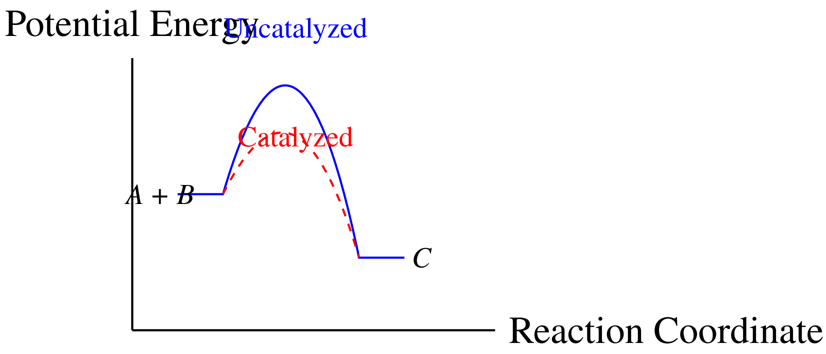
IISER Chemistry Sample Paper-3

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. The potential energy profile for a reaction $A + B \rightarrow C$ in the presence and absence of a catalyst is shown below. If the activation energy for the forward reaction without catalyst is 75 kJ/mol and the catalyst lowers it by 25 kJ/mol, while the enthalpy of the reaction $\Delta H = -20$ kJ/mol, find the activation energy for the backward reaction ($C \rightarrow A + B$) in the presence of the catalyst.



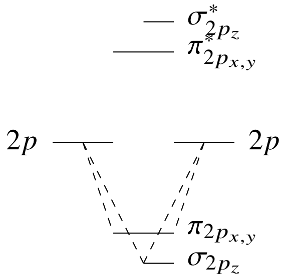
(A) 95 kJ/mol

(B) 70 kJ/mol

(C) 50 kJ/mol

(D) 45 kJ/mol

Q2. According to the Molecular Orbital (MO) theory, which of the following represents the correct electronic configuration and magnetic behavior of the superoxide ion (O_2^-)?



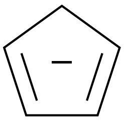
(A) Bond order = 2.0, Diamagnetic

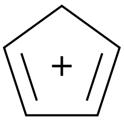
(B) Bond order = 1.5, Paramagnetic

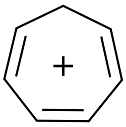
(C) Bond order = 2.5, Paramagnetic

(D) Bond order = 1.0, Diamagnetic

Q3. Identify which of the following cyclic compounds is aromatic based on Hückel's rule $(4n + 2)\pi$ electrons.


(I)


(II)


(III)

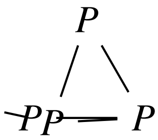
(A) Only (I)

(B) Only (III)

(C) (I) and (III)

(D) (II) and (III)

Q4. White phosphorus (P_4) exhibits a tetrahedral geometry. Which of the following statements regarding its structure and properties is CORRECT?



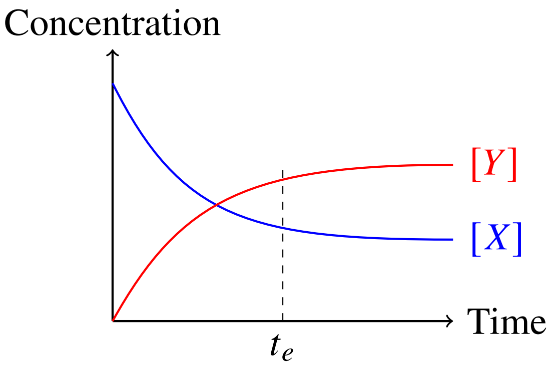
(A) The $P - P - P$ bond angle is 109°28′.

(B) Phosphorus atoms are sp^3 hybridized with a bond angle of 60°.

(C) It is the most stable allotrope of phosphorus.

(D) Each phosphorus atom is bonded to four other phosphorus atoms.

Q5. The variation of concentration with time for the reaction $X \rightleftharpoons Y$ is shown below. Based on the graph, determine the equilibrium constant K_c and the nature of the reaction.



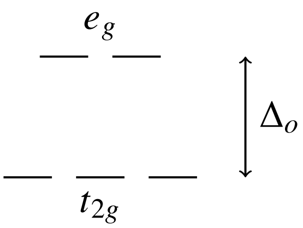
(A) $K_c \approx 1.9$, product favored

(B) $K_c \approx 0.5$, reactant favored

(C) $K_c = 1.0$, at equilibrium

(D) The reaction never reaches equilibrium

Q6. For a d^4 metal ion in an octahedral crystal field, the distribution of electrons in t_{2g} and e_g orbitals depends on the crystal field splitting energy (Δ_o) and the pairing energy (P). Which condition leads to a high-spin complex?



(A) $\Delta_o > P$

(B) $\Delta_o < P$

(C) $\Delta_o = P$

(D) High-spin is only possible for tetrahedral fields

Q7. Which of the following molecules will yield a yellow precipitate with iodine and sodium hydroxide but will NOT reduce Tollen's reagent?

(A) Acetaldehyde

(B) Acetophenone

(C) Propanal

(D) Benzaldehyde

Q8. Given the standard reduction potentials: $E°(Zn^{2+}/Zn) = -0.76$ V, $E°(Fe^{2+}/Fe) = -0.44$ V, and $E°(Cu^{2+}/Cu) = +0.34$ V. Which of the following reactions is NOT spontaneous?

(A) $Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$

(B) $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$

(C) $Cu + Zn^{2+} \longrightarrow Cu^{2+} + Zn$

(D) $Zn + Fe^{2+} \longrightarrow Zn^{2+} + Fe$

Q9. Ozonolysis of an alkene 'M' followed by workup with Zn and H_2O produces 2 moles of propanone. The IUPAC name of alkene 'M' is:

(A) 2,3-Dimethylbut-2-ene

(B) 2-Methylbut-2-ene

(C) Hex-3-ene

(D) 2,3-Dimethylbut-1-ene

Q10. For a reaction to be spontaneous specifically at low temperatures but non-spontaneous at high temperatures, the enthalpy change (ΔH) and entropy change (ΔS) must be:

(A) $\Delta H < 0, \Delta S < 0$

(B) $\Delta H > 0, \Delta S > 0$

(C) $\Delta H < 0, \Delta S > 0$

(D) $\Delta H > 0, \Delta S < 0$

Q11. The primary valence and secondary valence of cobalt in the complex $[Co(NH_3)_5Cl]Cl_2$ are respectively:

(A) 3 and 6

(B) 2 and 5

(C) 3 and 5

(D) 2 and 6

Q12. Which of the following undergoes nucleophilic addition most rapidly?

(A) $\mathrm{CH_3CHO}$

(B) $\mathrm{ClCH_2CHO}$

(C) $\mathrm{Cl_2CHCHO}$

(D) $\mathrm{Cl_3CCHO}$

Q13. The vapor pressure of pure liquid A is 100 torr and that of pure liquid B is 150 torr. In an ideal solution of A and B, the mole fraction of A in the vapor phase is 0.4. What is the mole fraction of A in the liquid phase?

(A) 0.5

(B) 0.4

(C) 0.6

(D) 0.2

Q14. Arrange the following carbocations in increasing order of stability: (I) $(CH_3)_2\mathrm{CH}^+$, (II) $CH_3\mathrm{CH}_2^+$, (III) $(CH_3)_3\mathrm{C}^+$, (IV) CH_3^+

(A) IV < II < I < III

(B) III < I < II < IV

(C) II < IV < I < III

(D) I < II < III < IV

Q15. Which of the following statements about DNA is CORRECT?

(A) It contains uracil as a nitrogenous base.

(B) The two strands are parallel to each other.

(C) Adenine pairs with thymine via two hydrogen bonds.

(D) The sugar moiety is ribose.

Detailed Solutions

Q1.

Solution

Concept: The activation energy (E_a) represents the kinetic barrier that reactants must overcome to reach the transition state during a chemical transformation. A catalyst operates by providing a lower-energy alternative mechanism, thereby reducing E_a and increasing the rate constant as per the Arrhenius equation. Crucially, the enthalpy of reaction (ΔH) is a thermodynamic state function defined by the energy difference between products and reactants. This value remains strictly invariant regardless of the presence of a catalyst. The fundamental relationship linking kinetics and thermodynamics for a reversible process is $\Delta H = E_{a,f} - E_{a,b}$, where $E_{a,f}$ and $E_{a,b}$ are the activation energies for the forward and backward directions, respectively.

Solution:

Step 1: We begin by analyzing the uncatalyzed pathway. The forward activation energy is $E_{a,f} = 75$ kJ/mol and the reaction enthalpy is $\Delta H = -20$ kJ/mol. Using the relation $\Delta H = E_{a,f} - E_{a,b}$, we find the uncatalyzed backward activation energy: $-20 = 75 - E_{a,b}(\text{uncat})$, which yields $E_{a,b}(\text{uncat}) = 95$ kJ/mol.

Step 2: Now consider the catalyzed pathway. The prompt states the catalyst reduces the forward activation energy by 25 kJ/mol. Consequently, the new forward barrier is $E_{a,f}(\text{cat}) = 75 - 25 = 50$ kJ/mol.

Step 3: A catalyst lowers the energy of the transition state equally for both the forward and backward reactions. Since the enthalpy ΔH is constant at -20 kJ/mol, we apply the same energy balance to the catalyzed state: $\Delta H = E_{a,f}(\text{cat}) - E_{a,b}(\text{cat})$.

Step 4: Substituting the known values into the equation: $-20 = 50 - E_{a,b}(\text{cat})$. Rearranging to solve for the target variable: $E_{a,b}(\text{cat}) = 50 - (-20) = 70$ kJ/mol.

Step 5: To verify, we can check the total reduction. If the forward barrier dropped by 25, the backward barrier must also drop by 25 from its uncatalyzed value ($95 - 25 = 70$). This confirms the calculation is robust. The resulting value represents the energy required for the products to return to the transition state in the presence of the catalyst.

Final Answer: $\boxed{70 \text{ kJ/mol}}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: Molecular Orbital (MO) theory utilizes the Linear Combination of Atomic Orbitals (LCAO) to predict the electronic structure, bond order, and magnetic properties of molecules. For homonuclear diatomic molecules of oxygen and heavier elements (where $Z > 7$), the energy ordering of molecular orbitals is: $\sigma_{2s} < \sigma^*_{2s} < \sigma_{2p_z} < \pi_{2p_{x,y}} < \pi^*_{2p_{x,y}} < \sigma^*_{2p_z}$. Bond order is calculated as half the difference between the number of electrons in bonding and antibonding orbitals ($B.O. = \frac{1}{2}(N_b - N_a)$). Magnetic behavior is determined by the presence (paramagnetic) or absence (diamagnetic) of unpaired electrons in the ground state configuration.

Solution:

Step 1: Calculate the total valence electron count for the superoxide ion, O_2^-. Each oxygen atom contributes 6 valence electrons ($2 \times 6 = 12$). The -1 charge adds an extra electron, resulting in a total of 13 valence electrons. (If using total electrons, it is $8 + 8 + 1 = 17$).

Step 2: Fill the molecular orbitals following the Aufbau principle and Hund's rule. The distribution of 13 valence electrons (ignoring $n = 1$ shell) is: $\sigma_{2s}^2 {\sigma^*_{2s}}^2 \sigma_{2p_z}^2 \pi_{2p_x}^2 \pi_{2p_y}^2 {\pi^*_{2p_x}}^2 {\pi^*_{2p_y}}^1$.

Step 3: Identify the bonding and antibonding counts in the valence shell. Bonding electrons (N_b) $= 2$ (σ_{2s}) $+ 2$ (σ_{2p_z}) $+ 4$ (π_{2p}) $= 8$. Antibonding electrons (N_a) $= 2$ (σ^*_{2s}) $+ 3$ (π^*_{2p}) $= 5$. Note: Including $1s$ gives $N_b = 10$ and $N_a = 7$.

Step 4: Calculate the bond order: $B.O. = \frac{10-7}{2} = 1.5$. A bond order of 1.5 indicates a bond strength intermediate between a single and a double bond, consistent with experimental observations of bond length.

Step 5: Assess magnetic properties. The last electron is placed in one of the degenerate π^*_{2p} orbitals. Because there is one unpaired electron, the O_2^- species is paramagnetic and will be attracted to an external magnetic field.

Step 6: Match with the given options. Option (B) correctly identifies the bond order as 1.5 and the magnetic state as paramagnetic.

Final Answer: $\boxed{Bondorder = 1.5, Paramagnetic}$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Aromaticity is a property of cyclic, planar, conjugated molecules that exhibit exceptional stability compared to their acyclic counterparts. According to Hückel's Rule, a molecule is aromatic if it possesses $(4n + 2)$ π-electrons, where n is an integer $(0, 1, 2, \ldots)$. Additionally, the system must be cyclic, the ring must be planar to allow for orbital overlap, and every atom in the ring must participate in the conjugation (possess an unhybridized p-orbital). If a system is cyclic, planar, and conjugated but has $4n$ π-electrons, it is categorized as anti-aromatic and is significantly destabilized.

Solution:

Step 1: Evaluate structure (I), the cyclopentadienyl anion. The ring is a five-membered cycle. It contains two double bonds (4π electrons) and a carbon with a negative charge. This negative carbon is sp^2 hybridized, and its lone pair resides in a p-orbital, contributing 2π electrons to the system. Total π electrons = $4 + 2 = 6$. Since $6 = 4(1) + 2$, it satisfies Hückel's rule for $n = 1$. It is aromatic.

Step 2: Evaluate structure (II), the cyclopentadienyl cation. This five-membered ring has two double bonds (4π electrons) and a positively charged carbon. The carbocation carbon is sp^2 hybridized but its p-orbital is empty. Total π electrons = 4. Since $4 = 4(1)$, it follows the $4n$ rule, making it anti-aromatic.

Step 3: Evaluate structure (III), the cycloheptatrienyl cation (tropylium ion). This is a seven-membered ring with three double bonds (6π electrons). The seventh carbon is positively charged and sp^2 hybridized with an empty p-orbital, allowing for continuous conjugation around the ring. Total π electrons = 6. As $6 = 4(1) + 2$, it satisfies Hückel's rule for $n = 1$. It is aromatic.

Step 4: Based on these analyses, both (I) and (III) are aromatic systems. This matches the criteria for stability through delocalization.

Final Answer: $\boxed{(I) and (III)}$

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: White phosphorus (P_4) is a molecular allotrope of phosphorus consisting of discrete tetrahedral molecules. In this structure, each phosphorus atom is covalently bonded to three other phosphorus atoms at the vertices of a regular tetrahedron. This geometry is unique because it forces the bond angles to be significantly different from the ideal angles expected for sp^3 hybridization. The resulting angular strain is a primary factor in the high chemical reactivity and thermodynamic instability of white phosphorus compared to other allotropes like red or black phosphorus.

Solution:

Step 1: Examine the coordination environment. Each phosphorus atom in the P_4 tetrahedron is bonded to exactly three other phosphorus atoms. Additionally, each phosphorus atom (Group 15) has one lone pair of electrons.

Step 2: Determine the hybridization. With three sigma bonds and one lone pair, the steric number is 4. According to VSEPR theory, the electron geometry is tetrahedral, which corresponds to sp^3 hybridization.

Step 3: Analyze the bond angles. In a regular tetrahedron, the geometric angle between any two edges meeting at a vertex is exactly 60°. Therefore, the $P - P - P$ bond angle in the molecule is 60°.

Step 4: Identify the steric strain. For an sp^3 hybridized atom, the ideal bond angle is 109.5°. The reduction to 60° causes severe "ring strain" or angular strain. This makes the $P - P$ bonds in white phosphorus weaker and more susceptible to oxidation, which is why white phosphorus is pyrophoric (ignites spontaneously in air).

Step 5: Evaluate the options. Option (B) correctly identifies the sp^3 hybridization and the 60° bond angle. Option (A) is incorrect as it gives the ideal rather than actual angle. Option (C) is incorrect as black phosphorus is the most stable. Option (D) is incorrect as each P is bonded to 3 others, not 4.

Final Answer: $\boxed{\text{Phosphorus atoms are } sp^3 \text{ hybridized with a bond angle of } 60^\circ.}$

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: The equilibrium constant (K_c) for a reversible chemical reaction $X \rightleftharpoons Y$ provides a quantitative measure of the extent to which a reaction proceeds before reaching equilibrium. It is defined as the ratio of the molar concentrations of the products to the reactants at equilibrium: $K_c = [Y]_{eq}/[X]_{eq}$. Graphically, equilibrium is identified as the point in time (t_e) after which the concentrations of all species remain constant, represented by horizontal lines on a concentration-time plot. The magnitude of K_c indicates whether the reaction favors products ($K_c > 1$) or reactants ($K_c < 1$).

Solution:

Step 1: Locate the equilibrium state on the provided graph. The concentrations of X and Y cease to change after the time marked t_e. At this plateau, the rates of the forward and backward reactions are equal.

Step 2: Estimate the equilibrium concentrations from the vertical axis. At $t > t_e$, the concentration of product Y, $[Y]_{eq}$, is clearly higher than the concentration of reactant X, $[X]_{eq}$. Specifically, looking at the initial value of X (3.5) and the final levels, Y reaches about 2.3 while X drops to about 1.2.

Step 3: Calculate the equilibrium constant: $K_c = [Y]_{eq}/[X]_{eq} \approx 2.3/1.2 \approx 1.91$.

Step 4: Interpret the result. Since K_c is significantly greater than 1, the product Y is more stable or favored under these conditions, and the equilibrium lies to the right.

Step 5: Review the choices. Option (A) provides the approximate value 1.9 and correctly identifies the reaction as product-favored. Options (B) and (C) contradict the visual evidence that $[Y] > [X]$. Option (D) is incorrect as the curves clearly plateau.

Final Answer: $\boxed{K_c \approx 1.9, \text{ product favored}}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: Crystal Field Theory (CFT) describes the electronic structure of transition metal complexes by considering the electrostatic interactions between the metal d-orbitals and the surrounding ligands. In an octahedral complex, the five d-orbitals split into two groups: the lower-energy t_{2g} set (d_{xy}, d_{yz}, d_{xz}) and the higher-energy e_g set ($d_{z^2}, d_{x^2-y^2}$). The energy difference is the splitting energy Δ_o. For d^4 through d^7 ions, two electronic configurations are possible: High Spin (maximum unpaired electrons) and Low Spin (minimum unpaired electrons). The configuration adopted depends on the relative magnitudes of Δ_o and the mean electron pairing energy (P).

Solution:

Step 1: Analyze the d^4 electronic arrangement. The first three electrons always occupy the three t_{2g} orbitals according to Hund's rule, providing stabilization. The fourth electron faces a choice.

Step 2: Consider the High-Spin condition. If the splitting energy Δ_o is small, specifically smaller than the pairing energy P ($\Delta_o < P$), the fourth electron will occupy a higher-energy e_g orbital rather than pairing up in a t_{2g} orbital. This is because the energy "cost" to jump to e_g is less than the repulsion energy of pairing. This results in 4 unpaired electrons.

Step 3: Consider the Low-Spin condition. If Δ_o is large ($\Delta_o > P$), the energy gap is too high for the electron to jump. It is energetically more favorable to pair up in a t_{2g} orbital despite the pairing energy P. This results in 2 unpaired electrons.

Step 4: Relate to ligand field. High-spin complexes are typical for weak-field ligands (like halides or OH^-), which produce small Δ_o. Low-spin complexes are typical for strong-field ligands (like CN^- or CO), which produce large Δ_o.

Step 5: Identify the correct option. The requirement for a high-spin complex is $\Delta_o < P$.

Final Answer: $\boxed{\Delta_o < P}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The Iodoform test identifies the presence of methyl ketones ($R-CO-CH_3$) or alcohols that can be oxidized to methyl ketones ($R-CH(OH)-CH_3$). A positive test is indicated by the formation of a yellow precipitate of iodoform (CHI_3). Tollen's reagent (ammoniacal silver nitrate) is a mild oxidizing agent that specifically reduces to metallic silver ("silver mirror") in the presence of aldehydes. Ketones, which lack the oxidizable hydrogen atom directly attached to the carbonyl carbon, generally do not react with Tollen's reagent.

Solution:

Step 1: Evaluate Acetaldehyde (CH_3CHO). It is a methyl aldehyde. It contains the CH_3-CO- equivalent, so it gives a positive Iodoform test. However, as an aldehyde, it reduces Tollen's reagent to form a silver mirror. This contradicts the "will NOT react" condition.

Step 2: Evaluate Acetophenone ($C_6H_5COCH_3$). It is a methyl ketone. The methyl group adjacent to the carbonyl allows it to undergo the haloform reaction to produce yellow CHI_3. As it is an aromatic ketone, it does not react with Tollen's reagent. This satisfies both conditions.

Step 3: Evaluate Propanal (CH_3CH_2CHO). It is an aldehyde (positive Tollen's). It is not a methyl ketone (negative Iodoform).

Step 4: Evaluate Benzaldehyde (C_6H_5CHO). It is an aromatic aldehyde. It reduces Tollen's reagent (albeit slowly compared to aliphatic ones). It is not a methyl ketone (negative Iodoform).

Step 5: Conclusion. Acetophenone is the molecule that shows a positive iodoform test and a negative Tollen's test.

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

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The spontaneity of a redox reaction is determined by the standard cell potential (E°_{cell}). A reaction is spontaneous under standard conditions if $E^\circ_{cell} > 0$. The cell potential is calculated using the standard reduction potentials of the cathode and anode: $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$. In any redox reaction, the species that is reduced acts as the cathode, and the species that is oxidized acts as the anode.

Solution:

Step 1: Analyze reaction (A): $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. Zinc is oxidized (Anode, −0.76 V) and Copper is reduced (Cathode, +0.34 V). $E^\circ_{cell} = 0.34 - (-0.76) = +1.10$ V. Since $E^\circ > 0$, it is spontaneous.

Step 2: Analyze reaction (B): $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$. Iron is oxidized (Anode, −0.44 V) and Copper is reduced (Cathode, +0.34 V). $E^\circ_{cell} = 0.34 - (-0.44) = +0.78$ V. Since $E^\circ > 0$, it is spontaneous.

Step 3: Analyze reaction (C): $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$. Copper is oxidized (Anode, +0.34 V) and Zinc is reduced (Cathode, −0.76 V). $E^\circ_{cell} = -0.76 - 0.34 = -1.10$ V. Since $E^\circ < 0$, it is non-spontaneous.

Step 4: Analyze reaction (D): $Zn + Fe^{2+} \rightarrow Zn^{2+} + Fe$. Zinc is oxidized (Anode, −0.76 V) and Iron is reduced (Cathode, −0.44 V). $E^\circ_{cell} = -0.44 - (-0.76) = +0.32$ V. Since $E^\circ > 0$, it is spontaneous.

Step 5: The question asks for the reaction that is NOT spontaneous. Reaction (C) fits this criteria.

Final Answer: $\boxed{Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn}$

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: Ozonolysis is a chemical reaction that cleaves carbon-carbon double bonds in alkenes using ozone (O_3). Reductive workup with zinc (Zn) and water (H_2O) ensures that the resulting fragments are aldehydes or ketones, preventing further oxidation to carboxylic acids. To identify the starting alkene, one can "reverse" the process by removing the oxygen atoms from the carbonyl products and joining the carbon atoms together with a double bond.

Solution:

Step 1: Identify the fragments produced. The problem states that 2 moles of propanone ($CH_3 - CO - CH_3$) are formed.

Step 2: Align the fragments to visualize the reconnection. We have two identical molecules: $(CH_3)_2C = O$ and $O = C(CH_3)_2$.

Step 3: Remove the oxygen atoms and connect the carbonyl carbons with a double bond. This reconstruction yields: $(CH_3)_2C = C(CH_3)_2$.

Step 4: Determine the IUPAC name of the reconstructed molecule. The longest chain containing the double bond has 4 carbons (Butene). The double bond is at position 2. There are two methyl groups at positions 2 and 3. Thus, the name is 2,3-dimethylbut-2-ene.

Step 5: Evaluate the options. Option (A) matches our derived structure. Option (B) would give propanone and ethanal. Option (C) would give propanal. Option (D) would give propanone and methanal.

Final Answer: $\boxed{\text{2,3-Dimethylbut-2-ene}}$

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

Go Back to Question 9

Q10.

Solution

Concept: The spontaneity of a chemical reaction is governed by the change in Gibbs Free Energy (ΔG), as defined by the equation $\Delta G = \Delta H - T\Delta S$. For a reaction to be spontaneous, ΔG must be negative. The signs of enthalpy change (ΔH) and entropy change (ΔS) determine how spontaneity varies with temperature (T). 1. If $\Delta H < 0$ and $\Delta S > 0$, ΔG is always negative (spontaneous at all T). 2. If $\Delta H > 0$ and $\Delta S < 0$, ΔG is always positive (non-spontaneous at all T). 3. If $\Delta H < 0$ and $\Delta S < 0$, the $T\Delta S$ term is positive; ΔG is negative only at low T. 4. If $\Delta H > 0$ and $\Delta S > 0$, the $T\Delta S$ term is negative; ΔG is negative only at high T.

Solution:

Step 1: The question specifies that the reaction is spontaneous at low temperatures and non-spontaneous at high temperatures.

Step 2: For spontaneity at low T, the ΔH term must be the dominant factor and must be negative ($\Delta H < 0$, exothermic).

Step 3: For non-spontaneity at high T, the $-T\Delta S$ term must eventually become positive and outweigh the negative ΔH. Since T is positive, this requires ΔS to be negative ($\Delta S < 0$).

Step 4: Combining these, we need $\Delta H < 0$ and $\Delta S < 0$. Under these conditions, ΔG becomes more positive as T increases, crossing from spontaneous to non-spontaneous at $T = \Delta H/\Delta S$.

Step 5: Review the options. Option (A) correctly identifies $\Delta H < 0$ and $\Delta S < 0$.

Final Answer: $\boxed{\Delta H < 0, \Delta S < 0}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Alfred Werner's theory of coordination compounds distinguishes between two types of valency for metal atoms. Primary valence (ionizable) corresponds to the oxidation state of the metal ion and is satisfied by negative ions. Secondary valence (non-ionizable) corresponds to the coordination number, which is the total number of ligands directly bonded to the metal atom in the coordination sphere.

Solution:

Step 1: Identify the oxidation state (Primary Valence) of Cobalt in $[Co(NH_3)_5Cl]Cl_2$. Let the oxidation state be x. NH_3 is neutral (0), and Cl has a -1 charge. The sum must equal the total charge. $x + 5(0) + 1(-1) + 2(-1) = 0 \implies x - 3 = 0 \implies x = +3$. Thus, the primary valence is 3.

Step 2: Identify the coordination number (Secondary Valence). The species inside the square brackets are directly bonded to the metal. There are five NH_3 molecules and one Cl^- ion. Total number of ligands $= 5 + 1 = 6$. Thus, the secondary valence is 6.

Step 3: Confirm the roles. The three Cl^- ions satisfy the primary valence (charge), while the five NH_3 and one internal Cl^- satisfy the secondary valence (geometry).

Step 4: Check the choices. Option (A) correctly lists 3 and 6. Option (C) confuses the number of ammonia molecules with the total coordination number.

Final Answer: $\boxed{\text{3 and 6}}$

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

Go Back to Question 11

Q12.

Solution

Concept: Nucleophilic addition to a carbonyl group involves the attack of a nucleophile on the electrophilic carbonyl carbon. The rate of this reaction is determined by two main factors: (1) The magnitude of the partial positive charge ($\delta+$) on the carbonyl carbon. Electron-withdrawing groups (EWG) increase this charge via the inductive effect ($-I$), thereby making the carbon more susceptible to attack. (2) Steric hindrance, which can block the nucleophile's approach. In this series, the steric environment is similar (all are aldehydes), so the inductive effect of the chlorine atoms is the primary differentiator.

Solution:

Step 1: Analyze the inductive effects in the given molecules. (I) CH_3CHO has an electron-donating methyl group ($+I$), which reduces the electrophilicity of the carbonyl. (II) $ClCH_2CHO$ has one chlorine atom (EWG), which increases electrophilicity. (III) Cl_2CHCHO has two chlorines, increasing it further. (IV) Cl_3CCHO (chloral) has three chlorine atoms.

Step 2: The three chlorine atoms in chloral exert a very strong $-I$ effect, significantly increasing the partial positive charge on the carbonyl carbon.

Step 3: Consequently, chloral is extremely reactive towards nucleophiles. It is so reactive that it can even form a stable hydrate (chloral hydrate) where two OH groups are attached to the same carbon, an otherwise unstable arrangement.

Step 4: Ranking the reactivity: $Cl_3CCHO > Cl_2CHCHO > ClCH_2CHO > CH_3CHO$. The most rapid reaction occurs with Cl_3CCHO.

Final Answer: $\boxed{Cl_3CCHO}$

Answer: (D)

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Q13.

Solution

Concept: For an ideal solution, the relationship between the composition of the liquid phase and the vapor phase is governed by Raoult's Law ($P_i = X_i P_i^\circ$) and Dalton's Law ($P_i = Y_i P_{total}$). Combining these gives $Y_A = \frac{X_A P_A^\circ}{X_A P_A^\circ + X_B P_B^\circ}$. Here, X_A is the mole fraction in the liquid phase, and Y_A is the mole fraction in the vapor phase.

Solution:

Step 1: State the given information: $P_A^\circ = 100$ torr, $P_B^\circ = 150$ torr, and $Y_A = 0.4$. Step 2: We know that $X_B = 1 - X_A$. Using the formula for Y_A: $0.4 = \frac{100X_A}{100X_A + 150(1-X_A)}$. Step 3: Simplify the denominator: $100X_A + 150 - 150X_A = 150 - 50X_A$. Step 4: Set up the equation: $0.4 = \frac{100X_A}{150-50X_A} \implies 0.4(150-50X_A) = 100X_A$. Step 5: Solve for X_A: $60-20X_A = 100X_A \implies 60 = 120X_A \implies X_A = 60/120 = 0.5$. Step 6: The mole fraction of A in the liquid phase is 0.5. This means the liquid contains equal parts A and B, but B's higher volatility results in it making up 60% of the vapor ($Y_B = 1 - 0.4 = 0.6$). Final Answer: $\boxed{0.5}$

Answer: (A)

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Q14.

Solution

Concept: The stability of carbocations is primarily determined by two effects: inductive effect and hyperconjugation. Alkyl groups are electron-donating via the inductive effect $(+I)$ and provide stabilization through the delocalization of σ-electrons from adjacent $C - H$ bonds into the empty p-orbital of the carbocation (hyperconjugation). Generally, the more alkyl groups attached to the positively charged carbon, the more stable the carbocation. The order of stability is: Tertiary (3°) > Secondary (2°) > Primary (1°) > Methyl.

Solution: Step 1: Identify the degree of each carbocation. (I) $(CH_3)_2\text{CH}^+$ is a secondary carbocation (2°). It has 6 alpha-hydrogens for hyperconjugation. (II) $CH_3\text{CH}_2^+$ is a primary carbocation (1°). It has 3 alpha-hydrogens. (III) $(CH_3)_3\text{C}^+$ is a tertiary carbocation (3°). It has 9 alpha-hydrogens. (IV) CH_3^+ is the methyl carbocation. It has 0 alpha-hydrogens and no $+I$ stabilization from alkyl groups.

Step 2: Apply the stability order: $3^\circ > 2^\circ > 1^\circ >$ Methyl.

Step 3: Ranking the structures: (III) is the most stable, followed by (I), then (II), and finally (IV).

Step 4: Convert this to an increasing order: IV < II < I < III. This matches option (A).

Final Answer: $\boxed{IV < II < I < III}$

Answer: (A)

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Q15.

Solution

Concept: Deoxyribonucleic acid (DNA) is the molecule that carries genetic information. Its structure, proposed by Watson and Crick, is a double helix consisting of two polynucleotide strands. Key structural features include: (1) The backbone is made of alternating sugar (deoxyribose) and phosphate groups. (2) The two strands are anti-parallel (run in opposite $5' \rightarrow 3'$ directions). (3) Nitrogenous bases are linked via hydrogen bonds according to base-pairing rules: Adenine (A) always pairs with Thymine (T) via two hydrogen bonds, and Cytosine (C) always pairs with Guanine (G) via three hydrogen bonds.

Solution:

Step 1: Evaluate statement (A). DNA contains Thymine, not Uracil. Uracil is found in RNA. Incorrect. Step 2: Evaluate statement (B). The strands are anti-parallel, not parallel. One runs $5' \rightarrow 3'$ and the other $3' \rightarrow 5'$. Incorrect. Step 3: Evaluate statement (C). Adenine and Thymine form two hydrogen bonds. This is a correct structural fact of DNA base pairing. Step 4: Evaluate statement (D). The sugar in DNA is 2-deoxyribose. Ribose is the sugar in RNA. Incorrect. Step 5: Based on the structural rules of nucleic acids, statement (C) is the only accurate description of DNA.

Final Answer: $\boxed{\text{Adenine pairs with thymine via two hydrogen bonds.}}$

Answer: (C)

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Answer Key

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