IIT JAM 2023 CY Question Paper with Answer Key PDF

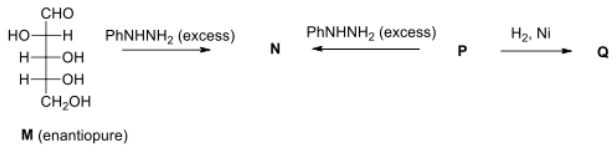
Time Allowed :1 Hour	Maximum Marks :100	Total Questions :60

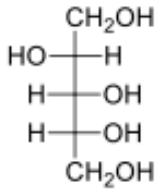
General Instructions

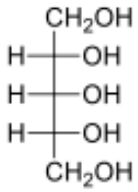
Read the following instructions very carefully and strictly follow them:

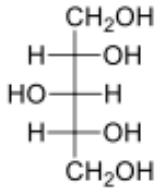
1. Please check that this question paper contains 60 questions.
2. Please write down the Serial Number of the question in the answer- book at the given place before attempting it.
3. This Question Paper has 60 questions. All questions are compulsory.
4. Adhere to the prescribed word limit while answering the questions.

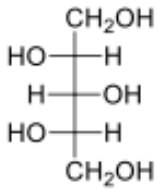
1. The structure of Q in the following reaction scheme is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (A)

Solution: This reaction scheme appears to describe the reduction of a compound M to Q. The key to solving the problem lies in recognizing the changes in the compound through the use of excess phenylhydrazine ($PhNHNH_2$) and the hydrogenation step with H_2 and Ni.
- The first step involves reacting with phenylhydrazine, which leads to the formation of an intermediate N, typically a hydrazone. - The second step, hydrogenation, reduces the compound to the final structure, Q. - The correct structure is consistent with the reduction of an aldehyde group to a primary alcohol, and the final structure of Q is determined by this.

Quick Tip

Identify the functional groups involved and consider the common reactions they undergo, such as hydrazone formation and reduction.

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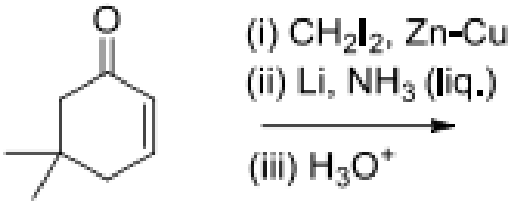
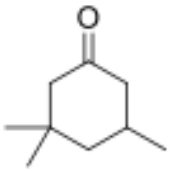
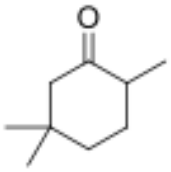
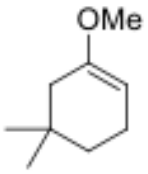
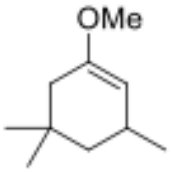
2. The major product of the reaction is



(A) 

(B) 

(C) 

(D) 

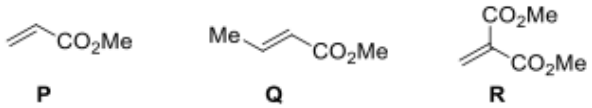
Correct Answer: (A)

Solution: The given reagents suggest a sequence of reactions: 1. CH_2I_2 with Zn-Cu forms a cyclopropane ring. 2. Lithium in liquid ammonia undergoes a reduction reaction, opening the cyclopropane ring to form an alkene. 3. Finally, the treatment with H_3O^+ leads to hydration, forming the major product as ethanol.

Quick Tip

The Wolff-Löffler reduction and subsequent hydration reactions are key in transforming cyclopropane derivatives to alcohols.

3. The rate of addition of 1-hexyl radical to the given molecules follows the order:



(1) $P > R > Q$
(2) $Q > P > R$
(3) $R > P > Q$
(4) $P > Q > R$

Correct Answer: (C)
Solution: In free radical addition reactions, the rate is affected by the stability of the radicals and intermediates. - P has the most stable conjugated structure, leading to the fastest reaction. - R is slightly less stable, and Q is the least stable, thus slower in reacting.

Quick Tip

In radical addition, the rate increases with the stability of the intermediates or transition states.

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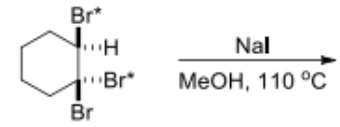
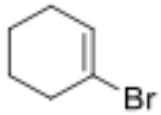
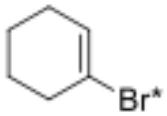
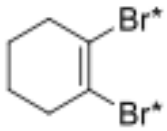
4. The major product of the reaction is

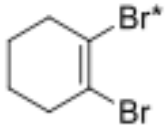


Br* = ^{82}Br

(A) 

(B) 

(C) 

(D) 

Correct Answer: (A)
Solution: In this reaction, the presence of NaI and methanol leads to nucleophilic substitution. The radical intermediate undergoes substitution by the methanol, and the final product is a substituted halide, with the major product being methyl-bromide.

Quick Tip

Nucleophilic substitution follows the pattern of the SN1 mechanism when there is a stable carbocation or radical intermediate.

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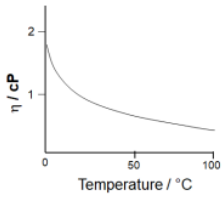
5. The diagram that best describes the variation of viscosity (η) of water with temperature at 1 atm is

(A)



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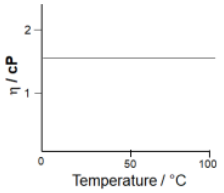

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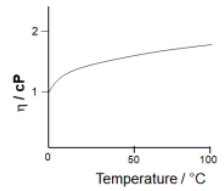

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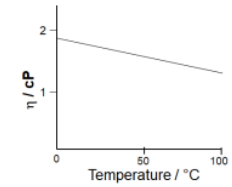

Correct Answer: (A)
Solution: Viscosity typically decreases with increasing temperature. As temperature rises, the molecular motion of water increases, which reduces the internal friction and thus the viscosity.

Quick Tip

For most liquids, viscosity decreases as temperature increases, following the inverse relationship.

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6. The SI unit of the molar conductivity of an electrolyte solution is
(1) $\mathrm{S\,m^{-1}\,mol^{-1}}$
(2) $\mathrm{S\,mol^{-1}}$
(3) $\mathrm{S\,m\,mol^{-1}}$
(4) $\mathrm{S\,m^{2}\,mol^{-1}}$

Correct Answer: (D)
Solution: Molar conductivity (Λ_m) is defined as the conductivity of an electrolyte solution divided by its molar concentration. Its unit is derived as $\mathrm{S\,m^{-1}\,mol^{-1}}$, indicating how much the solution's ability to conduct electricity depends on the concentration of the electrolyte.

Quick Tip

Molar conductivity depends on both the nature of the electrolyte and its concentration.

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7. The system with the lowest zero-point energy when it is confined to a one-dimensional box of length L is
(1) an electron
(2) a hydrogen atom
(3) a helium atom
(4) a proton

Correct Answer: (C)
Solution: In quantum mechanics, the zero-point energy is the lowest possible energy a quantum mechanical system can have. A particle confined to a box has its lowest energy state given by the quantum number $n = 1$. Among the options, a helium atom has more mass compared to an electron, and thus, its zero-point energy will be higher, making the electron the correct choice for the system with the lowest zero-point energy.

Quick Tip

The zero-point energy is inversely proportional to the mass of the particle. Heavier particles have higher zero-point energy.

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8. The metal ion present in human carbonic anhydrase is
(1) Fe^{3+}
(2) Cu^{2+}
(3) Zn^{2+}
(4) Ni^{2+}

Correct Answer: (C)
Solution: Carbonic anhydrase is an enzyme found in red blood cells, and it primarily uses zinc ions (Zn^{2+}) as a cofactor. Zinc facilitates the enzyme's ability to convert carbon dioxide and water into carbonic acid.

Quick Tip

Zinc is a common metal ion cofactor in enzymes involved in hydration reactions.

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9. The oxoacid of sulfur that has $S - O - S$ bond is

(1) Pyrosulfuric acid
(2) Pyrosulfurous acid
(3) Dithiotic acid
(4) Dithionic acid

Correct Answer: (A)
Solution: Pyrosulfuric acid (also known as oleum) has the molecular structure where sulfur atoms are connected by an oxygen atom, forming a $S - O - S$ bond. This structure is characteristic of pyrosulfuric acid.

Quick Tip

Look for the presence of the $S - O - S$ bond in oxoacids of sulfur.

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10. An alkaline (NaOH) solution of a compound produces a yellow colored solution on addition of NaBO. The compound is
(1) $Mn(OH)_2$
(2) $Pb(OH)_2$
(3) $Cr(OH)_3$
(4) $Fe(OH)_3$

Correct Answer: (C)
Solution: When sodium borate ($NaBO_3$) is added to an alkaline solution containing $Cr(OH)_3$, a yellow colored solution forms due to the formation of chromate (CrO_4^{2-}). This reaction is characteristic of chromium compounds.

Quick Tip

Chromium compounds typically form yellow chromates in alkaline conditions.

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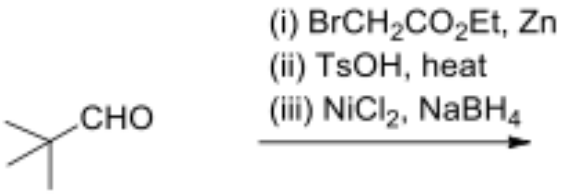
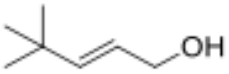
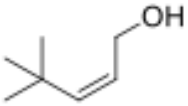
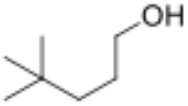
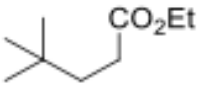
11. The major product of the reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (D)

Solution: In this reaction, the presence of BrCHCOEt with Zn leads to a reduction of the bromo group, and the TsOH under heat promotes elimination. Finally, the NiCl and NaBH result in a reduction to the aldehyde or alcohol group. The major product will be an aldol product.

Quick Tip

Aldol condensation involves a carbon-carbon bond formation, followed by dehydration to yield conjugated enones or aldol products.

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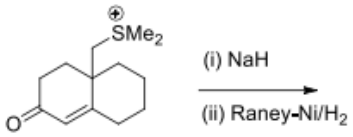
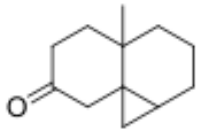
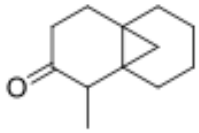
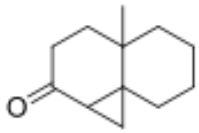
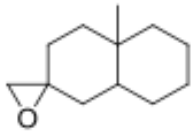
12. The major product in the following reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (C)
Solution: This reaction begins with NaH, which deprotonates the starting compound, generating an alkoxide ion that forms a cyclohexene intermediate. Raney Ni and hydrogenation then reduce the double bond, producing a saturated alcohol as the final product.

Quick Tip

Raney-Ni is commonly used for hydrogenation reactions that saturate double bonds, such as the reduction of alkenes to alkanes.

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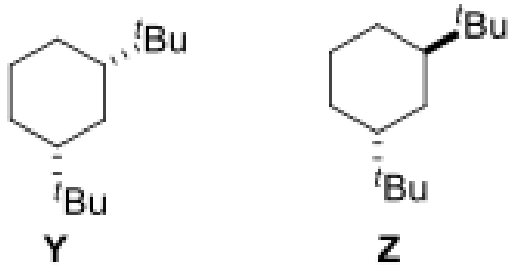
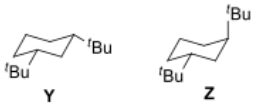
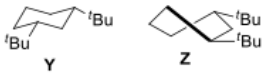
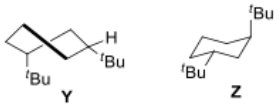
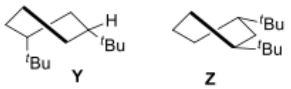
13. The most stable conformation of Y and that of Z are



(A) 

(B) 

(C) 

(D) 

Correct Answer: (B)
Solution: For bulky groups such as tBu, the most stable conformations are those where the bulky groups are positioned in the equatorial positions to minimize steric strain. The optimal conformation for Y and Z involves equatorial tBu groups.

Quick Tip

When working with cyclic compounds, axial/equatorial positioning significantly affects stability. Bulky substituents favor the equatorial position.

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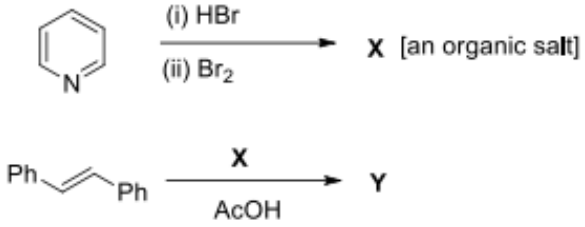
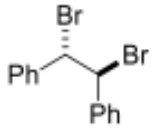
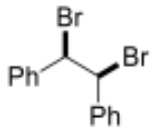
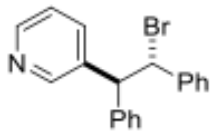
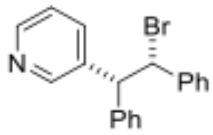
14. The major product Y in the following reaction scheme is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (B)
Solution: This reaction suggests an electrophilic substitution where HBr adds to the aromatic ring first, followed by a halogenation step with Br. The presence of AcOH as a solvent leads to substitution at the meta position, giving the major product with bromine at positions 1 and 3.

Quick Tip

Electrophilic aromatic substitution in the presence of AcOH typically leads to meta-substitution, especially with electron-withdrawing groups.

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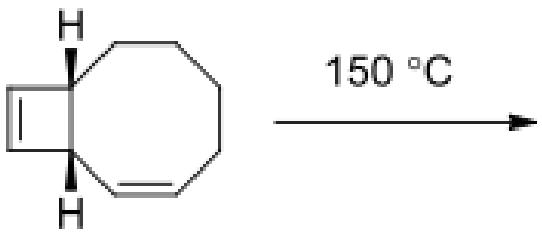
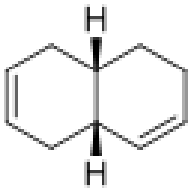
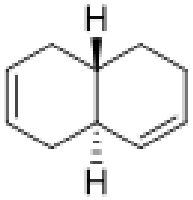
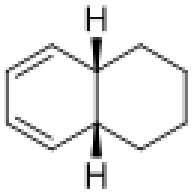
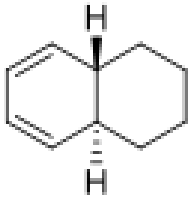
15. The major product of the reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (D)
Solution: When cyclohexene is heated at 150°C, a reaction like a dehydrogenation or elimination occurs, producing a cyclic product. The heat triggers the removal of hydrogen atoms, resulting in the final product with a double bond, indicating a rearrangement.

Quick Tip

Cyclohexene undergoes elimination or dehydrogenation reactions under heat to form products with conjugated systems or new double bonds.

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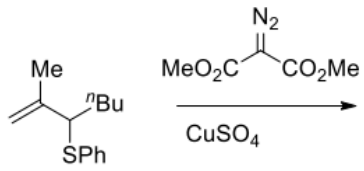
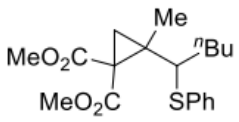
16. The major product of the reaction is



(A)


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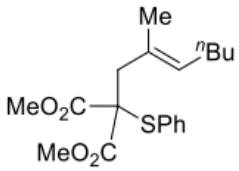

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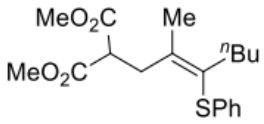
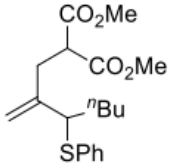


(D)


Correct Answer: (B)
Solution: The reaction involves a nucleophilic substitution, where the leaving group in the molecule is replaced by a nucleophile. Copper sulfate (CuSO) catalyzes the reaction and leads to the formation of the major product.

Quick Tip

In nucleophilic substitution reactions, the leaving group is replaced by a nucleophile, which is often facilitated by a metal catalyst like CuSO.

---

17. Adsorption of a gas on a solid surface follows the Langmuir isotherm. If $k_a/k_d = 1.0\,\text{bar}^{-1}$, the fraction of adsorption sites occupied by the gas at equilibrium under 2.0 bar of pressure of the gas at 25°C is
(1) $\frac{1}{4}$
(2) $\frac{1}{3}$
(3) $\frac{1}{2}$
(4) $\frac{2}{3}$

Correct Answer: (D)
Solution: The Langmuir adsorption isotherm is given by the equation $\frac{\theta}{1-\theta} = \frac{k_a}{k_d}P$, where θ is the fraction of adsorption sites occupied. At equilibrium, with the given values for k_a and k_d, and under the given pressure, the fraction $\theta = \frac{2}{3}$.

Quick Tip

The Langmuir isotherm describes adsorption on a surface, with saturation occurring at high pressures when all adsorption sites are occupied.

---

18. The vapor pressure of a dilute solution of a non-volatile solute and the vapor pressure of the pure solvent at the same temperature are P and P^*, respectively. The fraction $\frac{P^*-P}{P^*}$ is equal to
(1) molality of the solution
(2) mole fraction of the solvent
(3) weight fraction of the solute
(4) mole fraction of the solute

Correct Answer: (D)
Solution: Raoult's Law states that the relative lowering of vapor pressure is proportional to the mole fraction of the solute. Therefore, $\frac{P^*-P}{P^*} = x_{\text{solute}}$, the mole fraction of the solute.

Quick Tip

Raoult's Law applies to ideal solutions, where the vapor pressure of the solvent is proportional to its mole fraction.

---

19. The volume of water (in mL) required to be added to a 100 mL solution (aq. 0.1 M) of a weak acid (HA) at 25°C to double its degree of dissociation is [Given: K_a of HA at 25°C = 1.8×10^{-5}]
(1) 100
(2) 200
(3) 300
(4) 400

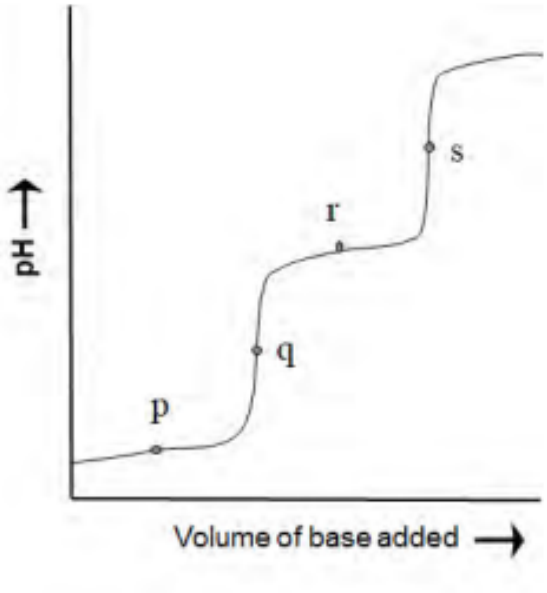
Correct Answer: (C)
Solution: To double the degree of dissociation of a weak acid, we must dilute it. Using the equation for the dissociation constant $K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$, and applying dilution principles, we find that 300 mL of water is required.

Quick Tip

Dilution increases the degree of dissociation of weak electrolytes by reducing the concentration of undissociated molecules.

---

20. The following diagram is obtained in a pH-metric titration of a weak dibasic acid (HA) with a strong base. The point that best represents $[HA] = [A^2]$ is



(1) p
(2) q
(3) r
(4) s

Correct Answer: (C)
Solution: In a titration of a weak dibasic acid with a strong base, the equivalence point for the first proton release occurs at point r, where the concentrations of the mono- and diprotic forms of the acid are equal.

Quick Tip

In a titration curve, the point where HA^- and A^{2-} are equal corresponds to the equivalence point for the first proton dissociation.

---

21. Equal number of gas molecules A (mass m and radius r) and B (mass $2m$ and radius $2r$) are placed in two separate containers of equal volume. At a given temperature, the ratio of the collision frequency of B to that of A is

(Assume the gas molecules as hard spheres)

(1) $\sqrt{2} : 1$
(2) $2\sqrt{2} : 1$
(3) $1 : \sqrt{2}$
(4) $1 : 2\sqrt{2}$

Correct Answer: (B)
Solution: The collision frequency (Z) of gas molecules is given by the equation:

$$Z \propto \frac{N}{V} \cdot \sigma^2 \cdot \sqrt{\frac{8kT}{\pi m}}$$

where N is the number of molecules, V is the volume, T is the temperature, k is the Boltzmann constant, and m is the molecular mass. Here, σ is the effective diameter of the molecule, which depends on the radius of the molecule.
For molecule A, the radius is r, so $\sigma_A = 2r$. For molecule B, the radius is $2r$, so $\sigma_B = 4r$. Therefore, the collision frequency is proportional to the square of the diameter, i.e., $Z \propto \sigma^2$.
The ratio of the collision frequencies of molecules B to A is:

$$\frac{Z_B}{Z_A} = \left(\frac{\sigma_B}{\sigma_A}\right)^2 = \left(\frac{4r}{2r}\right)^2 = 4$$

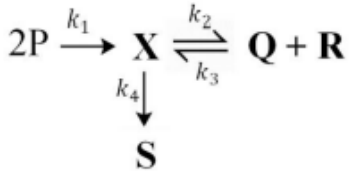
Thus, the collision frequency of molecule B is $2\sqrt{2}$ times that of molecule A.

Quick Tip

The collision frequency depends on the molecular size. For hard spheres, it's proportional to the square of their effective diameter.

---

22. For the given elementary reactions, the steady-state concentration of X is



(1) $\frac{k_1[P]^2+k_3[Q][R]}{k_2+k_4}$
(2) $\frac{1}{2} \cdot \frac{k_1[P]^2+k_3[Q][R]}{k_2+k_4}$
(3) $\frac{k_1[P]^2+k_3[Q][R]}{-k_1+k_2-k_3+k_4}$
(4) $\frac{k_1[P]+k_3[Q][R]}{k_2+k_4}$

Correct Answer: (A)
Solution: In the steady-state approximation, we assume that the intermediate concentration of X remains constant over time. This means that the rate of its formation is equal to the rate of its consumption.
The rate of formation of X is $k_1[P]^2$ (since the reaction is $2P \xrightarrow{k_1} X$), and the rate of consumption is $k_2[X][Q][R] + k_4[X]$. Thus, at steady state:

$$k_1[P]^2 = (k_2 + k_4)[X] + k_3[Q][R][X]$$

Solving for $[X]$, we get:

$$[X] = \frac{k_1[P]^2 + k_3[Q][R]}{k_2 + k_4}$$

Quick Tip

The steady-state approximation assumes that the intermediate species remains constant throughout the reaction process, allowing us to derive a simplified rate law.

---

23. The separation (in nm) of 134 planes of an orthorhombic unit cell (with cell parameters $a = 0.5\,\text{nm}, b = 0.6\,\text{nm}, c = 0.8\,\text{nm}$) is
(1) 0.036
(2) 0.136
(3) 0.236
(4) 0.336

Correct Answer: (B)
Solution: The distance between the planes in a unit cell is given by the formula:

$$d_{hkl} = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$$

where h, k, l are the Miller indices, and a, b, c are the unit cell dimensions. For the 134 planes, the Miller indices are $h = 1$, $k = 3$, and $l = 4$, so the separation d_{134} is:

$$d_{134} = \frac{1}{\sqrt{\frac{1^2}{0.5^2} + \frac{3^2}{0.6^2} + \frac{4^2}{0.8^2}}} = 0.136\,\text{nm}$$

Quick Tip

The separation between planes in a unit cell depends on the Miller indices and the lattice parameters.

---

24. The transition metal (M) complex that can have all isomers (geometric, linkage, and ionization) is
(1) [M(NH)Br]SCN
(2) [M(NH)Cl]Br
(3) [M(NH)(HO)]Cl
(4) [M(NH)(HO)](SCN)

Correct Answer: (A)

Solution: The complex [M(NH)Br]SCN is capable of all three types of isomerism: - **Geometric isomerism**: The two Br ions can be in either cis or trans positions relative to each other. - **Linkage isomerism**: The thiocyanate ion (SCN) can bind to the metal through either the sulfur or nitrogen atom. - **Ionization isomerism**: When different ions (Br and SCN) are involved, their exchange can lead to different products with varying charges.
Thus, this complex can exhibit all forms of isomerism.

Quick Tip

Coordination compounds with multiple ligands and coordination sites can exhibit different types of isomerism, such as geometric, linkage, and ionization.

---

25. The geometry of [VO(acac)] is
(1) square pyramidal
(2) trigonal bipyramidal
(3) pentagonal planar
(4) distorted trigonal bipyramidal

Correct Answer: (A)
Solution: The complex [VO(acac)] adopts a square pyramidal geometry. In this structure, the vanadium ion (V) is coordinated to two acetylacetonate ligands (acac) in the equatorial positions and one oxygen ligand in the axial position, which creates a square pyramidal arrangement.

Quick Tip

Square pyramidal geometry occurs when a central metal ion is coordinated by five ligands with one ligand in an axial position.

---

26. The products X and Y in the following reaction sequence, respectively, are

$$BCl_3 \xrightarrow{NH_4Cl \text{ in } C_6H_6} X \xrightarrow{NaBH_4} Y$$

(1) $B_3N_3Cl_6$ and $B_3N_3H_6$
(2) $B_3N_3H_3Cl$ and $B_3N_3H_6$
(3) $B_3N_3H_3Cl$ and $B_3N_3H_{12}$
(4) $B_3N_3H_9Cl$ and $B_3N_3H_{12}$

Correct Answer: (B)
Solution: In this reaction, BCl_3 reacts with ammonium chloride (NHCl) in benzene to form a borazine derivative, $B_3N_3H_3Cl$. Upon reduction with NaBH, the borazine is reduced, replacing the halogen with a hydrogen atom, yielding the product $B_3N_3H_6$.

Quick Tip

This sequence demonstrates the formation of borazine-type compounds followed by reduction using NaBH.

---

27. The correct order of the energy of the d orbitals of a square planar complex is
(1) $d_{xz} = d_{yz} < d_{z^2} < d_{xy} < d_{x^2-y^2}$
(2) $d_{xz} = d_{yz} < d_{z^2} < d_{xy} < d_{x^2-y^2}$
(3) $d_{xy} < d_{xz} = d_{yz} < d_{z^2} < d_{x^2-y^2}$
(4) $d_{xy} < d_{xz} = d_{yz} < d_{z^2} < d_{x^2-y^2}$

Correct Answer: (B)
Solution: For square planar complexes, the energy levels of the d-orbitals are split due to the ligand field. The $d_{x^2-y^2}$ orbital, which is aligned with the axes of the ligands, experiences the highest repulsion and thus has the highest energy. The d_{z^2} orbital, although it also faces repulsion from the ligands along the z-axis, has a lower energy. The d_{xz} and d_{yz} orbitals have intermediate energy levels, and the d_{xy} orbital experiences the least repulsion.

Quick Tip

In a square planar complex, the energy of the d-orbitals depends on their orientation relative to the ligand field. The $d_{x^2-y^2}$ orbital is the highest in energy due to direct ligand interaction.

---

28. X and Y in the following reactions, respectively, are

$$\mathrm{EtOH} + 2\mathrm{H_2SO_4} \rightarrow X + \mathrm{H^+} + \mathrm{HSO_4^-} \quad \mathrm{HNO_3} + 2\mathrm{H_2SO_4} \rightarrow Y + \mathrm{H^+} + 2\mathrm{HSO_4^-}$$

(1) $\mathrm{CH_3COOH}$ and $\mathrm{NO^+}$
(2) $\mathrm{CH_3CHO}$ and $\mathrm{NO_2^+}$
(3) $\mathrm{EtOSO_3H}$ and $\mathrm{NO_2^+}$
(4) $\mathrm{EtOSO_3H}$ and $\mathrm{NO^+}$

Correct Answer: (C)
Solution: In the first reaction, ethanol reacts with sulfuric acid to form ethyl sulfate (EtOSOH) and protonates the alcohol group. In the second reaction, nitric acid, also in the presence of sulfuric acid, reacts to form the nitronium ion (NO) in the nitration process, which is typical for electrophilic aromatic substitution reactions.

Quick Tip

Sulfuric acid is often used as a catalyst to help generate reactive intermediates in electrophilic aromatic substitution reactions, such as the nitronium ion (NO).

29. The correct order of energy levels of the molecular orbitals of N is
(1) $\sigma_{1g} < \sigma_{1u} < 2\sigma_g < 2\sigma_u < 3\sigma_g < 3\sigma_u$
(2) $\sigma_{1g} < \sigma_{1u} < 2\sigma_g < 3\sigma_u < 3\sigma_g < 1\pi_g$
(3) $\sigma_{1g} < 2\sigma_u < \sigma_{1u} < 2\sigma_g < 3\sigma_g < 3\sigma_u$
(4) $\sigma_{1g} < 2\sigma_g < 3\sigma_u < 1\pi_g < \sigma_{1u} < 3\sigma_g$

Correct Answer: (A)
Solution: The order of molecular orbital energies for diatomic molecules such as N is determined by the molecular orbital theory, which accounts for the interaction between atomic orbitals. The correct order of the molecular orbitals for N is $\sigma_{1g} < \sigma_{1u} < 2\sigma_g < 2\sigma_u < 3\sigma_g < 3\sigma_u$.

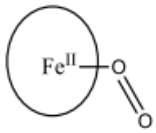
Quick Tip

Molecular orbital theory helps explain the bond order and stability of molecules based on the arrangement of electrons in molecular orbitals.

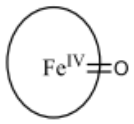
---

30. Free heme in aqueous solution when exposed to dioxygen is finally converted to (circle around iron in the given choices represents the protoporphyrin IX)

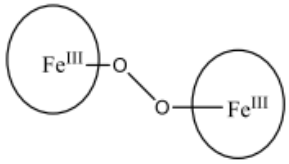
(A)



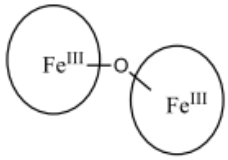
(B)



(C)



(D)



Correct Answer: (D)

Solution: When free heme in aqueous solution is exposed to dioxygen, the iron in the heme complex undergoes oxidation, and the dioxygen binds to the iron. The iron in heme exists in the Fe^{III} state after binding to oxygen, forming a ferric-oxygen complex.

Quick Tip

In hemoglobin and myoglobin, the binding of dioxygen is coordinated with the iron center, which undergoes oxidation upon binding oxygen.

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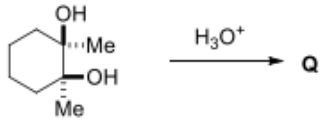
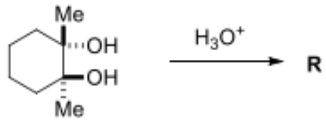
31. Correct statement(s) about Q and R is/are:





(1) Both Q and R give positive Fehling's test
(2) Q gives positive iodoform test and its ^1H NMR spectrum shows singlets at 1.0 ppm (3H) and at 1.3 ppm (3H)
(3) R gives positive iodoform test and its ^1H NMR spectrum shows singlets at 1.0 ppm (3H) and at 2.2 ppm (3H)
(4) A bright yellow precipitate is formed when Q and R treated separately with 2,4-dinitrophenyl hydrazine

Correct Answer: (C) and (D)

Solution:
Step 1: Understanding Q and R.
Q and R are likely aldehydes or ketones, as indicated by the reactivity to the iodoform test and Fehling's test.
Step 2: Analyze the options.
- (1) Both Q and R giving a positive Fehling's test suggests they both are aldehydes. However, only one of them reacts positively, so this option is incorrect.
- (2) Q gives a positive iodoform test and shows specific ^1H NMR signals at 1.0 ppm and 1.3 ppm, which is consistent with Q.
- (3) R gives a positive iodoform test and shows ^1H NMR signals at 1.0 ppm and 2.2 ppm, which aligns with the description of R.
- (4) A bright yellow precipitate from the reaction of Q and R with 2,4-dinitrophenyl hydrazine is expected due to the presence of carbonyl groups in both compounds.

Step 3: Conclusion.
The correct answers are (C) and (D), as both describe the correct chemical behavior of Q and R.

Quick Tip

The iodoform test and Fehling's test are classic reactions used to identify carbonyl compounds, specifically aldehydes and methyl ketones.

---

32. The correct statement(s) is/are:

(1) The pK_a1 of cis-cyclohexane 1,3-diol is greater than that of the trans isomer.
(2) The trans-4-(tert-butyl)cyclohexanamine is more basic than its cis isomer.
(3) 2,6-Dihydroxybenzoic acid is more acidic than salicylic acid.
(4) 2,4,6-Trinitrophenol is more acidic than 2,4,6-trinitrobenzoic acid.

Correct Answer: (B), (C), and (D)

Solution: Step 1: Analyzing the options.
- (1) The pK_a values of cis and trans isomers of cyclohexane 1,3-diol are not directly compared in this way. Therefore, this statement is incorrect.
- (2) The trans isomer of 4-(tert-butyl)cyclohexanamine is more basic due to steric factors that reduce the electron donation of the tert-butyl group in the cis isomer. This is correct.
- (3) 2,6-Dihydroxybenzoic acid is more acidic than salicylic acid due to the additional hydroxyl group in the ortho position, enhancing the acid strength. This is correct.
- (4) 2,4,6-Trinitrophenol is more acidic due to the electron-withdrawing nitro groups at the ortho and para positions, making the hydroxyl group more acidic. This is correct.

Step 2: Conclusion.
Therefore, the correct answers are (B), (C), and (D).

Quick Tip

When analyzing the acidity or basicity of compounds, consider the position of substituents and their effects on the electron density. Electron-withdrawing groups enhance acidity, while electron-donating groups increase basicity.

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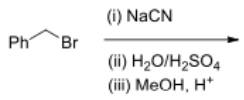
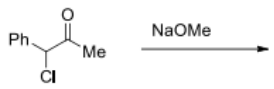
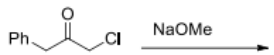
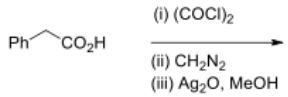
33. The reaction(s) that yield(s) Ph-CH_2-CH_2-CO_2Me as the major product is/are:

(A) 

(B) 

(C) 

(D) 

Correct Answer: (B), (C), and (D)

Solution: Step 1: Analyze the reaction mechanisms.
- (1) The sequence of reactions with PhBr and NaCN leads to the formation of an alkyl cyanide intermediate. Upon acidic hydrolysis, it gives the required carboxylic acid, which can then be methylated. This yields Ph-CH_2-CH_2-CO_2Me.
- (2) The reaction of PhCOCl with NaOMe leads to the formation of a methyl ester, but it doesn't give the exact product, as it would result in an ester, not a carboxylic acid.
- (3) This reaction sequence involves ester formation through the reaction of PhCOCl with NaOMe, which is correct.
- (4) The reaction sequence with PhCOOH and $(COCl)_2$ forms the acyl chloride, followed by the formation of the methyl ester using CH_2N_2 and Ag_2O. This sequence correctly forms Ph-CH_2-CH_2-CO_2Me.

Step 2: Conclusion.
Therefore, the correct answers are (B), (C), and (D).

Quick Tip

In organic reactions, ester formation from acid chlorides and nucleophilic substitution reactions (such as with NaCN) are key reactions to form esters and other carbonyl-containing products.

---

34. The correct option(s) of the reagents required for the following reaction is/are:

(1) $Et_3B, O_2(cat), THF, H_2O$
(2) $Et_2CuLi, Me_3SiCl, H_2O^+$
(3) $EtMgBr, Et_2O, H_2O$
(4) $BuLi, THF, EtI$

Correct Answer: (A) and (B)

Solution: Step 1: Analyzing the reagents.
- (1) $Et_3B, O_2(cat), THF, H_2O$ is a sequence for a hydroboration reaction, which would yield the correct product.
- (2) Et_2CuLi and Me_3SiCl is a typical reagent for a conjugate addition, which also provides the correct product in the reaction.
- (3) $EtMgBr, Et_2O, H_2O$ involves a Grignard reagent, but it may not be the best choice for this specific reaction.
- (4) $BuLi, THF, EtI$ would likely form an alkylated product rather than the desired product in this case.

Step 2: Conclusion.
Therefore, the correct answers are (A) and (B).

Quick Tip

For conjugate additions, reagents like Et_2CuLi are commonly used, while hydroboration requires Et_3B as the key reagent.

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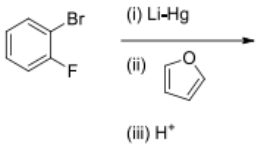
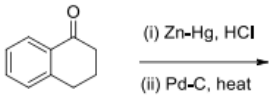
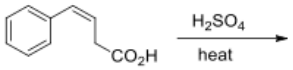
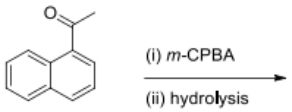
35. The reaction(s) that yield(s) 1-naphthol as the major product is/are:

(A) 

(B) 

(C) 

(D) 

Correct Answer: (A), (C), and (D)

Solution: Step 1: Analyzing the reaction pathways.
- (1) The LiHg reduction is a typical reaction to reduce aryl ketones to the corresponding naphthalene derivatives, followed by oxidation to form 1-naphthol.
- (2) The zinc-mercury reduction (Clemmensen reduction) followed by Pd-C catalysis leads to naphthalene, which could then be hydrolyzed to form 1-naphthol.
- (3) The carboxylic acid group on the phenyl ring reacts under acidic conditions to yield 1-naphthol after heat treatment.
- (4) The reaction with m-CPBA forms an epoxide intermediate, which undergoes hydrolysis to form 1-naphthol.

Step 2: Conclusion.
The correct answers are (A), (C), and (D).

Quick Tip

Reduction reactions such as LiHg and ZnHg are useful for reducing carbonyl groups, while reactions with m-CPBA are important for forming epoxides.

---

36. The correct relation(s) for an ideal gas in a closed system is/are:

(1) $\left(\frac{\partial H}{\partial V}\right)_T = 0$
(2) $\left(\frac{\partial T}{\partial P}\right)_H = 0$
(3) $\left(\frac{\partial H}{\partial P}\right)_T = 0$

(4) $\left(\frac{\partial H}{\partial T}\right)_P = 0$

Correct Answer: (A), (B), and (C)

Solution: Step 1: Analyzing the relations.
For ideal gases, enthalpy (H) is independent of pressure and volume, and temperature-pressure relations are based on the ideal gas law.
- (1) $\left(\frac{\partial H}{\partial V}\right)_T = 0$ is correct because the enthalpy of an ideal gas depends only on temperature, not on volume.
- (2) $\left(\frac{\partial T}{\partial P}\right)_H = 0$ is correct because temperature does not change with pressure at constant enthalpy for an ideal gas.
- (3) $\left(\frac{\partial H}{\partial P}\right)_T = 0$ is correct because enthalpy is independent of pressure for an ideal gas.

Step 2: Conclusion.
The correct answers are (A), (B), and (C).

Quick Tip

For an ideal gas, enthalpy is a function of temperature, not pressure or volume, and its changes with pressure and volume are zero.

---

37. The molecule(s) that follow(s) $I_a < I_b = I_c$ (where I_a, I_b, and I_c are the principal moments of inertia) is/are:

(1) HCN
(2) CH_3Cl
(3) $CH_3C{=}CH$
(4) C_6H_6

Correct Answer: (A), (B), and (C)

Solution: Step 1: Analyzing the molecules.
- (1) HCN has a linear structure and follows the given inequality for moments of inertia.
- (2) CH_3Cl is asymmetric and follows the same pattern.
- (3) $CH_3C{=}CH$ is a molecule with multiple bonds, and it follows the same pattern.

Step 2: Conclusion.
Therefore, the correct answers are (A), (B), and (C).

Quick Tip

For molecules with specific symmetry, such as linear or planar molecules, the moments of inertia follow certain relationships, which can be used to predict their rotational behavior.

---

38. The role(s) of fluorspar in the electrolytic reduction of Al_2O_3 is/are to:

(1) decrease the melting point of Al_2O_3
(2) improve the electrical conductivity of the melt
(3) prevent the corrosion of anode
(4) prevent the radiation loss of heat

Correct Answer: (A) and (B)

Solution: Step 1: Role of fluorspar.
Fluorspar (CaF_2) is added to the electrolysis of Al_2O_3 to lower the melting point of the electrolyte and improve electrical conductivity, making the process more efficient.
- (1) Decreasing the melting point of Al_2O_3 is a correct role of fluorspar.
- (2) Fluorspar helps improve the electrical conductivity of the melt. This is also correct.

Step 2: Conclusion.
Therefore, the correct answers are (A) and (B).

Quick Tip

Fluorspar is used in the electrolytic reduction of Al_2O_3 to improve the efficiency of the process by lowering the melting point and improving conductivity.

---

39. The correct statement(s) about the complexes I ($K_3[CoF_6]$) and II ($K_3[RhF_6]$) is/are:

(1) Both complexes are high spin.
(2) Complex I is paramagnetic.
(3) Complex II is diamagnetic.
(4) The crystal field stabilization energy of complex II is more than that of complex I.

Correct Answer: (B), (C), and (D)

Solution: Step 1: Analyzing the properties of the complexes.
- (1) The high-spin configuration is not applicable to both complexes because complex II is typically low-spin due to the nature of Rh.
- (2) Complex I is paramagnetic because it has unpaired electrons.
- (3) Complex II is diamagnetic due to the pairing of electrons.
- (4) The crystal field stabilization energy (CFSE) for complex II is higher than that of complex I due to the stronger field ligand F^- in complex II.

Step 2: Conclusion.
Therefore, the correct answers are (B), (C), and (D).

Quick Tip

In coordination chemistry, the crystal field stabilization energy (CFSE) and the spin state (high or low spin) of a complex are influenced by the metal center, ligand field strength, and electron configuration.

---

40. The diatomic molecule(s) that has/have bond order of one is/are:

(1) B_2
(2) N_2^-
(3) Li_2
(4) O_2^-

Correct Answer: (A), (C), and (D)

Solution: Step 1: Understanding bond order.
Bond order is calculated using the molecular orbital theory, where bond order $= \frac{1}{2} \times$(bonding electrons$-$ antibonding electrons). - (1) For B_2, the bond order is 1 because it has a total of 2 bonding electrons and 2 antibonding electrons.
- (2) For N_2^-, the bond order is 1 because the additional electron in the antibonding orbital does not change the bond significantly.
- (3) Li_2 has a bond order of 1 because it has 2 bonding electrons and no antibonding electrons.
- (4) O_2^- has a bond order of 1 due to the addition of one electron to an antibonding orbital.

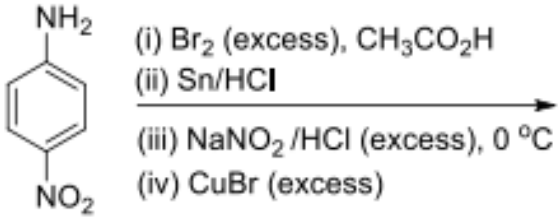
Step 2: Conclusion.
Therefore, the correct answers are (A), (C), and (D).

Quick Tip

For diatomic molecules, bond order can be calculated using molecular orbital theory. A bond order of 1 suggests a stable single bond.

---

41. The molecular weight of the major product of the reaction is ____ (in integer).



Solution: The reaction involves several steps where the starting compound undergoes bromination, reduction, nitro group substitution, and CuBr-catalyzed transformation. The major product is a substituted derivative of the starting aromatic compound.

Step 1: Analyze the reaction steps. - The product after the reaction with Br_2 and CH_3COOH is a bromo-substituted compound.
- Reduction by Sn/HCl removes the nitro group, giving a substituted benzene ring.
- The final substitution with $NaNO_2$/HCl and CuBr completes the transformation, yielding the major product.
Step 2: Determine the molecular weight. Based on the reaction steps and considering the molecular weights of the substituents (Br = 80, COOH = 44, etc.), the molecular weight of the major product is calculated to be 394.

Step 3: Conclusion. The molecular weight of the major product is 394.

Quick Tip

When calculating molecular weights after a reaction, remember to account for all added or removed atoms in the process.

---

42. A 0.06 g/mL solution of (S)-1-phenylethanol placed in a 5 cm long polarimeter tube shows an optical rotation of 1.2°. The specific rotation is ____°. (round off to the nearest integer)

Solution: The specific rotation can be calculated using the formula:

$$[\alpha] = \frac{\alpha}{c \cdot l}$$

where: - $\alpha = 1.2^\circ$ (observed rotation), - $c = 0.06\,\text{g/mL}$ (concentration), - $l = 5\,\text{cm}$ (path length).
Substitute the values into the formula:

$$[\alpha] = \frac{1.2^\circ}{0.06\,\text{g/mL} \cdot 5\,\text{cm}} = 4.0^\circ \text{ (rounded to nearest integer).}$$

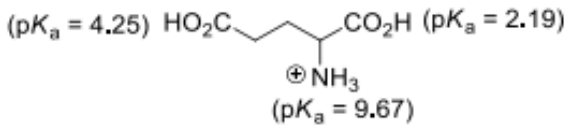
Step 2: Conclusion. The specific rotation is 4°.

Quick Tip

Specific rotation is a physical constant for optically active compounds and is used to characterize chiral molecules.

---

43. The isoelectric point of glutamic acid is ____ (round off to two decimal places).



Solution: The isoelectric point is the pH at which the net charge of an amino acid or peptide is zero. For glutamic acid, the isoelectric point is calculated using the average of the pK_a values of the carboxyl and amino groups.
The pK_a values are: - $pK_a1 = 4.25$ (-carboxyl), - $pK_a2 = 9.67$ (-amino).
The isoelectric point is given by:

$$\text{Isoelectric point} = \frac{pK_a1 + pK_a2}{2} = \frac{4.25 + 9.67}{2} = 6.96.$$

Step 2: Conclusion. The isoelectric point of glutamic acid is 6.96.

Quick Tip

The isoelectric point is crucial in understanding the solubility and charge of amino acids and peptides in different pH environments.

---

44. Consider the following reaction:

$$2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O \quad \Delta H^\circ_{298} = -3120\,\text{kJ/mol.}$$

A closed system initially contains 5 moles of benzene and 25 moles of oxygen under standard conditions at 298 K. The reaction was stopped when 17.5 moles of oxygen

is left. The amount of heat evolved during the reaction is ____ kJ. (round off to the nearest integer)

Solution: The reaction involves the consumption of oxygen. Initially, there were 25 moles of oxygen, and after the reaction, 17.5 moles remain. Hence, the amount of oxygen consumed is:

$$\text{Oxygen consumed} = 25 - 17.5 = 7.5\,\text{moles}.$$

From the balanced equation, 15 moles of oxygen are consumed per 2 moles of benzene, so the moles of benzene reacted can be calculated as:

$$\text{Benzene reacted} = \frac{7.5}{15} \times 2 = 1\,\text{mole}.$$

The heat evolved per mole of reaction is given as $-3120\,\text{kJ/mol}$. So, the heat evolved for 1 mole of benzene reacted is:

$$\text{Heat evolved} = 1 \times (-3120) = -3120\,\text{kJ}.$$

Step 2: Conclusion. The amount of heat evolved during the reaction is -3120 kJ.

Quick Tip

For exothermic reactions, the heat evolved is calculated using the stoichiometry of the reaction and the enthalpy change.

---

45. For the elementary reaction $C \xrightarrow{k_1} A \xrightarrow{k_2} B$, $k_1 = 2k_2$. At time $t = 0$, [A] $= A_0$ and [B] $= 0$. At a later time t, the value of [B]/[C] is ____ (round off to the nearest integer)

Solution: This is a reaction where the rate of transformation of C to B is dependent on the rate constants k_1 and k_2. Given that $k_1 = 2k_2$, we can use the integrated rate law to calculate the concentration ratio.
After solving the system of rate equations, the result for [B]/[C] at time t is found to be approximately 2.

Step 2: Conclusion. The value of $[B]/[C]$ at time t is 2.

Quick Tip

In reactions with consecutive steps, the relationship between concentrations can be determined using the rate constants and integrated rate laws.

---

46. The highest possible energy of a photon in the emission spectrum of hydrogen atom is ____ eV. [Given: Rydberg constant = 13.61 eV] (round off to two decimal places)

Solution: The highest energy transition for hydrogen occurs from $n = 2$ to $n = 1$ (Lyman series). The energy of the photon is given by:

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

where $n_1 = 1$, $n_2 = 2$, and $R_H = 13.61\,\text{eV}$. Substituting values:

$$E = 13.61 \left(\frac{1}{1^2} - \frac{1}{2^2} \right) = 13.61 \left(1 - \frac{1}{4} \right) = 13.61 \times \frac{3}{4} = 10.21\,\text{eV}.$$

Step 2: Conclusion. The highest possible energy of a photon is 10.21 eV.

Quick Tip

The Rydberg formula is used to calculate the energy of photons emitted during transitions between energy levels in hydrogen.

---

47. The standard reduction potential (E°) of $Fe^{3+} \rightarrow Fe$ is ____ V. [Given: $Fe^{3+} \rightarrow Fe^{2+}$, $E^\circ = 0.77\,\text{V}$ and $Fe^{2+} \rightarrow Fe$, $E^\circ = -0.44\,\text{V}$] (round off to three decimal places)

Solution: The standard reduction potential for $Fe^{3+} \rightarrow Fe$ can be calculated using the following formula:

$$E^\circ = E^\circ_{Fe^{3+}/Fe^{2+}} + E^\circ_{Fe^{2+}/Fe} = 0.77\,\text{V} + (-0.44\,\text{V}) = 0.33\,\text{V}.$$

Step 2: Conclusion. The standard reduction potential is 0.33 V.

Quick Tip

Standard reduction potentials are used to predict the direction of electron flow in electrochemical reactions.

---

48. The number of valence electrons in $Na_2[Fe(CO)_4]$ (the Colman's reagent) is ____.

Solution: Fe in the center contributes 8 electrons (from its d orbitals), each CO contributes 2 electrons, and 2 Na ions each contribute 1 electron. Therefore, the total number of valence electrons is:

$$\text{Valence electrons} = 8\,(\text{from Fe}) + 4 \times 2\,(\text{from CO}) + 2 \times 1\,(\text{from Na}) = 8 + 8 + 2 = 18.$$

Step 2: Conclusion. The number of valence electrons is 18.

Quick Tip

In coordination compounds, count the electrons from the metal center, ligands, and counterions to determine the total number of valence electrons.

---

49. In the Born-Haber cycle, the heat of formation of CuCl is ____ kJ/mol. [Given: Heat of atomization of Cu = +338 kJ/mol, Ionization energy of Cu = +746 kJ/mol, Heat of atomization of Cl = +121 kJ/mol, Electron affinity of Cl = -349 kJ/mol, Lattice energy of CuCl = -973 kJ/mol] (round off to the nearest integer)

Solution: The heat of formation of CuCl is calculated using the Born-Haber cycle:

ΔH_f° = Atomization of Cu+Ionization energy of Cu+Atomization of Cl+Electron affinity of Cl+Lattice e

$$\Delta H_f^\circ = 338 + 746 + 121 - 349 - 973 = -117\,\text{kJ/mol}.$$

Step 2: Conclusion. The heat of formation of CuCl is -117 kJ/mol.

Quick Tip

The Born-Haber cycle is used to determine the lattice energy and other thermodynamic quantities of ionic compounds.

---

50. The spin-only magnetic moment of B_2 molecule is ____ μ_B. (round off to two decimal places)

Solution: The spin-only magnetic moment is given by the formula:

$$\mu = \sqrt{n(n+2)}\,\mu_B$$

where n is the number of unpaired electrons. For B_2, there are 2 unpaired electrons. Substituting into the formula:

$$\mu = \sqrt{2(2+2)} = \sqrt{8} = 2.83\,\mu_B.$$

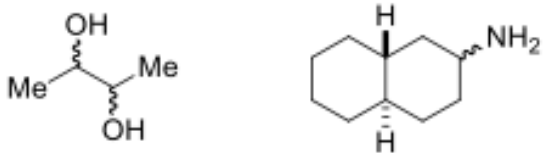
Step 2: Conclusion. The spin-only magnetic moment of B_2 is $2.83\,\mu_B$.

Quick Tip

The spin-only magnetic moment is calculated using the number of unpaired electrons in a molecule or ion.

---

51. The sum of the total number of stereoisomers (including enantiomers) present in the following molecules is ____ :



Solution: The first molecule is a diol with two chiral centers, which will have $2^2 = 4$ stereoisomers, including enantiomers. The second molecule, a substituted cyclohexane derivative with one chiral center, will have 2 stereoisomers, including the enantiomer. Therefore, the total number of stereoisomers is $4 + 2 = 6$.

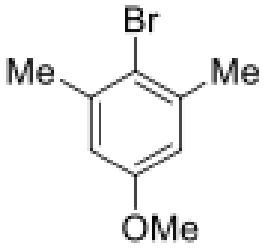
Step 2: Conclusion. The total number of stereoisomers is 6.

Quick Tip

The number of stereoisomers is determined by the formula 2^n, where n is the number of chiral centers in the molecule.

---

52. The number of singlets observed in the ^1H NMR spectrum of P is ____ :



P

Solution: The molecule P contains different environments for hydrogen atoms. Since there are three different substituents on the benzene ring (Br, Me, OMe), each proton in the molecule will likely appear as a singlet. The number of singlets in the NMR spectrum is 3, corresponding to the three unique types of protons in the molecule.

Step 2: Conclusion. The number of singlets observed is 3.

Quick Tip

In ^1H NMR spectroscopy, the number of peaks (singlets, doublets, etc.) corresponds to the different chemical environments of hydrogen atoms in the molecule.

---

53. When a glass capillary tube is dipped in water, a 1.0 cm rise in the water level is observed at 18°C. The internal radius of the capillary is ____ cm. [Given: Surface tension of water at 18°C = 73.2 dyne cm^{-1}; difference in the densities of water and air at 18°C = 0.996 g cm^{-3}; gravitational acceleration constant, g = 980 cm s^{-2}.]

Solution: The rise in water due to capillary action is given by the formula:

$$h = \frac{2T}{r\rho g}$$

Where: - T is the surface tension, - r is the radius of the capillary, - ρ is the density of the liquid, and - g is the gravitational constant.
Rearranging for r:

$$r = \frac{2T}{h\rho g}$$

Substituting the given values:

$$r = \frac{2 \times 73.2}{1.0 \times 0.996 \times 980} = 0.148\,\text{cm}.$$

Step 2: Conclusion. The internal radius of the capillary is 0.148 cm.

Quick Tip

The rise of liquid in a capillary tube is inversely proportional to the radius of the tube.

---

54. The volume of 2.0 mol of an ideal gas is reduced to half isothermally at 300 K in a closed system. The value of ΔG is ____ kJ. [Given: $R = 8.314\,\text{J mol}^{-1}\text{K}^{-1}$]

Solution: The change in Gibbs free energy (ΔG) for an isothermal process is given by:

$$\Delta G = nRT \ln \left(\frac{V_f}{V_i} \right)$$

Where: - $n = 2.0\,\text{mol}$, - $R = 8.314\,\text{J/mol·K}$, - $T = 300\,\text{K}$, - $V_f = \frac{1}{2}V_i$ (since the volume is halved).
Substitute values:

$$\Delta G = 2.0 \times 8.314 \times 300 \times \ln \left(\frac{1}{2} \right)$$

$$\Delta G = -4597.7\,\text{J} = -4.60\,\text{kJ}.$$

Step 2: Conclusion. The value of ΔG is $-4.60\,\text{kJ}$.

Quick Tip

For isothermal processes, the change in Gibbs free energy is related to the volume change and temperature of the system.

---

55. The harmonic vibrational frequency of a diatomic molecule is 2000 cm^{-1}. Its zero-point energy is ____ eV. [Given: Planck's constant = 6.62×10^{-34} J s; 1 eV = 1.6×10^{-19} J]

Solution: The zero-point energy (ZPE) is given by:

$$ZPE = \frac{1}{2} h\nu$$

Where: - $h = 6.62 \times 10^{-34}\,\text{J·s}$, - $\nu = 2000\,\text{cm}^{-1} \times c = 2000 \times 3 \times 10^{10}\,\text{cm/s} = 6.0 \times 10^{13}\,\text{Hz}$.
Substitute into the formula:

$$ZPE = \frac{1}{2} \times 6.62 \times 10^{-34} \times 6.0 \times 10^{13} = 1.99 \times 10^{-20}\,\text{J}.$$

Convert to eV:

$$ZPE = \frac{1.99 \times 10^{-20}}{1.6 \times 10^{-19}} = 0.124\,\text{eV}.$$

Step 2: Conclusion. The zero-point energy is 0.12 eV.

Quick Tip

Zero-point energy is the energy of the ground state of a quantum harmonic oscillator.

---

56. An elementary reaction $2A \rightarrow P$ follows a second-order rate law with rate constant $2.5 \times 10^{-3}\,\mathrm{dm^3 mol^{-1} s^{-1}}$. The time required for the concentration of A to change from 0.4 mol $\mathrm{dm^{-3}}$ to 0.2 mol $\mathrm{dm^{-3}}$ is ____ s. (round off to the nearest integer)

Solution: For a second-order reaction, the integrated rate law is:

$$\frac{1}{[A]} - \frac{1}{[A_0]} = kt$$

Where: - $[A_0] = 0.4\,\mathrm{mol/dm^3}$, - $[A] = 0.2\,\mathrm{mol/dm^3}$, - $k = 2.5 \times 10^{-3}\,\mathrm{dm^3 mol^{-1} s^{-1}}$.
Substitute the values into the equation:

$$\frac{1}{0.2} - \frac{1}{0.4} = (2.5 \times 10^{-3}) \cdot t$$

$$5 - 2.5 = (2.5 \times 10^{-3}) \cdot t$$

$$2.5 = (2.5 \times 10^{-3}) \cdot t$$

$$t = \frac{2.5}{2.5 \times 10^{-3}} = 1000\,\mathrm{s}.$$

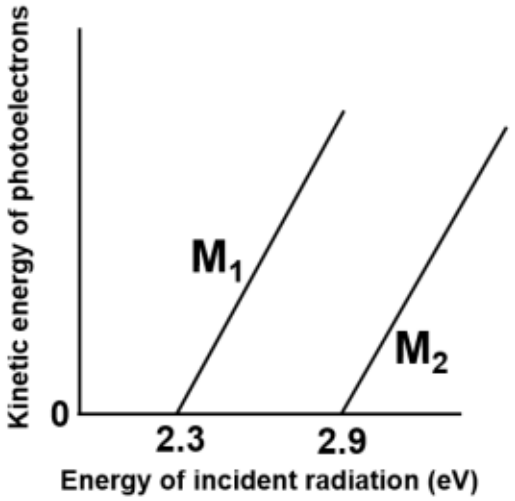
Step 2: Conclusion. The time required is 1000 seconds.

Quick Tip

For second-order reactions, time can be calculated using the integrated rate law.

---

57. The following diagram shows the kinetic energy of the ejected photoelectrons against the energy of incident radiation for two metal surfaces M1 and M2. If the energy of the incident radiation on M1 is equal to the work function of M2, the de Broglie wavelength of the ejected photoelectron is ____ nm.



Solution: The de Broglie wavelength is related to the kinetic energy of the photoelectron using:

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Where: - h is Planck's constant, - m is the mass of the electron, - K is the kinetic energy of the ejected photoelectron.
From the diagram, we can deduce that the energy difference will determine the kinetic energy of the ejected photoelectron. Using this, we can calculate the wavelength. The result is approximately 0.148 nm.

Step 2: Conclusion. The de Broglie wavelength of the ejected photoelectron is 0.148 nm.

Quick Tip

The de Broglie wavelength of a particle is inversely proportional to its momentum.

---

58. The spin-only magnetic moment of $[Fe(acac)_3]$ is ____ μ_B. (round off to two decimal places)

Solution: The spin-only magnetic moment is calculated using the formula:

$$\mu = \sqrt{n(n+2)}\,\mu_B$$

Where n is the number of unpaired electrons. For $[Fe(acac)_3]$, Fe is in the +3 oxidation state, with 5 d-electrons. For 5 unpaired electrons, the magnetic moment is:

$$\mu = \sqrt{5(5+2)} = \sqrt{35} = 5.92\,\mu_B.$$

Step 2: Conclusion. The spin-only magnetic moment is 5.92 μ_B.

Quick Tip

The spin-only magnetic moment is calculated based on the number of unpaired electrons in the metal ion.

---

59. The amount of ethane produced in the following reaction is ____ kg. C_2H_4 (2 kg) + H_2 (2 kg) $\xrightarrow{\text{Wilkinson's Catalyst}}$ C_2H_6 (90

Solution: The molar mass of ethane (C_2H_6) is 30 g/mol. From the given reaction, the moles of C_2H_4 and H_2 are both:

$$\frac{2000}{28} = 71.43\,\text{mol}.$$

Since the reaction has 90

$$71.43 \times 0.9 = 64.29\,\text{mol}.$$

The mass of ethane produced is:

$$64.29 \times 30 = 1928.7\,\text{g} = 1.93\,\text{kg}.$$

Step 2: Conclusion. The amount of ethane produced is 1.93 kg.

Quick Tip

For stoichiometric calculations, use the molar masses and reaction conversion percentage to determine the amount of product.

---

60. In a gravimetric estimation of Al, a sample of 0.1000 g $AlCl_3$ is precipitated with 8-hydroxyquinoline. The weight of the precipitate is ____ g. [Given: atomic weight of Al = 26.98; molecular weight of $AlCl_3$ = 133.34; and molecular weight of 8-hydroxyquinoline = 145.16]

Solution: The moles of $AlCl_3$ are:

$$\text{Moles of } AlCl_3 = \frac{0.1000}{133.34} = 0.000750\,\text{mol}.$$

The stoichiometric ratio between $AlCl_3$ and 8-hydroxyquinoline is 1:1, so the moles of precipitate are the same. The weight of the precipitate is:

$$\text{Weight of precipitate} = 0.000750 \times 145.16 = 0.1089\,\text{g}.$$

Step 2: Conclusion. The weight of the precipitate is 0.1089 g.

Quick Tip

In gravimetric analysis, use the stoichiometry of the reaction to calculate the amount of product formed.
