:

$$\text{Bond Order of } O_2 = \frac{10 - 6}{2} = 2.0$$

Step 2: Evaluate the other oxygen species by adding or removing electrons from the highest occupied molecular orbitals (π_{2p}^*):

- **O_2^+ (15 electrons):** One electron is removed from an antibonding π^* orbital. Thus, $N_b = 10$ and $N_a = 5$:

  $$\text{Bond Order} = \frac{10 - 5}{2} = 2.5$$

- **O_2^- (17 electrons):** One electron is added to an antibonding π^* orbital. Thus, $N_b = 10$ and $N_a = 7$:

  $$\text{Bond Order} = \frac{10 - 7}{2} = 1.5$$

- **O_2^{2-} (18 electrons):** Two electrons are added to the antibonding π^* orbitals. Thus, $N_b = 10$ and $N_a = 8$:

  $$\text{Bond Order} = \frac{10 - 8}{2} = 1.0$$

Step 3: Comparing the bond orders shows that O_2^+ (2.5) has the highest bond order.

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

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: The first member of each main group in the periodic table exhibits anomalous behavior relative to its heavier congeners. This is due to a combination of distinct physical and chemical characteristics unique to the period 2 elements.

Solution: Step 1: Identify the key properties of fluorine (F, $Z = 9$) compared to other halogens (Cl, Br, I):

- **Extremely small size:** Fluorine has the smallest atomic and ionic radius in Group 17, resulting in high charge density and strong electron-electron repulsions when extra electrons are added.
- **High electronegativity:** Fluorine is the most electronegative element in the periodic table, which dramatically alters the ionic character and hydrogen-bonding capabilities of its compounds.
- **Absence of d-orbitals:** Fluorine resides in Period 2, meaning it lacks valence-shell d-orbitals, restricting its maximum coordination number and valence to 1.
- **Low F-F bond dissociation energy:** The extremely small size of fluorine atoms brings their non-bonding lone pairs very close together, causing strong electrostatic repulsions that weaken the $\mathrm{F-F}$ single covalent bond.

Step 2: Because all of these factors collectively explain the high reactivity, weak single bond strength, and unusual physical properties of fluorine and its hydrides (such as HF), the anomalous behavior is attributed to their combined effect.

Final Answer:

$$\boxed{\begin{array}{c}\text{Combined effect of small size, high electronegativity}\\ \text{and low bond dissociation energy of } F-F\end{array}}$$

Answer: (D)

Go Back to Question 10

Q11.

Solution

Concept: The molecular geometries and bond angles of covalent molecules are predicted by Valence Shell Electron Pair Repulsion (VSEPR) theory. Repulsions decrease in the order:

$$\text{lone pair - lone pair (lp-lp)} > \text{lone pair - bond pair (lp-bp)} > \text{bond pair - bond pair (bp-bp)}$$

Solution: Step 1: Analyze the hybridization and electron geometry of each molecule. All three molecules ($\mathrm{CH_4}$, $\mathrm{NH_3}$, and $\mathrm{H_2O}$) have sp^3-hybridized central atoms and a tetrahedral arrangement of their electron pairs.

Step 2: Evaluate the count of bond pairs and lone pairs:

- $\mathrm{CH_4}$ **(Methane):** Carbon has 4 bond pairs and 0 lone pairs. There are no lone-pair repulsions, so the molecule retains a perfect tetrahedral geometry with a bond angle of exactly 109.5°.
- $\mathrm{NH_3}$ **(Ammonia):** Nitrogen has 3 bond pairs and 1 lone pair. The stronger lp-bp repulsion compresses the $\mathrm{H-N-H}$ bond angle down from the ideal tetrahedral angle to approximately 107°.
- $\mathrm{H_2O}$ **(Water):** Oxygen has 2 bond pairs and 2 lone pairs. The strong lp-lp repulsion, combined with lp-bp repulsions, compresses the $\mathrm{H-O-H}$ bond angle even further to approximately 104.5°.

Step 3: Arrange the bond angles in decreasing order:

$$\mathrm{CH_4}\ (109.5^\circ) > \mathrm{NH_3}\ (107^\circ) > \mathrm{H_2O}\ (104.5^\circ)$$

Final Answer: $\boxed{CH_4 > NH_3 > H_2O}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: According to Hückel's rule, a cyclic, planar, completely conjugated system is classified as aromatic if it contains $(4n + 2)$ π-electrons (where n is a non-negative integer).

Solution: Step 1: Identify the structure of the cycloheptatrienyl cation (tropylium ion, $C_7H_7^+$). It is a seven-membered ring containing three conjugated double bonds and one positively charged carbon atom.

Step 2: Determine hybridization and planarity. Every carbon atom in the ring is sp^2-hybridized, allowing for a planar ring. The carbon with the positive charge has an empty p-orbital, which allows the π-electrons to be completely and continuously delocalized around the entire ring.

Step 3: Count the number of π-electrons. The three conjugated double bonds contribute:

$$\text{Number of } \pi\text{-electrons} = 3 \times 2 = 6\ \pi\text{-electrons}$$

Step 4: Apply Hückel's rule. For $n = 1$:

$$4n + 2 = 4(1) + 2 = 6\ \pi\text{-electrons}$$

Because the tropylium ion is planar, completely conjugated, and contains exactly 6 π-electrons, it is highly stable and classified as aromatic.

Final Answer: $\boxed{6\pi\text{-electrons and is aromatic}}$

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

Go Back to Question 12

Q13.

Solution

Concept: While both cysteine and methionine are sulfur-containing amino acids, only cysteine possesses a reactive thiol group ($-SH$) capable of undergoing oxidation to form a covalent disulfide linkage ($-S-S-$) in proteins.

Solution: Step 1: Examine the chemical structure of the side chains of the listed amino acids:

- **Cysteine:** Contains a thiol group ($-CH_2-SH$). Under oxidizing conditions, the free $-SH$ groups of two cysteine residues can couple to form a disulfide bond:

$$R-SH+HS-R \xrightarrow{[O]} R-S-S-R+H_2O$$

- **Methionine:** Contains a thioether group ($-CH_2-CH_2-S-CH_3$). Because the sulfur atom is alkylated and lacks a hydrogen atom, it cannot undergo oxidation to form disulfide bonds.
- **Serine:** Contains a hydroxyl group ($-CH_2-OH$), which contains no sulfur.
- **Tyrosine:** Contains a phenolic group ($-CH_2-C_6H_4-OH$), which contains no sulfur.

Step 2: Thus, methionine is the sulfur-containing amino acid that does not participate directly in disulfide bond formation.

Final Answer: $\boxed{\text{Methionine}}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: The de Broglie hypothesis relates the wave-like character of a particle to its momentum (p):

$$\lambda = \frac{h}{p}$$

For a charged particle accelerated through an electric potential, its kinetic energy can be expressed in terms of the potential difference (V).

Solution: Step 1: Write down the kinetic energy (K) of an electron (charge e) accelerated through a potential difference V:

$$K = eV$$

Step 2: Relate kinetic energy to momentum (p). Since $K = \frac{p^2}{2m}$:

$$p = \sqrt{2mK} = \sqrt{2meV}$$

Step 3: Substitute the momentum into the de Broglie wavelength formula:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

Step 4: Identify the constants in the equation. Since Planck's constant (h), the electron mass (m), and the electron charge (e) are constant:

$$\lambda = \left(\frac{h}{\sqrt{2me}}\right) \cdot \frac{1}{\sqrt{V}} \implies \lambda \propto \frac{1}{\sqrt{V}}$$

Thus, the de Broglie wavelength of the accelerated electron is proportional to $1/\sqrt{V}$.

Final Answer: $\boxed{1/\sqrt{V}}$

Answer: (D)

Go Back to Question 14

Q15.

Solution

Concept: Le Chatelier's principle predicts how a system at chemical equilibrium shifts in response to changes in temperature, pressure, or concentration.

Solution: Step 1: Analyze the reaction stoichiometry:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

The forward reaction converts 2 moles of reactant gas into 1 mole of product gas ($\Delta n_g = 1-2 = -1$).

Step 2: Evaluate the effect of decreasing temperature.
Because the dimerization reaction is exothermic ($\Delta H < 0$), decreasing the temperature shifts the equilibrium in the direction that releases heat. This shifts the equilibrium to the **right**, producing more N_2O_4.

Step 3: Evaluate the effect of increasing pressure.
According to Le Chatelier's principle, increasing the pressure shifts the equilibrium in the direction that decreases the total number of gaseous moles to relieve the pressure. Since the forward direction reduces the number of gas moles, this shifts the equilibrium to the **right**, producing more N_2O_4.

Step 4: Evaluate the effect of adding a catalyst.
A catalyst accelerates the rates of both the forward and reverse reactions equally. It speeds up the rate at which equilibrium is established but does not alter the position of the equilibrium or the final concentrations.

Step 5: Combine the effects. Because both the temperature decrease and pressure increase shift the equilibrium in the same direction (to the right), the final mixture will contain more N_2O_4.

Final Answer: $\boxed{\text{More } N_2O_4}$

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

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Answer Key

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