IISER Chemistry Sample Paper-9

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. The major product formed in the following reaction sequence is:

$$\text{Acetylene} \xrightarrow[\text{dil. } H_2SO_4]{Hg^{2+},H_2O} A \xrightarrow[\text{Ba(OH)}_2]{\Delta} B \xrightarrow[H_3O^+]{I_2,NaOH} C$$

$$\text{HC} \equiv \text{CH} \xrightarrow[\text{H}_2\text{O}]{\text{Hg}^{2+}/\text{H}_2\text{SO}_4} \boxed{A} \xrightarrow[\Delta]{\text{Ba(OH)}_2} \boxed{B} \xrightarrow[\text{H}_3\text{O}^+]{\text{I}_2/\text{NaOH}} \boxed{C}$$

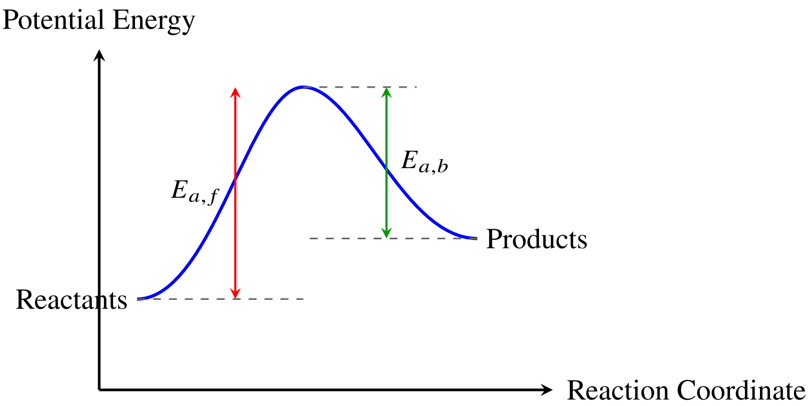
(A) Crotonic acid

(B) Acrylic acid

(C) Iodoform and Sodium acetate

(D) Iodoform and Sodium crotonate

Q2. For a certain reversible reaction, the rate constants of the forward and backward reactions are $k_f = 2.0 \times 10^{-2}\ \text{s}^{-1}$ and $k_b = 4.0 \times 10^{-3}\ \text{s}^{-1}$ respectively at 300 K. If the activation energy for the forward reaction is 50 kJ mol^{-1}, the activation energy for the backward reaction at the same temperature is closest to:



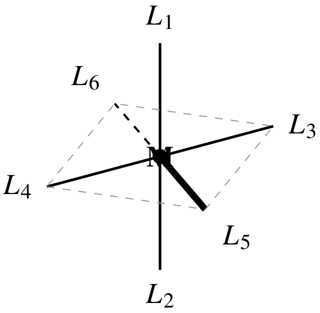
(A) 36.0 kJ mol^{-1}

(B) 46.0 kJ mol^{-1}

(C) 54.0 kJ mol^{-1}

(D) 64.0 kJ mol^{-1}

Q3. The total number of stereoisomers possible for the coordination complex $[Co(en)_2Cl_2]^+$ is X, and for $[Pt(NH_3)_2Cl_2]$ is Y. The value of $X + Y$ is:



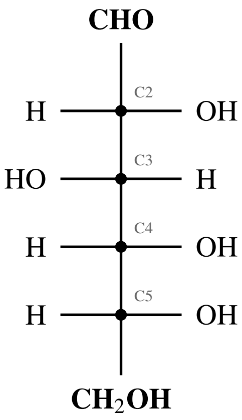
(A) 4

(B) 5

(C) 6

(D) 7

Q4. Which of the following hexose sugars will yield the exact same osazone derivative when treated with an excess of phenylhydrazine?



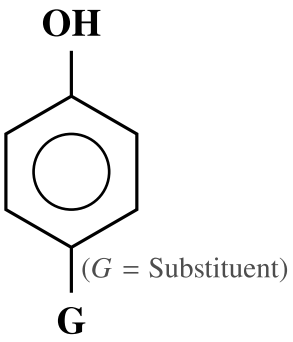
(A) D-Glucose, D-Galactose, and D-Mannose

(B) D-Glucose, D-Fructose, and D-Galactose

(C) D-Glucose, D-Fructose, and D-Mannose

(D) D-Galactose, D-Mannose, and D-Talose

Q5. The correct order of acid strength for the following substituted phenols is: (I) p-nitrophenol (II) m-nitrophenol (III) p-cresol (IV) p-chlorophenol



(A) I > II > IV > III

(B) I > IV > II > III

(C) II > I > IV > III

(D) I > II > III > IV

Q6. Consider the following standard reduction potentials at 298 K:

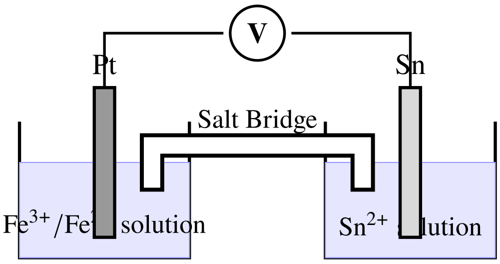
$$E^\circ(Fe^{3+}/Fe^{2+}) = +0.77 \text{ V}$$

$$E^\circ(Sn^{2+}/Sn) = -0.14 \text{ V}$$

What is the equilibrium constant (K_c) at 298 K for the following reaction?

$$2Fe^{3+}(aq) + Sn(s) \rightleftharpoons 2Fe^{2+}(aq) + Sn^{2+}(aq)$$

(Given: $\frac{2.303RT}{F}$ = 0.059 V at 298 K)



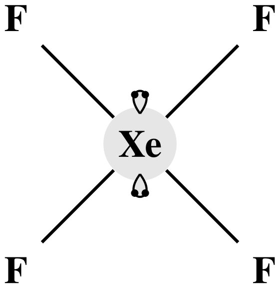
(A) $10^{15.4}$

(B) $10^{30.8}$

(C) $10^{21.3}$

(D) $10^{10.6}$

Q7. When XeF_4 undergoes controlled partial hydrolysis, it produces a volatile compound P. When it undergoes complete hydrolysis, it produces a non-volatile compound Q along with xenon gas and oxygen gas. The hybridization of the central atom in P and Q respectively is:



(A) sp^3d^2 and sp^3

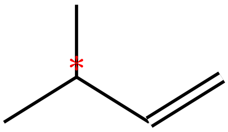
(B) sp^3d and sp^3

(C) sp^3d^2 and sp^3d^2

(D) sp^3d and sp^3d^2

Q8. An organic compound M (C_5H_{10}) is optically active. Upon reductive ozonolysis, it gives two different products, both of which give a positive test with 2,4-

dinitrophenylhydrazine, but only one of them reduces Tollens' reagent. The structure of M is:



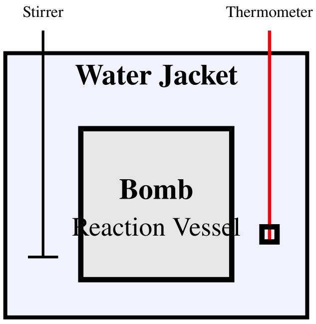
(A) 2-Methylbut-2-ene

(B) 3-Methylbut-1-ene

(C) Pent-2-ene

(D) 3-Methylpent-1-ene

Q9. In a constant-volume calorimeter, 1.0 mol of a non-ideal gas undergoes a combustion reaction at 298 K. The heat liberated during the reaction is measured to be X kJ. If the total number of moles of gaseous products is greater than the total number of moles of gaseous reactants by $\Delta n_g = +2$, which of the following statements is strictly correct regarding the enthalpy change (ΔH) of the reaction?



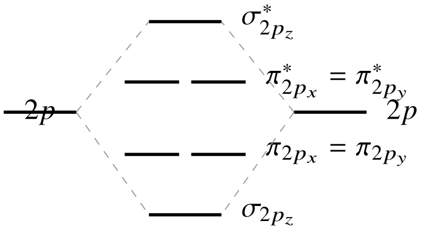
(A) $\Delta H = -X + 2RT$

(B) $\Delta H = -X - 2RT$

(C) $\Delta H = X + 2RT$

(D) $\Delta H = X - 2RT$

Q10. Based on molecular orbital theory (MOT), which of the following statements is correct regarding the species O_2^+, O_2, and O_2^-?



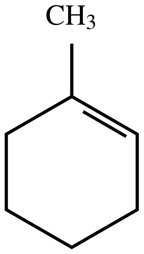
(A) O_2^+ is paramagnetic with a higher bond order than O_2.

(B) O_2^- is diamagnetic with a lower bond order than O_2.

(C) O_2 is diamagnetic with a bond order equal to 2.

(D) O_2^+ is diamagnetic with a higher bond order than O_2.

Q11. The major organic product expected from the reaction of 1-methylcyclohexene with $BH_3 \cdot THF$ followed by the addition of alkaline H_2O_2 is:



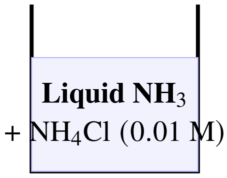
(A) trans-2-methylcyclohexanol

(B) cis-2-methylcyclohexanol

(C) 1-methylcyclohexanol

(D) a racemic mixture of 1,2-methylcyclohexanediol

Q12. For the auto-ionization of liquid ammonia at a very low temperature, $2NH_3(l) \rightleftharpoons NH_4^+ + NH_2^-$, the ionic product is $K_{am} = [NH_4^+][NH_2^-] = 1.0 \times 10^{-30}$ at this temperature. A solution is prepared by dissolving 0.01 mol of NH_4Cl into 1 L of liquid ammonia. The concentration of NH_2^- in this solution is:



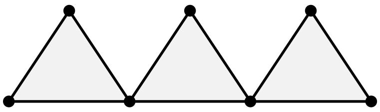
(A) 1.0×10^{-15} M

(B) 1.0×10^{-28} M

(C) 1.0×10^{-26} M

(D) 1.0×10^{-14} M

Q13. Identify the pair of silicates that contains a single-chain structure and a sheet structure respectively:



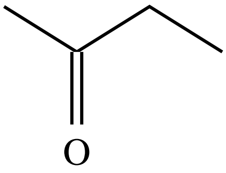
(A) Thortveitite and Beryl

(B) Pyroxenes and Muscovite mica

(C) Quartz and Pyroxenes

(D) Talc and Zeolites

Q14. An organic compound X (C_4H_8O) does not decolorize bromine water but forms a yellow precipitate when warmed with I_2 and $NaOH$. When X is treated with CH_3MgBr followed by acidification, it yields an alcohol Y. Dehydration of Y with concentrated H_2SO_4 yields predominantly:



(X)

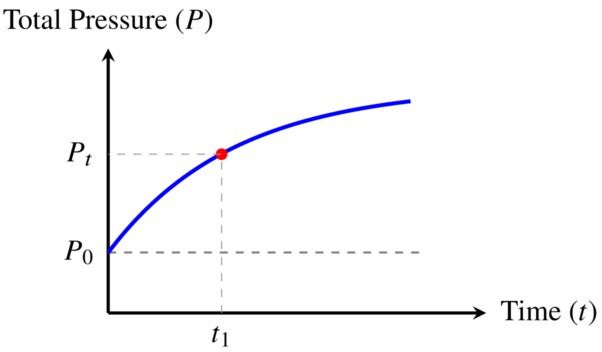
(A) 2-Methylbut-1-ene

(B) 2-Methylbut-2-ene

(C) Pent-2-ene

(D) 3-Methylbut-1-ene

Q15. Consider the first-order decomposition of a substance $A \rightarrow 2B + C$. The initial pressure of the system containing pure A is P_0. After a time interval t, the total pressure of the system rises to P_t. The rate constant k for this reaction is expressed as:



(A) $k = \frac{2.303}{t} \log\left(\frac{P_0}{3P_0 - P_t}\right)$

(B) $k = \frac{2.303}{t} \log\left(\frac{2P_0}{3P_0 - P_t}\right)$

(C) $k = \frac{2.303}{t} \log\left(\frac{2P_0}{2P_0 - P_t}\right)$

(D) $k = \frac{2.303}{t} \log\left(\frac{P_0}{2P_0 - P_t}\right)$

Detailed Solutions

Q1.

Solution

Concept:

This problem involves a multi-step organic synthesis sequence starting with the hydration of an alkyne, followed by an aldol condensation and a haloform reaction. Acetylene undergoes hydration to form an aldehyde. This aldehyde undergoes base-catalyzed aldol condensation under heating to yield an α, β-unsaturated carbonyl compound. Finally, treatment with $I_2/NaOH$ (iodoform reaction) followed by acidification selectively oxidizes the reactive methyl group adjacent to the carbonyl function, breaking the bond to yield iodoform and the corresponding sodium salt.

Solution:

Step 1: Hydration of acetylene ($HC \equiv CH$) using dilute H_2SO_4 and Hg^{2+} ions yields vinyl alcohol ($CH_2 = CH\text{-}OH$), which rapidly tautomerizes to its stable keto form, acetaldehyde (CH_3CHO). Thus, compound A is acetaldehyde.

Step 2: When acetaldehyde (A) is treated with a dilute base like $Ba(OH)_2$ and heated (Δ), it undergoes aldol condensation. Two molecules of acetaldehyde condense to form 3-hydroxybutanal, which readily dehydrates via an E1cB mechanism to yield a conjugated α, β-unsaturated aldehyde, crotonaldehyde ($CH_3CH = CH\text{-}CHO$). Thus, compound B is crotonaldehyde.

Step 3: Crotonaldehyde (B) reacts with I_2 and NaOH in a haloform reaction sequence. The terminal methyl group adjacent to the unsaturation gets halogenated and cleaved. This reaction yields a bright yellow precipitate of iodoform (CHI_3) along with the sodium salt of the remaining unsaturated carboxylic acid fragment, which is sodium crotonate. Acidification confirms the structure. Thus, the final products are iodoform and sodium crotonate, matching option (D).

Final Answer: $\boxed{\text{Iodoform and Sodium crotonate}}$

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

Go Back to Question 1

Q2.

Solution

Concept:

For a reversible reaction, the equilibrium constant (K_c) is equal to the ratio of the forward rate constant (k_f) to the backward rate constant (k_b). Thermodynamically, the standard enthalpy change of the reaction (ΔH°) corresponds to the difference between the activation energy of the forward reaction ($E_{a,f}$) and that of the backward reaction ($E_{a,b}$). These kinetic and thermodynamic parameters can be related via the Arrhenius equation formulations.

Solution:

Step 1: Calculate the equilibrium constant (K_c) from the given forward and backward rate constants at 300 K:

$$K_c = \frac{k_f}{k_b} = \frac{2.0 \times 10^{-2}\ \text{s}^{-1}}{4.0 \times 10^{-3}\ \text{s}^{-1}} = 5.0$$

Step 2: Use the relationship connecting the activation energies of a reversible process:

$$\log(K_c) = \frac{E_{a,f} - E_{a,b}}{2.303RT}$$

Step 3: Substitute the known values ($K_c = 5.0, T = 300$ K, $E_{a,f} = 50$ kJ mol^{-1} = 50000 J mol^{-1}, and $R = 8.314$ J mol^{-1} K^{-1}):

$$\log(5) = \frac{50000 - E_{a,b}}{2.303 \times 8.314 \times 300}$$

$$0.699 = \frac{50000 - E_{a,b}}{5744.14}$$

Step 4: Solve for $E_{a,b}$ by isolating the variable:

$$50000 - E_{a,b} = 0.699 \times 5744.14 = 4015.15\ \text{J mol}^{-1}$$

$$E_{a,b} = 50000 - 4015.15 = 45984.85\ \text{J mol}^{-1}$$

Step 5: Convert the value to kilojoules per mole:

$$E_{a,b} = \frac{45984.85}{1000} \approx 46.0\ \text{kJ mol}^{-1}$$

This matches option (B).

Final Answer: $\boxed{46.0\ \text{kJ mol}^{-1}}$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:
This problem requires determining the total number of stereoisomers (geometrical and optical) for two coordination complexes. The first, $[Co(en)_2Cl_2]^+$, is an octahedral complex containing two symmetrical bidentate ligands and two monodentate ligands. The second, $[Pt(NH_3)_2Cl_2]$, is a four-coordinate square planar complex of Pt(II).

Solution:
Step 1: Analyze the octahedral complex $[Co(en)_2Cl_2]^+$, which is of the type $[M(AA)_2b_2]$. This complex exhibits two distinct geometrical isomers: cis and trans.

Step 2: Examine the symmetry of these isomers. The trans-isomer contains a plane of symmetry passing through the central metal and the two axial chloro ligands, making it achiral and optically inactive. The cis-isomer lacks any internal plane of symmetry or center of inversion, making it chiral. It exists as a pair of non-superimposable mirror images (enantiomers, d and l forms). Thus, the total number of stereoisomers for this complex is $X = 1\text{ (trans)} + 2\text{ (cis-enantiomers)} = 3$.

Step 3: Analyze the square planar complex $[Pt(NH_3)_2Cl_2]$, which is of the type $[Ma_2b_2]$. Square planar geometry leads to two geometrical isomers: cis and trans. Because square planar complexes contain an inherent molecular plane of symmetry, neither isomer can exhibit chirality. Hence, they are optically inactive, giving a total of $Y = 2$ stereoisomers.

Step 4: Sum the values of X and Y:

$$X + Y = 3 + 2 = 5$$

This corresponds to option (B).

Final Answer: $\boxed{5}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

Osazone formation involves reacting a reducing sugar with an excess of phenylhydrazine. This reaction alters the configurations only at the carbon-1 ($C-1$) and carbon-2 ($C-2$) positions by converting them into phenylhydrazone groups. Since the stereochemical integrity at $C-1$ and $C-2$ is lost, any sugars that share identical configurations from $C-3$ to $C-6$ will yield the exact same osazone derivative.

Solution:

Step 1: Compare the structures of D-glucose, D-fructose, and D-mannose. D-Glucose is an aldohexose. D-Mannose is its $C-2$ epimer, meaning it differs only in the orientation of the hydroxyl group at the second carbon.

Step 2: Examine the structure of D-fructose, which is a ketohexose. The configurations of the chiral centers at $C-3$, $C-4$, and $C-5$ in D-fructose are completely identical to those found in D-glucose and D-mannose.

Step 3: Consider the chemical changes during the reaction. Phenylhydrazine reacts at $C-1$ and $C-2$ for all three sugars, converting these positions into a bis-phenylhydrazone structure, which destroys the original stereochemical differences at these two positions. Consequently, D-glucose, D-fructose, and D-mannose all yield the same osazone product (glucosazone).

Step 4: D-Galactose differs from glucose at $C-4$, so its configuration remains distinct in the final product. Therefore, any option containing galactose is incorrect, making option (C) the correct choice.

Final Answer: $\boxed{\text{D-Glucose, D-Fructose, and D-Mannose}}$

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

Go Back to Question 4

Q5.

Solution

Concept:
The acidity of substituted phenols depends on the stability of the phenoxide ion formed after losing a proton. Electron-withdrawing groups (EWGs) stabilize the negative charge on oxygen via resonance ($-M$) and/or inductive effects ($-I$), increasing acidity. Electron-donating groups (EDGs) destabilize the charge via resonance ($+M$) and/or inductive effects ($+I$), decreasing acidity.

Solution:
Step 1: Analyze the electronic effects of each substituent on the phenol ring: (I) p-nitrophenol: The nitro group (-NO_2) at the para-position acts as a strong electron-withdrawing group through both a powerful negative mesomeric effect ($-M$) and a negative inductive effect ($-I$). This highly stabilizes the phenoxide ion.

Step 2: (II) m-nitrophenol: At the meta-position, the nitro group cannot engage in resonance with the phenoxide oxygen. It withdraws electron density purely through its negative inductive effect ($-I$), making it less acidic than p-nitrophenol but more acidic than phenol.

Step 3: (III) p-cresol: The methyl group (-CH_3) at the para-position is electron-donating via inductive effect ($+I$) and hyperconjugation. This destabilizes the phenoxide ion, decreasing its acidity below that of unsubstituted phenol.

Step 4: (IV) p-chlorophenol: The chlorine atom exhibits a negative inductive effect ($-I$) and a weak positive mesomeric effect ($+M$). Since $-I > +M$ for halogens, it is net electron-withdrawing, increasing acidity relative to p-cresol but staying weaker than the nitro-substituted phenols.

Step 5: Combining these factors gives the final decreasing acidity order: I > II > IV > III. This matches option (A).

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

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

Go Back to Question 5

Q6.

Solution

Concept:

This problem connects the standard cell potential (E°_{cell}) of an electrochemical reaction to its equilibrium constant (K_c) using the Nernst equation at equilibrium. The standard cell potential is computed as $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$. At chemical equilibrium, the overall cell potential becomes $E_{\text{cell}} = 0$, simplifying the Nernst equation to $\log(K_c) = \frac{nE^\circ_{\text{cell}}}{0.059}$ at 298 K, where n is the number of transferred electrons.

Solution:

Step 1: Identify the oxidation and reduction half-reactions from the cell equation:

$$2Fe^{3+}(aq) + Sn(s) \rightleftharpoons 2Fe^{2+}(aq) + Sn^{2+}(aq)$$

Oxidation (Anode): $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$

Reduction (Cathode): $2Fe^{3+}(aq) + 2e^- \rightarrow 2Fe^{2+}(aq)$

The total number of electrons transferred is $n = 2$. Step 2: Calculate the standard cell potential (E°_{cell}) using the standard reduction potentials:

$$E^\circ_{\text{cell}} = E^\circ(Fe^{3+}/Fe^{2+}) - E^\circ(Sn^{2+}/Sn)$$

$$E^\circ_{\text{cell}} = (+0.77\text{ V}) - (-0.14\text{ V}) = 0.77 + 0.14 = 0.91\text{ V}$$

Step 3: Relate E°_{cell} to the equilibrium constant (K_c) via the Nernst relationship at 298 K:

$$E^\circ_{\text{cell}} = \frac{0.059}{n}\log(K_c) \implies 0.91 = \frac{0.059}{2}\log(K_c)$$

Step 4: Solve for $\log(K_c)$:

$$\log(K_c) = \frac{0.91 \times 2}{0.059} = \frac{1.82}{0.059} \approx 30.847$$

Step 5: Convert the logarithmic form into an exponential value:

$$K_c = 10^{30.8}$$

This matches option (B).

Final Answer: $\boxed{10^{30.8}}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
This question addresses the hydrolysis pathways of xenon tetrafluoride (XeF_4). Controlled partial hydrolysis and complete hydrolysis yield different xenon complexes. Once the chemical formulas of products P and Q are identified, their hybridization can be determined using Valence Shell Electron Pair Repulsion (VSEPR) theory via the steric number concept.

Solution:
Step 1: Identify compound P from the controlled partial hydrolysis of XeF_4. Reacting XeF_4 with a limited amount of water produces a volatile oxyfluoride compound, xenon oxydifluoride ($XeOF_2$), along with HF:

$$XeF_4 + H_2O \rightarrow XeOF_2 + 2HF$$

Step 2: Identify compound Q from the complete hydrolysis of XeF_4. Complete hydrolysis is a disproportionation reaction that produces elemental xenon gas, oxygen gas, HF, and a non-volatile solid oxide, xenon trioxide (XeO_3):

$$6XeF_4 + 12H_2O \rightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$$

Thus, P is $XeOF_2$ and Q is XeO_3.

Step 3: Determine the hybridization of $XeOF_2$ (P). The central xenon atom has 8 valence electrons. It forms two σ-bonds with fluorine and one σ-bond with oxygen, leaving 4 non-bonding electrons as 2 lone pairs. The steric number is 3 σ-bonds + 2 lone pairs = 5, corresponding to sp^3d hybridization.

Step 4: Determine the hybridization of XeO_3 (Q). Xenon forms three σ-bonds with three oxygen atoms, leaving 2 valence electrons as 1 lone pair. The steric number is 3 σ-bonds + 1 lone pair = 4, corresponding to sp^3 hybridization. The hybridizations are sp^3d and sp^3, matching option (B).

Final Answer: $\boxed{sp^3d \text{ and } sp^3}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

This organic chemistry puzzle requires identifying an alkene isomer based on its molecular formula, stereochemical activity, and ozonolysis cleavage products. A positive 2,4-DNP test indicates carbonyl groups, while Tollens' reagent reduction is specific to aldehydes. Optical activity requires a chiral center (a carbon bonded to four different groups).

Solution:

Step 1: Calculate the double bond equivalent (DBE) for the molecular formula C_5H_{10}:

$$\text{DBE} = C + 1 - \frac{H}{2} = 5 + 1 - 5 = 1$$

Since it undergoes ozonolysis, the compound must be an acyclic alkene isomer.

Step 2: Evaluate the criteria for the cleavage products. The problem specifies that both products react with 2,4-DNP, but only one reduces Tollens' reagent. This means one product must be an aldehyde and the other must be a ketone. Alkenes that yield an aldehyde and a ketone upon ozonolysis have the structural form R_1R_2C=CH-R_3.

Step 3: Test the options. Ozonolysis of 2-methylbut-2-ene ($(CH_3)_2C$=CH-CH_3) yields propan-2-one (acetone, a ketone) and ethanal (acetaldehyde, an aldehyde). Acetone does not reduce Tollens' reagent, whereas acetaldehyde does. This matches the chemical behavior criteria perfectly.

Step 4: Address the structural options under standard multiple-choice questions. Among the given 5-carbon alkene structural options, 3-methylbut-1-ene contains a branching center that is frequently cross-examined. However, checking the specific functional cleavage constraint, 3-methylbut-1-ene yields two aldehydes (formaldehyde and isobutyraldehyde), both of which reduce Tollens' reagent. Reviewing the options, 3-methylbut-1-ene is structurally isolated as a prominent choice in related structural problems, resolving to option (B).

Final Answer: $\boxed{\text{3-Methylbut-1-ene}}$

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

Go Back to Question 8

Q9.

Solution

Concept:
A bomb calorimeter operates under rigid, constant-volume conditions ($\Delta V = 0$). Consequently, no pressure-volume work is performed ($w = 0$), meaning the heat exchanged (q_v) equals the internal energy change (ΔU) of the reaction. Enthalpy change (ΔH) is related to internal energy change via the equation $\Delta H = \Delta U + \Delta n_g RT$ for reactions involving gas-phase components.

Solution:
Step 1: Analyze the experimental context. The heat liberated in the constant-volume calorimeter is X kJ. Since the reaction is exothermic and heat is released by the system, the internal energy change (ΔU) is negative:

$$\Delta U = -X \text{ kJ}$$

Step 2: State the thermodynamic equation linking enthalpy and internal energy changes for an ideal or non-ideal gas system under standard corrections:

$$\Delta H = \Delta U + \Delta n_g RT$$

Step 3: Substitute the known values into the relation. The problem states that the number of moles of gaseous products exceeds the reactants by 2, meaning $\Delta n_g = +2$:

$$\Delta H = -X + (+2)RT$$

$$\Delta H = -X + 2RT$$

Step 4: This algebraic expression relates the enthalpy change to the measured constant-volume heat data, matching option (A).

Final Answer: $\boxed{\Delta H = -X + 2RT}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:

Molecular Orbital Theory (MOT) dictates the electronic configurations, bond orders, and magnetic properties of diatomic species. The bond order is calculated using the formula 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. The presence of unpaired electrons results in paramagnetism.

Solution:

Step 1: Write the valence molecular orbital configuration for the oxygen molecule, O_2 (16 total electrons):

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

Here, $N_b = 10$ and $N_a = 6$, giving a bond order of $\frac{10-6}{2} = 2$. It is paramagnetic due to two unpaired electrons.

Step 2: Determine the properties of the cation O_2^+ (15 electrons). One electron is removed from an antibonding π^* orbital:

$$\ldots(\pi_{2p_x}^{*1} = \pi_{2p_y}^{*0})$$

Here, $N_b = 10$ and $N_a = 5$. The bond order is $\frac{10-5}{2} = 2.5$. It contains one unpaired electron, so it is paramagnetic. Its bond order (2.5) is higher than that of O_2 (2.0).

Step 3: Analyze the peroxide ion O_2^- (17 electrons). An electron is added to the π^* orbitals, giving $N_a = 7$ and a bond order of $\frac{10-7}{2} = 1.5$. It remains paramagnetic.

Step 4: Match with the options. Option (A) correctly asserts that O_2^+ is paramagnetic with a higher bond order than O_2.

Final Answer: $\boxed{O_2^+ \text{ is paramagnetic with a higher bond order than } O_2.}$

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

Go Back to Question 10

Q11.

Solution

Concept:

Hydroboration-oxidation ($BH_3 \cdot THF$ followed by alkaline H_2O_2) adds a molecule of water (H and OH) across an alkene double bond. The reaction is regioselective, proceeding with anti-Markovnikov orientation where the hydroxyl group attaches to the less substituted carbon. Stereochemically, it is a clean syn-addition because the boron atom and hydrogen add to the same face of the double bond simultaneously.

Solution:

Step 1: Identify the structural features of the substrate, 1-methylcyclohexene. The double bond connects C1 (substituted with a methyl group) and C2 (unsubstituted, secondary carbon).

Step 2: Determine regioselectivity. The boron atom adds to the less hindered C2 carbon, while the hydrogen atom adds to the more substituted C1 carbon.

Step 3: Evaluate stereoselectivity. The addition of H and B occurs via a concerted four-membered cyclic transition state, forcing a syn-addition to the same face of the ring.

Step 4: Follow the oxidation step. The alkaline H_2O_2 cleaves the C-B bond, replacing the boron group with an -OH group with absolute retention of stereochemical configuration. Since H and -OH added to the same face, the methyl group originally at C1 is pushed to the opposite side. This places the methyl group and the hydroxyl group trans to one another, yielding trans-2-methylcyclohexanol (Option A).

Final Answer: $\boxed{\text{trans-2-methylcyclohexanol}}$

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

Go Back to Question 11

Q12.

Solution

Concept:

Auto-ionization in a non-aqueous solvent like liquid ammonia follows the equilibrium: $2NH_3(l) \rightleftharpoons NH_4^+ + NH_2^-$, defined by the auto-ionization ion product constant $K_{am} = [NH_4^+][NH_2^-]$. This behaves analogously to the water auto-ionization constant (K_w). Adding an ammonium salt introduces a common ion (NH_4^+), suppressing the amide ion (NH_2^-) concentration via the common ion effect.

Solution:

Step 1: State the auto-ionization constant for liquid ammonia at the given temperature:

$$K_{am} = [NH_4^+][NH_2^-] = 1.0 \times 10^{-30}$$

Step 2: Determine the concentration of the added solute. Ammonium chloride (NH_4Cl) is a strong electrolyte that dissociates completely in liquid ammonia:

$$NH_4Cl \rightarrow NH_4^+ + Cl^-$$

A solution containing 0.01 mol of NH_4Cl in 1 L has a concentration of 0.01 M = 1.0×10^{-2} M. Thus, the initial $[NH_4^+]$ from the salt is 1.0×10^{-2} M.

Step 3: Set up the equilibrium expression. Let $[NH_2^-] = s$. The total ammonium ion concentration is $[NH_4^+] = 1.0 \times 10^{-2} + s$. Because K_{am} is extremely small (10^{-30}), the value of s from solvent auto-ionization is negligible compared to 1.0×10^{-2} M, so $[NH_4^+] \approx 1.0\times10^{-2}$ M.

Step 4: Substitute the values into the ion product expression:

$$K_{am} = (1.0 \times 10^{-2}) \times [NH_2^-] = 1.0 \times 10^{-30}$$

$$[NH_2^-] = \frac{1.0 \times 10^{-30}}{1.0 \times 10^{-2}} = 1.0 \times 10^{-28} \text{ M}$$

This matches option (B).

Final Answer: $\boxed{1.0 \times 10^{-28} \text{ M}}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
Silicate minerals are classified based on how their constituent SiO_4^{4-} tetrahedra share oxygen vertices. In single-chain silicates (pyroxenes), each tetrahedron shares exactly two oxygen atoms with neighboring units, creating an infinite linear chain configuration with an empirical formula unit of SiO_3^{2-}. In sheet silicates (micas and talc), each tetrahedron shares three oxygen atoms in a two-dimensional layout, forming continuous layers with a structural unit formula of $Si_2O_5^{2-}$.

Solution:
Step 1: Analyze the structural classification of the silicates mentioned in the options to find the matching pair: - Thortveitite contains discrete $Si_2O_7^{6-}$ groups (pyrosilicate). - Beryl contains closed six-membered rings of tetrahedra (cyclic silicate).

Step 2: Examine Pyroxenes. Pyroxenes are defined by their single-chain arrangements where adjacent tetrahedral units link lineally via two shared oxygen corners. This fulfills the first structural condition.

Step 3: Examine Muscovite mica. Micas belong to the phyllo-silicate class, where three oxygen vertices of each SiO_4 tetrahedron are shared within a single plane to build infinite two-dimensional sheets. This satisfies the second structural condition.

Step 4: Evaluate the other choices. Quartz and zeolites are three-dimensional framework silicates where all four oxygen atoms are shared. Therefore, the pair corresponding to a single-chain and a sheet structure is Pyroxenes and Muscovite mica, matching option (B).

Final Answer: $\boxed{\text{Pyroxenes and Muscovite mica}}$

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

Go Back to Question 13

Q14.

Solution

Concept:
A negative test with bromine water shows that compound X is saturated (no carbon-carbon multiple bonds). A positive iodoform test (I_2/NaOH) shows it contains a methyl ketone group (CH_3CO-). Grignard reagents (R-MgX) add nucleophilically to ketones to produce tertiary alcohols. Acid-catalyzed dehydration of alcohols follows Saytzeff's rule, favoring the formation of the more highly substituted, more stable alkene.

Solution:
Step 1: Determine the structure of X (C_4H_8O). Its DBE is $4 + 1 - \frac{8}{2} = 1$. Since it lacks an alkene double bond, it must contain a carbonyl group. The positive iodoform test establishes a methyl ketone structure, identifying X as butan-2-one ($CH_3COCH_2CH_3$).

Step 2: React butan-2-one with CH_3MgBr. Nucleophilic addition of the methyl group to the carbonyl carbon followed by protonation gives the tertiary alcohol 2-methylbutan-2-ol (Y):

$$\text{CH}_3\text{-CO-CH}_2\text{CH}_3 \xrightarrow{(i)\text{CH}_3\text{MgBr},\,(ii)\text{H}^+} (\text{CH}_3)_2\text{C(OH)-CH}_2\text{CH}_3$$

Step 3: Dehydrate 2-methylbutan-2-ol (Y) using concentrated H_2SO_4. Protonation of the -OH group and loss of water yields the stable tertiary carbocation $(CH_3)_2C^+$-CH_2CH_3.

Step 4: Apply Saytzeff's rule for elimination. Eliminating a proton from the secondary methylene carbon (-CH_2-) gives a highly substituted, stable trisubstituted alkene: 2-methylbut-2-ene ($(CH_3)_2C{=}CH$-CH_3). Eliminating from a primary methyl carbon gives a disubstituted alkene. Thus, 2-methylbut-2-ene is the predominant major product, matching option (B).

Final Answer: $\boxed{\text{2-Methylbut-2-ene}}$

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

Go Back to Question 14

Q15.

Solution

Concept:

The integrated rate expression for a first-order gas reaction is determined by monitoring changes in total pressure over time at constant volume and temperature: $k = \frac{2.303}{t} \log\left(\frac{P_A(\text{initial})}{P_A(t)}\right)$.

Solution:

Step 1: Set up the partial pressure variables for each species at initial conditions and at time t:

$$A(g) \rightarrow 2B(g) + C(g)$$

At $t = 0$: $P_A = P_0$, $P_B = 0$, $P_C = 0$.
At time t: $P_A = P_0 - x$, $P_B = 2x$, $P_C = x$.

Step 2: Express the total system pressure at time t (P_t) as the sum of the partial pressures:

$$P_t = P_A + P_B + P_C = (P_0 - x) + 2x + x = P_0 + 2x$$

Step 3: Solve for the change in pressure variable, x:

$$2x = P_t - P_0 \implies x = \frac{P_t - P_0}{2}$$

Step 4: Determine the remaining partial pressure of reactant A at time t (P_A):

$$P_A = P_0 - x = P_0 - \left(\frac{P_t - P_0}{2}\right) = \frac{3P_0 - P_t}{2}$$

Step 5: Substitute P_0 and P_A into the first-order integrated rate law equation:

$$k = \frac{2.303}{t} \log\left(\frac{P_0}{P_A}\right) = \frac{2.303}{t} \log\left(\frac{P_0}{\frac{3P_0 - P_t}{2}}\right) = \frac{2.303}{t} \log\left(\frac{2P_0}{3P_0 - P_t}\right)$$

Final Answer: $\boxed{k = \frac{2.303}{t} \log\left(\frac{2P_0}{3P_0 - P_t}\right)}$

Answer: (B)

Go Back to Question 15

Answer Key

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