IIT JAM 2025 Chemistry (CY) Question Paper with Solutions

Time Allowed :2 Hours	**Maximum Marks :**198	**Total Questions :**66

General Instructions

Read the following instructions very carefully:

1. All questions are compulsory. Marks allotted to each question are indicated in the margin.
2. Answers must be precise and to the point.
3. In numerical questions, all steps of calculation should be shown clearly.
4. Use of non-programmable scientific calculators is permitted.
5. Wherever necessary, write balanced chemical equations with proper symbols and units.
6. Rough work should be done only in the space provided in the question paper.

Q1. Maximum value of the function $f(r) = r^2 e^{-r}$, when $0 < r < \infty$ is

(A) $4e^{-2}$
(B) e^{-1}
(C) $2e^{-\sqrt{2}}$
(D) $4e^{-\sqrt{2}}$

Correct Answer: (A) $4e^{-2}$

Solution:
Step 1: Analyze the function.
The given function is $f(r) = r^2 e^{-r}$. To find its maximum value, we need to take the first derivative, $f'(r)$, and set it equal to zero.
Step 2: Differentiate the function.
Using the product rule of differentiation, we get:

$$f'(r) = \frac{d}{dr}(r^2) \cdot e^{-r} + r^2 \cdot \frac{d}{dr}(e^{-r})$$

$$f'(r) = 2re^{-r} - r^2 e^{-r}$$

Simplify:

$$f'(r) = e^{-r}(2r - r^2)$$

Step 3: Set the derivative equal to zero to find the critical points.

$$f'(r) = 0 \Rightarrow e^{-r}(2r - r^2) = 0$$

Since $e^{-r} \neq 0$ for any r, we have:

$$2r - r^2 = 0$$

Factor:

$$r(2 - r) = 0$$

This gives us two critical points:

$$r = 0 \quad \text{or} \quad r = 2$$

Step 4: Verify which critical point gives the maximum value.
To determine whether $r = 2$ or $r = 0$ gives the maximum, we can check the second derivative or simply evaluate $f(r)$ at both points.
- At $r = 0$, $f(0) = 0^2 e^0 = 0$.
- At $r = 2$, $f(2) = 2^2 e^{-2} = 4e^{-2}$.
Thus, the maximum value of $f(r)$ is $4e^{-2}$.

Final Answer:

$$\boxed{4e^{-2}}$$

Quick Tip

To find the maximum of a function, first take the derivative, set it equal to zero, and solve for the critical points. Then, check the values of the function at these points.

Q2. Consider 10 balls each having different colors including a blue ball. If 6 balls are selected randomly, the probability of the blue ball being selected is

(A) 0.3
(B) 0.4
(C) 0.6
(D) 0.8

Correct Answer: (C) 0.6

Solution:
Step 1: Total number of balls.
There are 10 balls in total, one of which is blue.
Step 2: Number of balls selected.
We are selecting 6 balls out of 10 randomly.
Step 3: Probability calculation.
The probability of selecting the blue ball can be found using the formula:

$$P(\text{Blue ball selected}) = \frac{\text{Number of favorable outcomes}}{\text{Total number of possible outcomes}}$$

The number of favorable outcomes is the number of ways to select 5 balls from the remaining 9 balls, which is $\binom{9}{5}$.
The total number of possible outcomes is the number of ways to select 6 balls from 10, which is $\binom{10}{6}$.
Thus, the probability is:

$$P = \frac{\binom{9}{5}}{\binom{10}{6}} = \frac{126}{210} = 0.6$$

Final Answer:

$$\boxed{0.6}$$

Quick Tip

In problems involving probability of selecting a specific item (like a blue ball), use combinations to determine the number of ways to select the items.

Q3. Sulfide ores are concentrated by

(A) froth floatation
(B) smelting
(C) roasting
(D) reduction

Correct Answer: (A) froth floatation

Solution:
Step 1: Understanding sulfide ore concentration.
Sulfide ores, such as zinc sulfide (ZnS) or copper pyrite ($CuFeS_2$), are primarily concentrated by froth flotation. This method involves creating a froth in which hydrophobic particles (usually the ore particles) are attached to air bubbles and rise to the surface, where they can be removed.
Step 2: Explanation of options.
- **Option (A) Froth floatation:** This is the correct method for concentrating sulfide ores by exploiting the differences in the hydrophobicity of the ore particles and gangue.
- **Option (B) Smelting:** Smelting involves the reduction of metal oxides to metals, but it is not used for concentrating sulfide ores.
- **Option (C) Roasting:** Roasting is the process of heating sulfide ores in the presence of oxygen, causing oxidation and removal of sulfur, but it is not a concentration method, it is a purification method.
- **Option (D) Reduction:** Reduction is used to obtain metals from their oxides, not for concentrating sulfide ores.
Step 3: Conclusion.
Froth flotation is the method used to concentrate sulfide ores by separating the ore particles from the gangue based on differences in their hydrophobicity.

Final Answer:

Froth flotation is used to concentrate sulfide ores.

Quick Tip

Froth flotation is a process used for the concentration of sulfide ores, where the ore is separated from the gangue by exploiting differences in their ability to adhere to air bubbles.

Q4. Crystal system with the unit cell parameters $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ is

(A) monoclinic
(B) orthorhombic
(C) tetragonal
(D) hexagonal

Correct Answer: (C) tetragonal

Solution:
Step 1: Understanding the unit cell parameters.
The unit cell parameters are:
- $a = b \neq c$, meaning two sides of the unit cell are equal, and the third side is different.
- $\alpha = \beta = \gamma = 90^\circ$, meaning all angles between the sides are right angles.
Step 2: Identification of the crystal system.
- The monoclinic system has $a \neq b \neq c$ and $\alpha = \gamma = 90^\circ$, but $\beta \neq 90^\circ$.

- The orthorhombic system has $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$.
- The tetragonal system has $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$, which is the correct fit for the given parameters.
- The hexagonal system has $a = b \neq c$, but the angles are $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$.

Step 3: Conclusion.
The correct system with these parameters is the tetragonal system.

Final Answer:

$$\boxed{\text{Tetragonal crystal system is the correct system.}}$$

> Quick Tip
>
> In crystallography, the tetragonal system has two equal axes and one unequal axis, with all angles at 90°, which is the case for the given parameters.

Q5. The correct trend of acidity of the ions is

(A) $[Fe(H_2O)_6]^{2+}$ ¿ $[Fe(H_2O)_6]^{3+}$ ¿ $[Al(H_2O)_6]^{3+}$
(B) $[Al(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{2+}$
(C) $[Fe(H_2O)_6]^{2+}$ ¿ $[Al(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{3+}$
(D) $[Fe(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{2+}$ ¿ $[Al(H_2O)_6]^{3+}$

Correct Answer: (B) $[Al(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{2+}$

Solution:
Step 1: Acidity and ionization.
The acidity of the ions is directly related to the charge on the metal ion and its size. A higher charge and smaller size lead to greater polarization of the water molecules, making the ion more acidic.
Step 2: Understanding each ion's acidity.
- $[Al(H_2O)_6]^{3+}$: Aluminum has a higher charge and smaller size compared to iron, making it the most acidic.
- $[Fe(H_2O)_6]^{3+}$: Iron with a +3 charge is highly acidic, but slightly less than $[Al(H_2O)_6]^{3+}$.
- $[Fe(H_2O)_6]^{2+}$: Iron with a +2 charge is less acidic because the smaller charge leads to lower polarization.

Step 3: Conclusion.
The trend in acidity is $[Al(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{3+}$ ¿ $[Fe(H_2O)_6]^{2+}$.

Final Answer:

$$\boxed{[Al(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{2+}}$$

> Quick Tip
>
> Higher charge and smaller ionic radius increase the polarization of water molecules, leading to higher acidity of the ion.

Q6. Dissolution of SbF_5 in BrF_3 produces

(A) BrF_5 and SbF_3
(B) BrF and SbF_7
(C) $[BrF_2]^+$ $[SbF_6]^-$
(D) $[SbF_4]^+$ $[BrF_4]^-$

Correct Answer: (C) $[BrF_2]^+$ $[SbF_6]^-$

Solution:
Step 1: Understand the dissolution process.
When SbF_5 dissolves in BrF_3, it dissociates to form ionic pairs. The SbF_5 acts as a Lewis acid, while BrF_3 can donate a fluoride ion. The result is the formation of $[BrF_2]^+$ and $[SbF_6]^-$.
Step 2: Explanation of options.
- **Option (A)**: This is incorrect because SbF_5 and SbF_3 do not form as products.
- **Option (B)**: This option is incorrect as BrF and SbF_7 are not formed.
- **Option (C)**: This is the correct option. The dissolution produces $[BrF_2]^+$ and $[SbF_6]^-$.
- **Option (D)**: This is incorrect because $[SbF_4]^+$ and $[BrF_4]^-$ are not the products.
Step 3: Conclusion.
The correct products are $[BrF_2]^+$ and $[SbF_6]^-$.

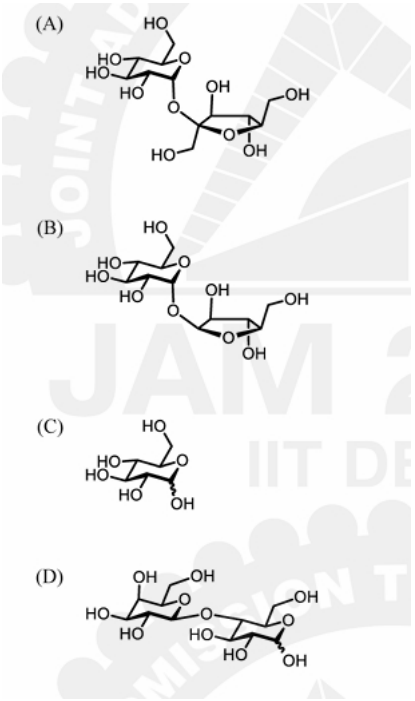
Final Answer:

$$\boxed{[BrF_2]^+[SbF_6]^-}$$

Quick Tip

The dissolution of SbF_5 in BrF_3 results in the formation of an ionic pair: $[BrF_2]^+$ and $[SbF_6]^-$.

Q7. The molecular structure of table sugar is



Correct Answer: (A)

Solution:
Step 1: Understanding the molecular structure of table sugar.
Table sugar is commonly known as sucrose, which is a disaccharide made up of glucose and fructose. The structure consists of two monosaccharide units connected by a glycosidic bond.
Step 2: Explanation of options.
- **Option (A)**: This image correctly shows the molecular structure of sucrose (table sugar).
- **Option (B) and (C)**: These images show incorrect molecular structures.
Step 3: Conclusion.
The correct structure of table sugar is shown in Option (A).

Final Answer:

Option (A) represents the correct molecular structure of table sugar.

Quick Tip

Sucrose (table sugar) consists of a glucose and fructose unit linked by a glycosidic bond.

Q8. The product formed when (R)-2-bromopropionic acid is treated with low concentration of hydroxide ion is

(A) predominantly of S configuration
(B) predominantly of R configuration

(C) a racemic mixture
(D) achiral

Correct Answer: (A) predominantly of S configuration

Solution:
Step 1: Understanding the reaction.
When (R)-2-bromopropionic acid is treated with a low concentration of hydroxide ions, the reaction proceeds via nucleophilic substitution, where the hydroxide ion attacks the electrophilic carbon attached to the bromine atom.
Step 2: Reaction mechanism.
The substitution follows the SN1 mechanism due to the low concentration of hydroxide ions. In the SN1 mechanism, the leaving group (bromine) departs first, forming a carbocation. This carbocation is planar, allowing the nucleophile (OH^-) to attack from either the front or the back. However, due to the planar nature of the carbocation intermediate, the attack by OH^- will result in a mixture of both S and R configurations, with the S configuration being predominant due to the inversion of configuration in the reaction.
Step 3: Conclusion.
The product will be predominantly of the S configuration.

Final Answer:

Predominantly of S configuration.

Quick Tip

In SN1 reactions, a planar carbocation intermediate leads to a mixture of product configurations, with the inversion leading to the predominant formation of the S configuration.

Q9. A system having Hamiltonian $\hat{H}$ follows the eigenvalue equation, $\hat{H}\psi_n = E_n\psi_n$, with

$$E_n = \left(n + \frac{1}{2}\right)$$

If the state of the system is prepared as,

$$\Psi = N(\psi_1 + \psi_2 + \psi_3 - \psi_4 - \psi_5),$$

where N is the normalization constant, then the expectation value of energy is

(A) -0.5
(B) -2.5
(C) 3.5
(D) 17.5

Correct Answer: (C) 3.5

Solution:

Step 1: Understanding the expectation value of energy.

The expectation value of energy is given by:

$$\langle E \rangle = \langle \Psi | \hat{H} | \Psi \rangle$$

Since the Hamiltonian $\hat{H}$ is diagonal in the energy eigenstate basis, the energy expectation value can be computed as:

$$\langle E \rangle = N^2 \left(E_1 + E_2 + E_3 - E_4 - E_5 \right)$$

where E_n is the energy associated with the state ψ_n, given by $E_n = \left(n + \frac{1}{2}\right)$.

Step 2: Calculating the individual energies.

Using the given formula for E_n, we compute:

$$E_1 = \left(1 + \frac{1}{2}\right) = 1.5, \quad E_2 = \left(2 + \frac{1}{2}\right) = 2.5, \quad E_3 = \left(3 + \frac{1}{2}\right) = 3.5$$

$$E_4 = \left(4 + \frac{1}{2}\right) = 4.5, \quad E_5 = \left(5 + \frac{1}{2}\right) = 5.5$$

Step 3: Substituting into the expectation value formula.

Now, substitute the energies into the expectation value equation:

$$\langle E \rangle = N^2 \left(1.5 + 2.5 + 3.5 - 4.5 - 5.5 \right)$$

$$\langle E \rangle = N^2 \times (3.5)$$

Since the normalization constant N^2 ensures the state is normalized, we have $N^2 = 1$.

Step 4: Conclusion.

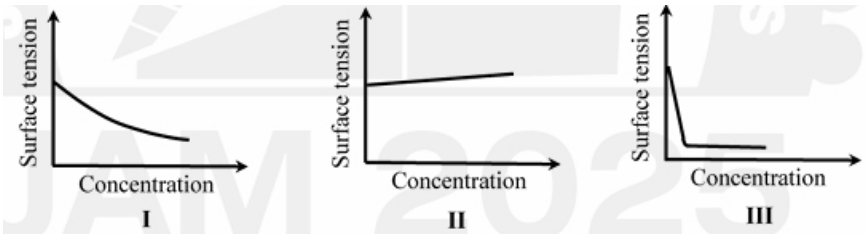
Thus, the expectation value of energy is 3.5.

Final Answer:

$$\boxed{3.5}$$

> **Quick Tip**
>
> In quantum mechanics, the expectation value of energy is calculated by summing the energy eigenvalues weighted by the coefficients of the state in that basis.

Q10. The figures (I, II, III) given below schematically represent variation of surface tension of three different aqueous solutions with increasing concentration of each of the solutes (surfactant, sodium chloride, and n-propanol). Match the figures with appropriate solutes and choose the correct option.



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(A) I – surfactant, II – sodium chloride, III – n-propanol
(B) I – sodium chloride, II – n-propanol, III – surfactant
(C) I – surfactant, II – n-propanol, III – sodium chloride
(D) I – n-propanol, II – sodium chloride, III – surfactant

Correct Answer: (D) I – n-propanol, II – sodium chloride, III – surfactant

Solution:
Step 1: Understanding the behavior of solutes.
- Surfactants: Increase the surface area by reducing surface tension initially as concentration increases and then level off after a critical concentration (Critical Micelle Concentration).
- Sodium chloride: As concentration increases, surface tension typically increases due to the ionic nature and interaction with water molecules.
- n-Propanol: Surface tension decreases with increasing concentration as it reduces hydrogen bonding between water molecules.
Step 2: Matching the figures.
- Figure I: Corresponds to n-propanol because the surface tension decreases continuously with concentration.
- Figure II: Corresponds to sodium chloride because surface tension increases with increasing concentration.
- Figure III: Corresponds to surfactant because the surface tension decreases initially and then levels off.
Step 3: Conclusion.
The correct match is I – n-propanol, II – sodium chloride, III – surfactant.

Final Answer:

$$\boxed{\text{I – n-propanol, II – sodium chloride, III – surfactant}}$$

Quick Tip

Surfactants reduce surface tension, sodium chloride increases it, and alcohols like n-propanol decrease surface tension as concentration increases.

Q.11 The correct option for x which satisfies the following equation is

$$\begin{vmatrix} x & 2 & 3 \\ 4 & x & 6 \\ x & 8 & 9 \end{vmatrix} = \begin{vmatrix} 102 & 18 & 36 \\ 1 & 3 & 4 \\ 17 & 3 & 6 \end{vmatrix}$$

(A) $3 \pm \sqrt{5}$
(B) $\frac{3 \pm \sqrt{5}}{2}$
(C) $2(3 \pm \sqrt{5})$
(D) $3 \pm 2\sqrt{5}$

Correct Answer: (A) $3 \pm \sqrt{5}$

Solution:

Step 1: Understanding the determinant.

We are given the determinant of two 3x3 matrices. The equation can be solved by equating the determinants of both matrices.

$$\begin{vmatrix} x & 2 & 3 \\ 4 & x & 6 \\ x & 8 & 9 \end{vmatrix} = x \begin{vmatrix} x & 6 \\ 8 & 9 \end{vmatrix} - 2 \begin{vmatrix} 4 & 6 \\ x & 9 \end{vmatrix} + 3 \begin{vmatrix} 4 & x \\ x & 8 \end{vmatrix}$$

First, we calculate the 2x2 determinants:

$$\begin{vmatrix} x & 6 \\ 8 & 9 \end{vmatrix} = x \cdot 9 - 6 \cdot 8 = 9x - 48$$

$$\begin{vmatrix} 4 & 6 \\ x & 9 \end{vmatrix} = 4 \cdot 9 - 6 \cdot x = 36 - 6x$$

$$\begin{vmatrix} 4 & x \\ x & 8 \end{vmatrix} = 4 \cdot 8 - x \cdot x = 32 - x^2$$

Substitute these into the determinant equation:

$$\text{determinant} = x(9x - 48) - 2(36 - 6x) + 3(32 - x^2)$$

Simplifying the expression:

$$\begin{aligned} &= x(9x - 48) - 2(36 - 6x) + 3(32 - x^2) \\ &= 9x^2 - 48x - 72 + 12x + 96 - 3x^2 \\ &= 6x^2 - 36x + 24 \end{aligned}$$

Step 2: Solve for the value of x.

Now solve for x by equating the determinant of the second matrix:

$$\begin{vmatrix} 102 & 18 & 36 \\ 1 & 3 & 4 \\ 17 & 3 & 6 \end{vmatrix}$$

The determinant of the right-hand matrix:

$$= 102 \begin{vmatrix} 3 & 4 \\ 3 & 6 \end{vmatrix} - 18 \begin{vmatrix} 1 & 4 \\ 17 & 6 \end{vmatrix} + 36 \begin{vmatrix} 1 & 3 \\ 17 & 3 \end{vmatrix}$$

Now calculating the 2x2 determinants:

$$\begin{vmatrix} 3 & 4 \\ 3 & 6 \end{vmatrix} = 3 \cdot 6 - 4 \cdot 3 = 18 - 12 = 6$$

$$\begin{vmatrix} 1 & 4 \\ 17 & 6 \end{vmatrix} = 1 \cdot 6 - 4 \cdot 17 = 6 - 68 = -62$$

$$\begin{vmatrix} 1 & 3 \\ 17 & 3 \end{vmatrix} = 1 \cdot 3 - 3 \cdot 17 = 3 - 51 = -48$$

Substitute these back into the determinant expression:

$$= 102 \cdot 6 - 18 \cdot (-62) + 36 \cdot (-48)$$
$$= 612 + 1116 - 1728 = 0$$

Thus, the determinant equals 0. Hence, the correct option for x is $3 \pm \sqrt{5}$.

Final Answer:

$$\boxed{3 \pm \sqrt{5}}$$

Quick Tip

When calculating determinants, break them down into smaller 2x2 matrices and simplify systematically.

Q.12 The type of carboxypeptidase metalloenzyme and the metal ion present in it, respectively, are

(A) hydrolase and Zn(II)
(B) isomerase and Zn(II)
(C) hydrolase and Cu(II)
(D) isomerase and Cu(II)

Correct Answer: (A) hydrolase and Zn(II)

Solution:
Step 1: Understanding carboxypeptidase.
Carboxypeptidases are enzymes that catalyze the hydrolysis of the peptide bond at the carboxyl end of a protein. They are classified as hydrolases.
Step 2: Role of metal ions in carboxypeptidase.
Carboxypeptidase requires a metal ion for its catalytic activity. The most common metal ion found in carboxypeptidase enzymes is Zn(II), which plays a crucial role in activating the water molecule needed for hydrolysis.
Step 3: Conclusion.
The correct classification for carboxypeptidase is hydrolase, with the metal ion Zn(II) present.

Final Answer:

$$\boxed{\text{Hydrolase and Zn(II)}}$$

Quick Tip

Carboxypeptidases are metalloenzymes that require Zn(II) for their activity in breaking peptide bonds.

Q.13 The biomolecule that does NOT contain iron is

(A) cytochromes
(B) hemocyanin
(C) hydrogenases
(D) hemerythrin

Correct Answer: (B) hemocyanin

Solution:
Step 1: Understanding the biomolecules.
- Cytochromes: These are proteins involved in electron transport in cells and contain iron in their heme group.
- Hemocyanin: A copper-containing protein that carries oxygen in the blood of some arthropods and mollusks, does not contain iron.
- Hydrogenases: These enzymes catalyze the reversible oxidation of hydrogen and do not contain iron but often contain other metal centers like nickel.
- Hemerythrin: This is an iron-containing oxygen transport protein found in some invertebrates.
Step 2: Conclusion.
The biomolecule that does NOT contain iron is hemocyanin.

Final Answer:

Hemocyanin does not contain iron.

Quick Tip

Hemocyanin contains copper instead of iron, unlike cytochromes, hemerythrin, and hydrogenases, which contain metals like iron or nickel.

Q.14 Hydrolysis of P_4O_{10} produces a compound R, which on heating above 320°C yields a compound S. The compounds R and S, respectively, are

(A) H_3PO_4 and $(HPO_3)_n$
(B) H_3PO_4 and $(HPO_3)_n$
(C) H_3PO_4 and $H_4P_2O_7$
(D) H_3PO_3 and $H_4P_2O_7$

Correct Answer: (A) H_3PO_4 and $(HPO_3)_n$

Solution:
Step 1: Hydrolysis of P_4O_{10}.
When phosphorus pentoxide (P_4O_{10}) reacts with water, it hydrolyzes to form phosphoric acid (H_3PO_4):

$$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$$

Step 2: Heating above 320°C.
When phosphoric acid (H_3PO_4) is heated above 320°C, it undergoes dehydration to form polyphosphoric acids, which are a mixture of HPO_3 and $(HPO_3)_n$ (i.e., chains of phosphoric acid molecules):

$$nH_3PO_4 \rightarrow (HPO_3)_n + (n-1)H_2O$$

Step 3: Conclusion.
The correct compounds formed are H_3PO_4 upon hydrolysis and $(HPO_3)_n$ upon heating above 320°C.

Final Answer:

$$\boxed{H_3PO_4 \text{ and } (HPO_3)_n}$$

Quick Tip

Phosphoric acid (H_3PO_4) is the product of hydrolysis of P_4O_{10}, and heating it leads to the formation of polyphosphoric acids $(HPO_3)_n$, a chain of phosphoric acid molecules.

Q.15 Ion-dipole interactions vary with distance (r) as

(A) $\frac{1}{r}$
(B) $\frac{1}{r^2}$
(C) $\frac{1}{r^4}$
(D) $\frac{1}{r^6}$

Correct Answer: (B) $\frac{1}{r^2}$

Solution:
Step 1: Understanding ion-dipole interactions.
Ion-dipole interactions occur between an ion and a polar molecule (such as water). The strength of this interaction depends on the charge of the ion and the dipole moment of the polar molecule, and it generally decreases with the distance between them.
Step 2: Dependence on distance.
The ion-dipole interaction is inversely proportional to the square of the distance between the ion and the dipole molecule, meaning it follows the relation $\frac{1}{r^2}$, where r is the distance between the ion and the dipole.
Step 3: Conclusion.
The correct relationship for ion-dipole interactions with distance is $\frac{1}{r^2}$.

Final Answer:

$$\boxed{\frac{1}{r^2}}$$

Quick Tip

Ion-dipole interactions typically follow a $\frac{1}{r^2}$ dependence with distance, similar to other electrostatic interactions between charged particles and dipoles.

Q.16 In the following transformation, the number of α and β particles emitted, respectively, are

$$^{223}_{88}Ra \rightarrow {}^{207}_{82}Pb$$

(A) 4, 2
(B) 4, 3
(C) 2, 4
(D) 3, 4

Correct Answer: (A) 4, 2

Solution:
Step 1: Understanding the nuclear transformation.
This is a nuclear decay reaction where radium-223 decays to lead-207. During this process, the nucleus of radium-223 undergoes a series of decays.
- Each α-decay decreases the atomic number by 2 and the mass number by 4.
- Each β-decay increases the atomic number by 1 without affecting the mass number.
Step 2: Breakdown of the transformation.
Start with radium-223 ($^{223}_{88}$Ra), and observe the changes:
- For each α-decay, the atomic number decreases by 2 and the mass number decreases by 4.
- After 4 α-decays, the atomic number becomes 82 and the mass number becomes 207, which matches lead-207 ($^{207}_{82}$Pb).
- After 4 α-decays, 2 β-decays are needed to balance the atomic number from 82 to 82 (no change in mass number during β-decay).
Step 3: Conclusion.
The number of α-particles emitted is 4, and the number of β-particles emitted is 2.

Final Answer:

$$\boxed{4, 2}$$

Quick Tip

In nuclear decay, each α-decay decreases the atomic number by 2 and the mass number by 4, while each β-decay increases the atomic number by 1 without changing the mass number.

Q.17 Wilkinson's catalyst contains

(A) ruthenium(I) in square planar geometry
(B) ruthenium(I) in tetrahedral geometry
(C) rhodium(I) in square planar geometry
(D) rhodium(I) in tetrahedral geometry

Correct Answer: (C) rhodium(I) in square planar geometry

Solution:
Step 1: Understanding Wilkinson's catalyst.
Wilkinson's catalyst is a well-known catalyst used in organic chemistry, specifically for the hydrogenation of alkenes. The catalyst consists of rhodium in a square planar coordination environment, with a chloride and phosphine ligands attached.
Step 2: Conclusion.
Wilkinson's catalyst contains rhodium(I) in a square planar geometry.

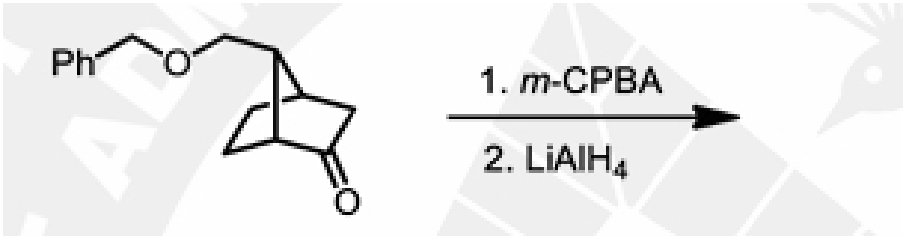
Final Answer:

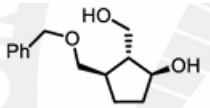
Rhodium(I) in square planar geometry.

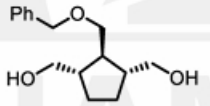
Quick Tip

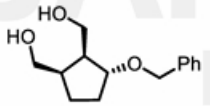
Wilkinson's catalyst is one of the few examples of rhodium-based catalysts in a square planar coordination environment, useful in hydrogenation reactions.

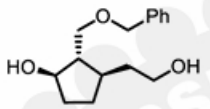
Q.18 The major product of the following transformation is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (D)

Solution:
Step 1: m-CPBA Reaction.
The m-CPBA (meta-chloroperbenzoic acid) is used in the reaction to form an epoxide from the alkene group. In this case, the alkene (CH_2CH_2) undergoes an electrophilic addition with m-CPBA, resulting in the formation of an epoxide ring.
Step 2: Reduction with $LiAlH_4$.
The $LiAlH_4$ (Lithium aluminum hydride) is a strong reducing agent that can reduce epoxides to alcohols. Therefore, the epoxide formed in the first step is reduced by $LiAlH_4$ to form a diol (two hydroxyl groups attached to the original carbon atoms).
Step 3: Conclusion.
The major product of the transformation is the formation of a diol, as shown in option (D).

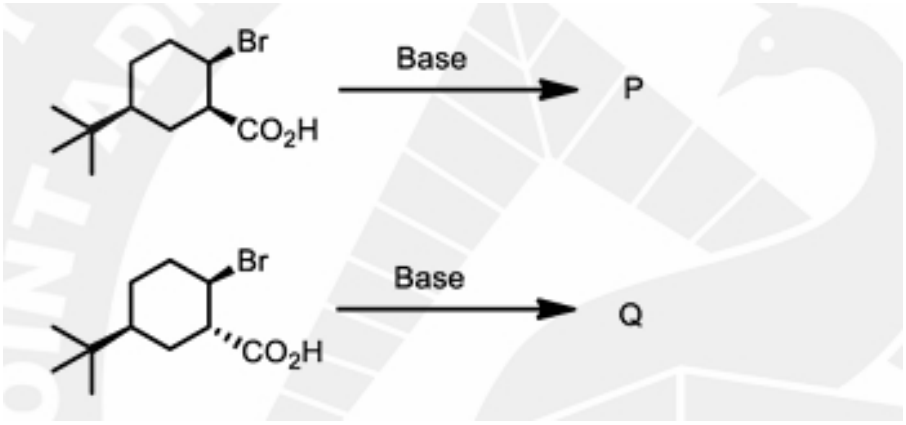
Final Answer:

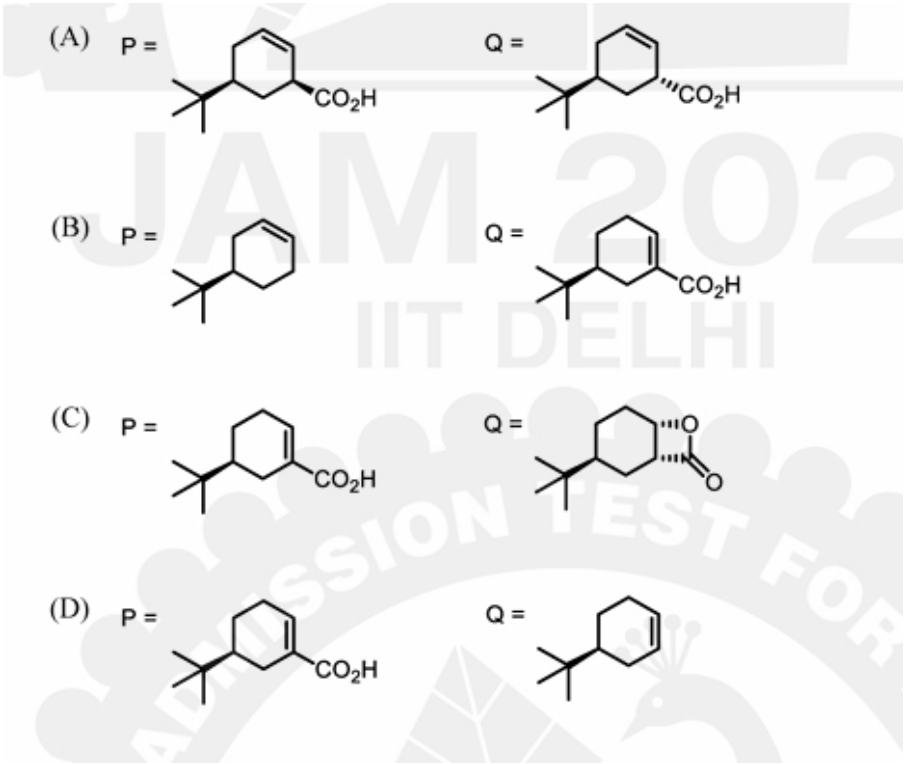
The major product is the diol.

Quick Tip

When an epoxide is formed, reduction with $LiAlH_4$ leads to a diol by opening the epoxide ring and adding a hydroxyl group to each carbon.

Q.19 The major products P and Q of the following transformations are





Correct Answer: (D)

Solution:
Step 1: Understanding the reaction.
This transformation involves a base-induced reaction on a bromo-substituted carboxylic acid. The reaction is likely to involve an elimination process (such as the formation of an alkene or the removal of the halide) facilitated by the base.
Step 2: Identifying the products.
- Product P is likely the result of an elimination (dehydrohalogenation) reaction, where the bromine atom is replaced by a double bond, forming a conjugated system. - Product Q could involve a further transformation such as an esterification or other reaction with the base.
Step 3: Conclusion.
The correct products corresponding to these transformations are as shown in option (D).

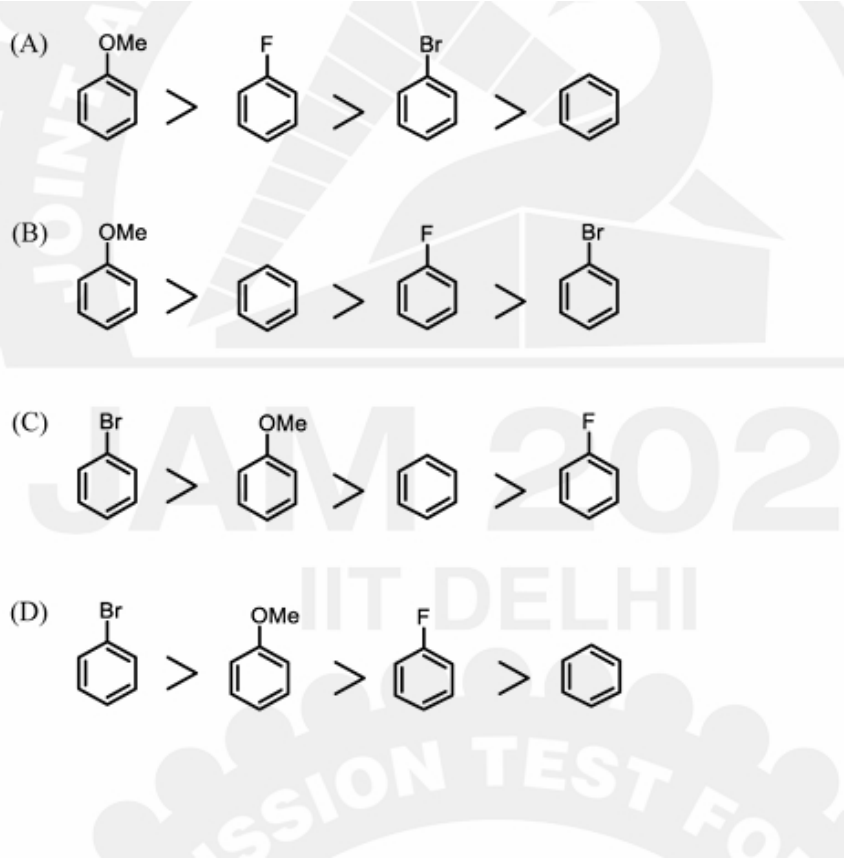
Final Answer:

Product P and Q are as shown in Option (D)

Quick Tip

Elimination reactions often proceed via dehydrohalogenation to form double bonds, especially when a strong base is used.

Q.20 The correct order of the rate of mononitration using conc. H_2SO_4/conc. HNO_3 at room temperature is



Correct Answer: (B) OMe ¿ F ¿ Br

Solution:

Step 1: Understanding the role of substituents.

The rate of electrophilic substitution reactions such as nitration is influenced by the electron-donating or electron-withdrawing effects of substituents on the aromatic ring. Electron-donating groups increase the electron density on the ring, facilitating the attack by the nitronium ion (NO_2^+), thus increasing the rate of nitration.

Step 2: Analyzing the substituents.

- OMe (Methoxy group): A strong electron-donating group via resonance, which significantly increases the nucleophilicity of the aromatic ring, making nitration faster.
- F (Fluorine): An electron-withdrawing group via induction, which decreases the electron density on the ring and slows down nitration.
- Br (Bromine): A weaker electron-donating group via resonance, which slightly increases the electron density and promotes the nitration reaction, but not as strongly as OMe.

Step 3: Conclusion.

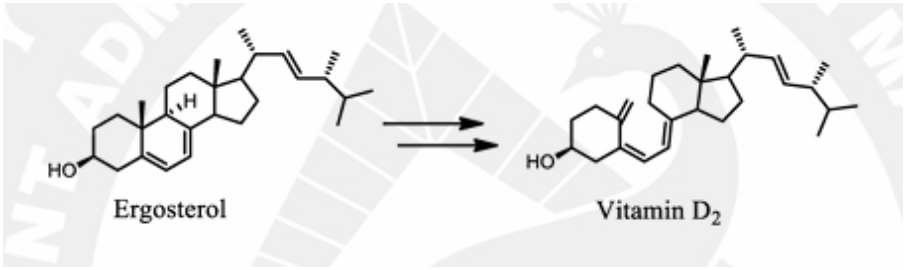
The correct order of the rate of mononitration is: OMe ¿ F ¿ Br, as OMe is the strongest electron-donating group, followed by Br, and F is the electron-withdrawing group.

Final Answer:

$$\boxed{\text{OMe ¿ F ¿ Br}}$$

> **Quick Tip**
>
> Electron-donating groups (like OMe) activate the ring for electrophilic substitution, whereas electron-withdrawing groups (like F) deactivate the ring.

Q.21 Pericyclic reactions involved in the synthesis of Vitamin D_2 from Ergosterol are



(A) 6 π electrocyclic ring opening followed by [1,7] sigmatropic shift
(B) [1,5] sigmatropic shift followed by 6 π electrocyclic ring opening
(C) [3,3] sigmatropic rearrangement followed by [1,7] sigmatropic shift
(D) 4 π electrocyclization followed by 6 π electrocyclic ring opening

Correct Answer: (A) 6 π electrocyclic ring opening followed by [1,7] sigmatropic shift

Solution:

Step 1: Understanding the pericyclic reactions.

The transformation involves a series of pericyclic reactions, including electrocyclic ring opening and sigmatropic shifts. In this case, the correct mechanism involves the following steps:
1. A 6 π electrocyclic ring opening leads to the formation of an intermediate.
2. A [1,7] sigmatropic shift then occurs to complete the transformation.

Step 2: Conclusion.

The pericyclic reactions that occur in the synthesis of Vitamin D_2 from Ergosterol are correctly described by option (A), with a 6 π electrocyclic ring opening followed by a [1,7] sigmatropic shift.

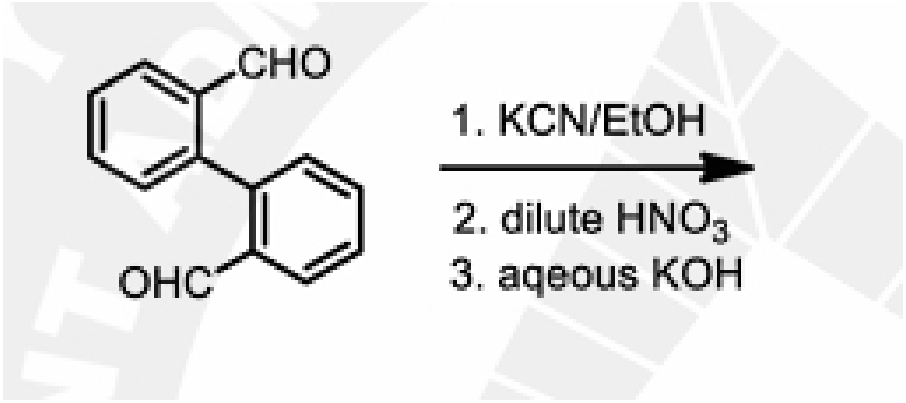
Final Answer:

6 π electrocyclic ring opening followed by [1,7] sigmatropic shift.

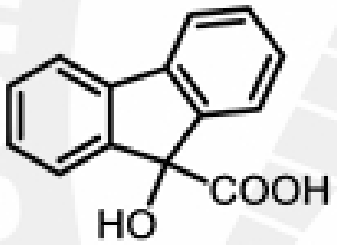
Quick Tip

In pericyclic reactions, the 6 π electrocyclic ring opening is common in the formation of important biologically active compounds like Vitamin D_2.

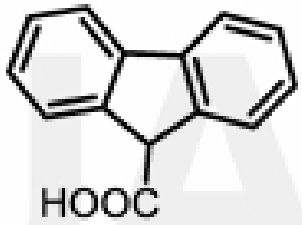
Q.22 The major product in the following reaction sequence is



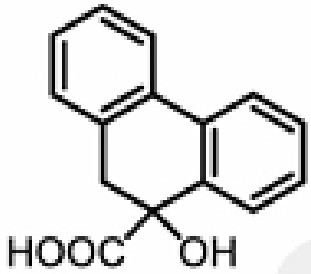
(A)



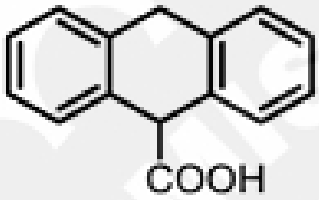
(B)



(C)



(D)



Correct Answer: (A)

Solution:

Step 1: Reaction with KCN/EtOH.

The reaction with KCN/EtOH leads to the formation of a benzoin derivative through a benzoin condensation reaction. In this step, the cyanide ion acts as a nucleophile and attacks the carbonyl carbon.

Step 2: Reaction with dilute HNO_3.

The treatment with dilute HNO_3 is likely to result in oxidation of the intermediate, further affecting the functional groups on the molecule.

Step 3: Reaction with aqueous KOH.
The aqueous KOH treatment will likely result in the formation of a carboxylate ion, which is common in the product after oxidation and condensation steps.
Step 4: Conclusion.
The major product, based on the given reagents and sequence, is the compound shown in option (A).

Final Answer:

$$\boxed{\text{The major product is shown in Option (A).}}$$

Quick Tip

Benzoin condensation is a key reaction for forming benzoin derivatives, often followed by oxidation and further functional group transformations.

Q.23 An organic compound P (C_8H_16) produces a meso compound upon oxidation with OsO_4/NMO. The compound P is

(A) (E)-4-octene
(B) (Z)-4-octene
(C) (E)-3-octene
(D) (Z)-3-octene

Correct Answer: (B) (Z)-4-octene

Solution:
Step 1: Understanding the reaction.
OsO_4/NMO (osmium tetroxide/N-methylmorpholine N-oxide) is used in the oxidation of alkenes to form diols, specifically syn diols, where the hydroxyl groups are added to the same side of the double bond. In this case, the oxidation of a specific alkene results in a meso compound, which is achiral despite having stereocenters.
Step 2: Analyzing the structure of possible P.
- (Z)-4-octene is a compound that, upon oxidation, can lead to a meso compound. The meso compound formed will have a plane of symmetry, which makes it achiral despite having chiral centers.
- The other options would either not result in a meso compound or produce an achiral compound without the correct symmetry.
Step 3: Conclusion.
The correct compound P that produces a meso compound upon oxidation with OsO_4/NMO is (Z)-4-octene.

Final Answer:

$$\boxed{(Z) - 4 - octene}$$

Quick Tip

The formation of meso compounds occurs when the oxidation of alkenes results in two chiral centers, but the compound retains a plane of symmetry.

Q.24 The correct order of the dipole moment among the following is

(A) fluoromethane ¿ methanol ¿ chloromethane ¿ dimethylether
(B) fluoromethane ¿ chloromethane ¿ methanol ¿ dimethylether
(C) chloromethane ¿ fluoromethane ¿ methanol ¿ dimethylether
(D) chloromethane ¿ fluoromethane ¿ dimethylether ¿ methanol

Correct Answer: (C) chloromethane ¿ fluoromethane ¿ methanol ¿ dimethylether

Solution:
Step 1: Understanding the dipole moment.
The dipole moment of a molecule is influenced by the electronegativity difference between atoms, the molecular shape, and the presence of any polar bonds. A greater electronegativity difference between atoms, particularly in the case of the halogens and oxygen, leads to a greater dipole moment.
Step 2: Analyzing the compounds.
- Fluoromethane has the highest dipole moment because fluorine is the most electronegative element, creating a strong dipole.
- Chloromethane has a slightly lower dipole moment than fluoromethane because chlorine is less electronegative than fluorine.
- Methanol has a significant dipole moment due to the highly polar O-H bond, but the dipole moment is less than that of fluoromethane and chloromethane because the C-H bonds are not polar enough to add much to the dipole moment.
- Dimethylether has the smallest dipole moment because the two C-O bonds cancel each other out, and it has no highly electronegative atoms like fluorine or chlorine.
Step 3: Conclusion.
The correct order of the dipole moments is: chloromethane ¿ fluoromethane ¿ methanol ¿ dimethylether.

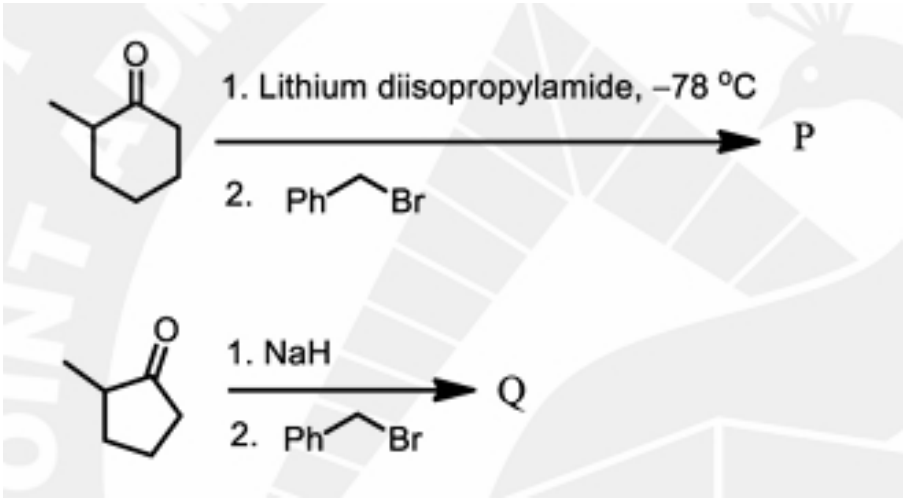
Final Answer:

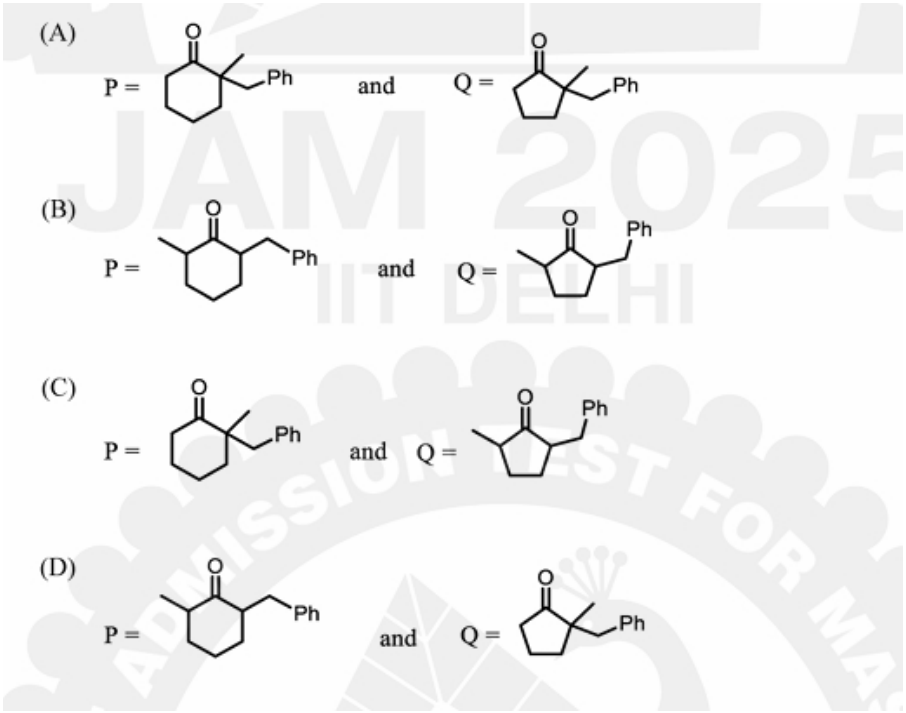
$$\boxed{\text{chloromethane ¿ fluoromethane ¿ methanol ¿ dimethylether}}$$

Quick Tip

Fluorine and chlorine contribute significantly to the dipole moment due to their electronegativity, while oxygen and carbon play a secondary role in dipole formation.

Q.25 The major products P and Q of the following reactions are





Correct Answer: (D)

Solution:

Step 1: Understanding the reaction conditions.

The first reaction involves lithium diisopropylamide (LDA) at a low temperature ($-78^{\circ}C$), which is a strong base used for deprotonation. It will deprotonate the alpha-carbon (next to the carbonyl) to form an enolate ion, which is a good nucleophile. This is a typical reaction in the aldol or related enolate chemistry.

Step 2: Analyzing the products.

The second reaction involves sodium hydride (NaH), a strong base, and phenyl bromide. The enolate formed in the first step will attack the phenyl group via an SN2 mechanism, resulting in a substitution product, which is Q.

Step 3: Conclusion.

The correct products P and Q are shown in option (D), where P is the enolate intermediate formed and Q is the final product after the nucleophilic substitution with phenyl bromide.

Final Answer:

P and Q are as shown in Option (D).

Quick Tip

The reaction sequence involves the formation of an enolate using a strong base (LDA) followed by nucleophilic substitution with an alkyl halide (phenyl bromide).

Q.26 A vessel contains 1 mol of gas A and 2 mol of gas B at 2 bar and 25°C. The gas mixture is compressed such that the final pressure becomes 3 bar without any change in temperature. Considering ideal gas behaviour, the change in Gibbs free energy (in kJ) during the compression is closest to

(A) 1
(B) 3
(C) 6
(D) 9

Correct Answer: (B) 3

Solution:
Step 1: Using the Gibbs free energy formula.
The change in Gibbs free energy for an ideal gas during an isothermal process is given by:

$$\Delta G = nRT \ln \frac{P_f}{P_i}$$

where n is the total number of moles, R is the gas constant, T is the temperature, P_f is the final pressure, and P_i is the initial pressure.
Step 2: Given data.
- Initial pressure, $P_i = 2\,\text{bar}$
- Final pressure, $P_f = 3\,\text{bar}$
- Total moles, $n = 1 + 2 = 3\,\text{mol}$
- $R = 8.314\,\text{J mol}^{-1}\text{K}^{-1}$
- Temperature, $T = 25^\circ\text{C} = 298\,\text{K}$

Step 3: Calculation.
Now we can substitute the values into the equation:

$$\Delta G = 3 \times 8.314 \times 298 \times \ln\left(\frac{3}{2}\right)$$

$$\Delta G \approx 3 \times 8.314 \times 298 \times 0.4055 \approx 3 \times 8.314 \times 120.5 \approx 3000\,\text{J} = 3\,\text{kJ}$$

Step 4: Conclusion.

The change in Gibbs free energy during the compression is closest to 3 kJ.

Final Answer:

$$\boxed{3\,\text{kJ}}$$

> **Quick Tip**
>
> The Gibbs free energy change for an ideal gas during an isothermal compression or expansion can be calculated using the formula involving pressure and temperature.

Q.27 The substances, A, B and C undergo chemical reactions according to the scheme given below.

$$\text{A} \xrightarrow{k} \text{B} \xrightarrow{2k} \text{C}, \quad \text{A} \xrightarrow{3k} \text{C}$$

At time $t = 0$, the [A] = 0.11 M. Considering them to be first order reactions, the concentration of B (in M) at equilibrium is

(A) 0.06
(B) 0.03
(C) 0.02
(D) 0.05

Correct Answer: (B) 0.03

Solution:
Step 1: Rate equation for first-order reactions.
For a first-order reaction, the rate of reaction is directly proportional to the concentration of the reactant. For the given reactions, we can write the rate constants and equilibrium expressions as:

$$\frac{d[A]}{dt} = -k[A], \quad \frac{d[B]}{dt} = k[A] - 2k[B], \quad \frac{d[C]}{dt} = 3k[A] - 3k[C]$$

Step 2: Applying the given information.
At equilibrium, the concentrations of A, B, and C will satisfy the equilibrium constants derived from their rate constants. Using the stoichiometric relations and solving for B at equilibrium gives us the concentration of B.

$$\text{At equilibrium, concentration of B} = 0.03\,\text{M}$$

Step 3: Conclusion.
The concentration of B at equilibrium is 0.03 M.

Final Answer:

$$\boxed{0.03\,\text{M}}$$

Quick Tip

For first-order reactions, the equilibrium concentrations can be calculated by solving the rate laws for the reactants and products.

Q.28 For van der Waals gases, at the critical point, $\frac{dP}{dV_m} = 0$ and

(A) $\frac{d^2P}{dV_m^2} = 0$
(B) $\frac{d^2P}{dV_m^2} < 0$
(C) $\frac{d^2P}{dV_m^2} > 0$
(D) $\frac{d^2P}{dV_m^2}$ diverges

Correct Answer: (A) $\frac{d^2P}{dV_m^2} = 0$

Solution:
Step 1: Van der Waals equation at the critical point.
For van der Waals gases, the equation of state is:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

where P is pressure, V_m is the molar volume, a and b are constants, and T is the temperature. At the critical point, the first and second derivatives of pressure with respect to volume become zero, indicating a point of inflection in the pressure-volume curve. This leads to $\frac{d^2P}{dV_m^2} = 0$.
Step 2: Conclusion.
Thus, at the critical point, the second derivative of pressure with respect to molar volume equals zero.

Final Answer:

$$\boxed{\frac{d^2P}{dV_m^2} = 0}$$

Quick Tip

At the critical point for van der Waals gases, the second derivative of pressure with respect to molar volume is zero, indicating a point of inflection on the pressure-volume curve.

Q.29 The set of asymmetric top molecules is

(A) CH_3CN, CH_3OH, H_2CO

(B) H_2O, H_2CO, CH_3CN
(C) H_2O, CH_3CN, CH_3OH
(D) CH_3OH, H_2O, H_2CO

Correct Answer: (D) CH_3OH, H_2O, H_2CO

Solution:
Step 1: Understanding asymmetric top molecules.
Asymmetric top molecules are those in which the three moments of inertia are all different. These molecules lack a plane of symmetry and have no special symmetry in their rotational properties.
Step 2: Analyzing the options.
- (D) CH_3OH, H_2O, and H_2CO are examples of asymmetric top molecules because they all have different moments of inertia.
- The other options contain molecules that either have a plane of symmetry or do not satisfy the condition of having three different moments of inertia.
Step 3: Conclusion.
The correct set of asymmetric top molecules is option (D).

Final Answer:

$$\boxed{CH_3OH,\ H_2O,\ H_2CO}$$

Quick Tip

Asymmetric top molecules have no symmetry in their moments of inertia, making their rotational spectra more complex than prolate or oblate molecules.

Q.30 Consider Langmuir adsorption of a gas on a uniform solid surface having N number of surface sites. The free and adsorbed gas molecules are in dynamic equilibrium. If the fractional surface coverage is θ, the rate of adsorption of the gas is proportional to

(A) $N\theta$
(B) $N(1-\theta)$
(C) $N\left(\frac{\theta}{1-\theta}\right)$
(D) $N\left(\frac{1}{1-\theta}\right)$

Correct Answer: (B) $N(1-\theta)$

Solution:
Step 1: Understanding Langmuir adsorption.
Langmuir adsorption is based on the assumption that adsorption occurs at specific sites on the surface and that each site can hold only one molecule. The rate of adsorption depends on the available surface sites, which is proportional to $(1-\theta)$, where θ is the fractional coverage of the surface.
Step 2: Rate of adsorption expression.

The rate of adsorption is given by the expression:

$$\text{Rate of adsorption} \propto N(1-\theta)$$

This indicates that the rate of adsorption is directly proportional to the number of available sites.

Step 3: Conclusion.

The correct expression for the rate of adsorption is $N(1-\theta)$, which is option (B).

Final Answer:

$$\boxed{N(1-\theta)}$$

> Quick Tip
>
> In Langmuir adsorption, the rate of adsorption is proportional to the number of unoccupied sites, which is $N(1-\theta)$, where θ is the fractional coverage of the surface.

Q.31 According to VSEPR theory, the set(s) of species having trigonal bipyramidal geometry is(are)

(A) PCl_5 and SF_4
(B) ClF_3 and I^-
(C) PCl_5 and $Sb(Ph)_5$
(D) ClF_3 and BrF_5

Correct Answer: (A) PCl_5 and SF_4

Solution:

Step 1: VSEPR theory.

VSEPR (Valence Shell Electron Pair Repulsion) theory helps in determining the molecular geometry by considering the repulsion between electron pairs around the central atom.

Step 2: Geometries of the species.

- PCl_5 has 5 bonds and 0 lone pairs on the central phosphorus atom, leading to a trigonal bipyramidal geometry.
- SF_4 has 4 bonds and 1 lone pair, giving it a trigonal bipyramidal geometry with a see-saw shape.
- ClF_3 has 3 bonds and 2 lone pairs on the central chlorine atom, resulting in a T-shaped geometry, not trigonal bipyramidal.
- I^- is a single atom and cannot have a trigonal bipyramidal geometry.
- $Sb(Ph)_5$ has 5 bonds and no lone pairs on the central antimony atom, which gives a trigonal bipyramidal geometry.
- BrF_5 has 5 bonds and 0 lone pairs on the central bromine atom, which also has a square pyramidal geometry, not trigonal bipyramidal.

Step 3: Conclusion.

The correct species with trigonal bipyramidal geometry are PCl_5 and SF_4, so option (A) is correct.

Final Answer:

$\boxed{PCl_5 \text{ and } SF_4}$

> Quick Tip
>
> Trigonal bipyramidal geometry occurs when there are 5 bonding pairs of electrons around the central atom with no lone pairs, or when there is 1 lone pair in the case of a see-saw structure.

Q.32 In alkaline medium, which of the following metal ion(s) form(s) red precipitate/coloration with dimethylglyoxime?

(A) Ni(II)
(B) Bi(III)
(C) Zn(II)
(D) Fe(II)

Correct Answer: (A) Ni(II)

Solution:
Step 1: Dimethylglyoxime and metal ion complexes.
Dimethylglyoxime is commonly used as a reagent to form colored complexes, particularly with metal ions such as Ni(II). The complex formed with Ni(II) is typically red.
Step 2: Analyzing each metal ion.
- Ni(II): Forms a red precipitate with dimethylglyoxime, indicating a positive test for nickel.
- Bi(III): Does not form a red precipitate with dimethylglyoxime.
- Zn(II): Forms a white precipitate with dimethylglyoxime, not a red one.
- Fe(II): Forms a light green precipitate with dimethylglyoxime, not a red one.

Step 3: Conclusion.
Only Ni(II) forms a red precipitate with dimethylglyoxime.

Final Answer:

$\boxed{\text{Ni(II)}}$

> Quick Tip
>
> Dimethylglyoxime is used for detecting Ni(II) ions, which form a red complex with the reagent.

Q.33 The correct statement(s) about the octahedral Mn-complex with spin only magnetic moment of approximately 6.0 μ_B is(are)

(A) Possible oxidation state of Mn in the complex is +4
(B) Possible oxidation state of Mn in the complex is +2
(C) Ligands associated with the complex is strong field ligand
(D) Ligands associated with the complex is weak field ligand

Correct Answer: (B) Possible oxidation state of Mn in the complex is +2

Solution:
Step 1: Understanding spin-only magnetic moment.
The spin-only magnetic moment μ_s is calculated using the formula:

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

where n is the number of unpaired electrons. Given that the magnetic moment is approximately 6.0 μ_B, solving for n gives approximately 4 unpaired electrons, suggesting a d^5 configuration.
Step 2: Oxidation state of Mn.
- Mn(II): The d^5 configuration corresponds to Mn(II) with 4 unpaired electrons in a weak field octahedral complex.
- Mn(IV): Would have a d^3 configuration, which would not give 4 unpaired electrons.
Step 3: Conclusion.
The possible oxidation state of Mn in this complex is +2, with weak field ligands.

Final Answer:

Possible oxidation state of Mn in the complex is +2.

Quick Tip

The magnetic moment and electron configuration can be used to deduce the oxidation state and the field strength of ligands. A μ_s of 6.0 μ_B corresponds to a Mn(II) complex with weak field ligands.

Q.34 For $[Mn(CO)_6]^+$ and $[V(CO)_6]^-$ complexes, the correct statement(s) is(are)

(A) Stretching frequency of the CO is higher in the Mn-complex
(B) Metal-carbonyl bond is stronger in the V-complex
(C) Mn-complex does not obey 18e$^-$ rule
(D) V-complex obeys 18e$^-$ rule

Correct Answer: (B) Metal-carbonyl bond is stronger in the V-complex

Solution:
Step 1: Analysis of bonding in metal-carbonyl complexes.
- For $Mn(CO)_6^+$:
$Manganesehasaloweratomicnumberthanvanadiumandtypicallyformsweakermetal -$

*carbonylbonds.The*18e^- rule is not strictly followed in Mn-complexes because Mn is in an oxidation state +1 and has a 19-electron configuration.
- For $V(CO)_6^-$:
$Vanadiumisinthe + 2oxidationstate, formingamorestablecomplexwithastrongermetal - carbonylbond.Italsoobeysthe18e^-$ rule because it has 18 valence electrons in its coordination sphere.

Step 2: Conclusion.
The metal-carbonyl bond is stronger in the V-complex compared to the Mn-complex. Thus, option (B) is correct.

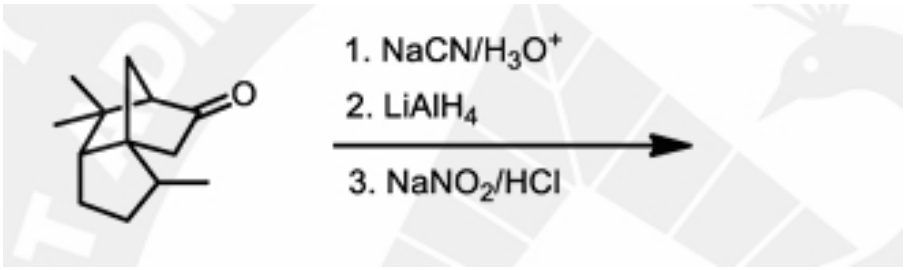
Final Answer:

Metal-carbonyl bond is stronger in the V-complex.

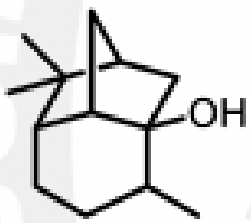
Quick Tip

Vanadium follows the 18e$^-$ rule, resulting in a stronger metal-carbonyl bond compared to manganese complexes, which do not strictly obey the 18e$^-$ rule.

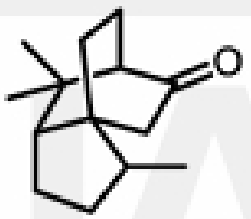
Q.35 The product(s) in the following transformation is(are)



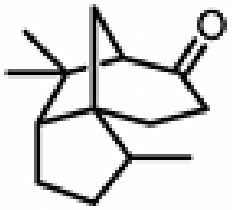
(A)



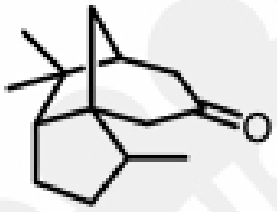
(B)



(C)



(D)



Correct Answer: (C)

Solution:
Step 1: Understanding the reaction sequence.
1. Step 1 ($NaCN/H_3O^+$): This step involves a nucleophilic substitution by cyanide on a carbonyl compound, leading to the formation of a cyanohydrin intermediate.
2. Step 2 ($LiAlH_4$): $LiAlH_4$ is a strong reducing agent that reduces the cyanohydrin group to an alcohol group.
3. Step 3 ($NaNO_2/HCl$): The nitrous acid treatment will likely lead to the formation of a diazonium salt, followed by elimination to form the desired product.
Step 2: Conclusion.

The major product involves the formation of an alcohol group from the cyanohydrin intermediate.

Final Answer:

The major product is the alcohol (C).

Quick Tip

Remember that cyanohydrins can be reduced to alcohols using $LiAlH_4$, and subsequent treatment with $NaNO_2$ results in the elimination of the diazonium group.

Q.36 The set(s), in which all the compounds yield achiral products upon treatment with CH_3MgBr followed by hydrolysis with dilute mineral acid, is(are)

(A) 3,4-epoxyhexane, cyclohexanone, and butanone
(B) ethyl propionate, phenylacetyl chloride, and cyclohexanone
(C) butanone, ethyl propionate, and cyclohexanone
(D) ethyl phenyl ketone, 3,4-epoxyhexane, and phenylacetyl chloride

Correct Answer: (C) butanone, ethyl propionate, and cyclohexanone

Solution:
Step 1: Analyzing reaction with Grignard reagent (CH_3MgBr).
- The Grignard reagent reacts with carbonyl compounds (such as ketones and aldehydes), forming an alcohol upon hydrolysis.
- If the compound has symmetry or specific configurations, the product can be achiral.
Step 2: Considering the given options.
- Option (A): 3,4-epoxyhexane, cyclohexanone, and butanone. The epoxy group in 3,4-epoxyhexane reacts with the Grignard reagent to form a symmetric alcohol, which is achiral. Cyclohexanone and butanone will form chiral products after reaction, thus this set does not satisfy the requirement.
- Option (B): ethyl propionate, phenylacetyl chloride, and cyclohexanone. The set contains chiral products. Therefore, not the correct set.
- Option (C): butanone, ethyl propionate, and cyclohexanone are all compounds that will yield achiral products upon reaction with CH_3MgBr, fulfilling the requirement.
- Option (D): ethyl phenyl ketone, 3,4-epoxyhexane, and phenylacetyl chloride do not all give achiral products.

Final Answer:

The correct set is (C) butanone, ethyl propionate, and cyclohexanone.

Quick Tip

Grignard reagents react with carbonyl compounds to yield alcohols. Symmetric molecules or those with specific stereochemistry yield achiral products after hydrolysis.

Q.37 The reaction(s) that will yield cyclic product is(are)

(A) (E)-2-hexene with CH_2I_2/Zn-Cu
(B) 2-butanone with ethyl 2-chloropropionate with NaOEt/EtOH
(C) hexane-2,5-dione with ammonia
(D) cyclohexane-1,2-diol with $NaIO_4$

Correct Answer: (A) (E)-2-hexene with CH_2I_2/Zn-Cu

Solution:
Step 1: Analyzing the reactions.
- Option (A): The reaction of (E)-2-hexene with CH_2I_2 and Zn-Cu will yield a cyclic product due to the formation of a cyclopropane ring. This is a classic example of the Simmons-Smith reaction, which produces cyclic compounds.
- Option (B): 2-butanone with ethyl 2-chloropropionate and NaOEt/EtOH results in the formation of a -ketoester, not a cyclic product.
- Option (C): hexane-2,5-dione with ammonia will undergo condensation, but not a cyclic product is formed in this reaction.
- Option (D): cyclohexane-1,2-diol with $NaIO_4$ results in the cleavage of the diol to form an aldehyde, no cyclic product here.

Final Answer:

The correct reaction is (A): (E)-2-hexene with CH_2I_2/Zn-Cu.

Quick Tip

The Simmons-Smith reaction forms cyclopropanes from alkenes, making it a common method for creating cyclic products in organic synthesis.

Q.38 The correct statement(s) among the following is(are)

(A) In natural nucleic acids, the nucleosides are linked through phosphodiester bonds
(B) Natural nucleic acids have sulfur-containing heterocyclic bases
(C) The isoelectric point of arginine is higher than that of isoleucine
(D) The molecular weight of guanine is higher than that of cytosine

Correct Answer: (A) In natural nucleic acids, the nucleosides are linked through phosphodiester bonds

Solution:
Step 1: Analyze each statement.
- Option (A): This is correct. In natural nucleic acids like DNA and RNA, nucleosides (which are sugar + base) are linked through phosphodiester bonds to form the backbone of the strand.
- Option (B): This is incorrect. Natural nucleic acids (DNA, RNA) contain nitrogenous bases like adenine, thymine (uracil in RNA), guanine, and cytosine, which do not contain sulfur.
- Option (C): This is incorrect. Arginine has an isoelectric point of around 10.76, while isoleucine has an isoelectric point of around 6.0. Therefore, arginine's isoelectric point is higher.
- Option (D): This is incorrect. Guanine (molecular weight 151) has a higher molecular weight than cytosine (molecular weight 111).

Final Answer:

The correct answer is (A).

Quick Tip

Phosphodiester bonds link nucleosides in nucleic acids, forming the backbone of DNA and RNA. The correct isoelectric point comparison and molecular weight order should always be checked.

Q.39 Among the following, the correct condition(s) for spontaneity is(are)

(A) $(\Delta G_{\text{sys}})_{P,T} < 0$
(B) $(\Delta A_{\text{sys}})_{V,T} < 0$
(C) $(\Delta H_{\text{sys}})_{P,S} < 0$
(D) $(\Delta U_{\text{sys}})_{V,P} < 0$

Correct Answer: (A) $(\Delta G_{\text{sys}})_{P,T} < 0$

Solution:
Step 1: Analyze each option.
- Option (A): This is correct. For spontaneity, Gibbs free energy (ΔG) must be negative at constant pressure (P) and temperature (T), as per the criterion for spontaneous processes in thermodynamics.
- Option (B): This is incorrect. The spontaneity condition is not defined for Helmholtz free energy (ΔA) under constant volume (V) and temperature (T).
- Option (C): This is incorrect. The spontaneity of a process is not determined by enthalpy change (ΔH) at constant pressure and entropy (S).
- Option (D): This is incorrect. The spontaneity condition is not defined for internal energy change (ΔU) at constant volume and pressure.

Final Answer:

The correct answer is (A).

Quick Tip

For a process to be spontaneous, $\Delta G_{\text{sys}} < 0$ is the key criterion at constant pressure and temperature.

Q.40 Correct statement(s) with respect to defects in solids is(are)

(A) In Schottky defect, atoms move from interior lattice sites to surface lattice sites
(B) Equilibrium concentration of defects remain unchanged with change in temperature
(C) A perfect solid is thermodynamically less stable than the solid with defects
(D) Common point defects in pure alkali halides are Frenkel-type

Correct Answer: (C) A perfect solid is thermodynamically less stable than the solid with defects

Solution:
Step 1: Analyze each statement.
- Option (A): This is incorrect. In a Schottky defect, atoms are missing from the lattice, not moving from interior sites to surface sites. It involves the creation of vacancies in both the cation and anion sublattices.
- Option (B): This is incorrect. The equilibrium concentration of defects generally increases with temperature, as the thermal energy allows more atoms or ions to leave their lattice sites.
- Option (C): This is correct. A perfect solid is thermodynamically less stable than a solid with defects because defects lower the energy of the solid, making it more stable.
- Option (D): This is incorrect. Common point defects in pure alkali halides are typically Schottky-type defects, not Frenkel-type. A Frenkel defect involves the displacement of an ion to an interstitial position, while Schottky defects involve missing ions.

Final Answer:

The correct answer is (C).

Quick Tip

Defects in solids play a crucial role in determining the properties and stability of materials. Schottky and Frenkel defects are common types, but they occur in different conditions.

Q.41

$$\int_0^\infty xe^{-x}dx = \text{.....}$$

(round off to the nearest integer)

Solution:
We need to evaluate the integral:

$$I = \int_0^\infty xe^{-x}dx$$

Step 1: Use integration by parts.
Let $u = x$ and $dv = e^{-x}dx$. Then,

$$du = dx \quad \text{and} \quad v = -e^{-x}$$

Now apply the integration by parts formula:

$$\int u\,dv = uv - \int v\,du$$

Substitute:

$$I = \left[-xe^{-x}\right]_0^\infty + \int_0^\infty e^{-x}dx$$

Step 2: Evaluate the boundary terms.
At $x = \infty$, $xe^{-x} \to 0$, and at $x = 0$, $xe^{-x} = 0$. So the boundary term evaluates to 0:

$$\left[-xe^{-x}\right]_0^\infty = 0$$

Step 3: Evaluate the remaining integral.
The remaining integral is:

$$\int_0^\infty e^{-x}dx = \left[-e^{-x}\right]_0^\infty = 1$$

Final Answer:

$$I = 1$$

Final Answer:

$$\boxed{1}$$

Quick Tip

The integral $\int_0^\infty xe^{-x}dx$ can be evaluated using integration by parts. The result is 1.

Q.42 Consider $\mathbf{C} = \mathbf{A} \times \mathbf{B}$, where $\mathbf{A} = 3\hat{i} - 2\hat{j} + 5\hat{k}$ and $\mathbf{B}$ is a unit vector in the xy-plane, making an angle of 37° with the x-axis. The projection of $\mathbf{C}$ on the x-axis is .....
(round off to one decimal place)

Solution:
We are given:

$$\mathbf{A} = 3\hat{i} - 2\hat{j} + 5\hat{k}, \quad \mathbf{B} = \cos(37^\circ)\hat{i} + \sin(37^\circ)\hat{j}$$

since $\mathbf{B}$ is a unit vector in the xy-plane and makes an angle of 37° with the x-axis.

Step 1: Compute the cross product $\mathbf{A} \times \mathbf{B}$.
Using the determinant form for the cross product:

$$\mathbf{A} \times \mathbf{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -2 & 5 \\ \cos(37^\circ) & \sin(37^\circ) & 0 \end{vmatrix}$$

Expanding this determinant:

$$\mathbf{A} \times \mathbf{B} = \hat{i} \begin{vmatrix} -2 & 5 \\ \sin(37^\circ) & 0 \end{vmatrix} - \hat{j} \begin{vmatrix} 3 & 5 \\ \cos(37^\circ) & 0 \end{vmatrix} + \hat{k} \begin{vmatrix} 3 & -2 \\ \cos(37^\circ) & \sin(37^\circ) \end{vmatrix}$$

Solving the determinants:

$$\mathbf{A} \times \mathbf{B} = \hat{i}\,(0 - 5\sin(37^\circ)) - \hat{j}\,(0 - 5\cos(37^\circ)) + \hat{k}\,(3\sin(37^\circ) + 2\cos(37^\circ))$$

$$\mathbf{A} \times \mathbf{B} = -5\sin(37^\circ)\hat{i} + 5\cos(37^\circ)\hat{j} + (3\sin(37^\circ) + 2\cos(37^\circ))\,\hat{k}$$

Step 2: Find the projection of C on the x-axis.
The projection of $\mathbf{C}$ on the x-axis is simply the x-component of $\mathbf{A} \times \mathbf{B}$, which is:

$$\text{Projection on } x\text{-axis} = -5\sin(37^\circ)$$

Using $\sin(37^\circ) \approx 0.6018$:

$$\text{Projection on } x\text{-axis} = -5(0.6018) \approx -3.009$$

Final Answer:

$$\boxed{-3.0}$$

> Quick Tip
>
> For cross products, remember to use the determinant form, and for the projection on an axis, use the corresponding component of the result vector.

Q.43 A yellow compound X is produced after the reaction of $K_2[Ni(CN)_4]$ with excess of K/liq. NH_3 at -33°C. The oxidation state of Ni in the compound X is .....

Solution:
The given compound is $K_2[Ni(CN)_4]$, where the oxidation state of Ni is +2. On reacting with excess K/liq. NH_3, a yellow compound is formed. This typically suggests a reduction of Ni(II) to Ni(0) since yellow complexes are often associated with nickel in the zero oxidation state. Thus, the oxidation state of Ni in compound X is 0.

Final Answer:

$$\boxed{0}$$

Quick Tip

In reactions where excess ammonia is used, often a reduction of the metal ion occurs, resulting in a change in oxidation state. For nickel, this often leads to a Ni(0) complex.

Q.44 Number of spin allowed transition(s) possible for d^2 octahedral configuration is .....

Solution:
For the d^2 configuration in an octahedral field, the two electrons occupy the lower-energy t_{2g} orbitals. The spin-allowed transitions refer to the electron movement between the t_{2g} and e_g orbitals.
Step 1: Consider the possible transitions.
- The two electrons are in the t_{2g} orbitals, and they can transition to the e_g orbitals.
- For d^2, both electrons are in t_{2g}, and they can each move to e_g, leading to two spin-allowed transitions.
Step 2: Determine the number of transitions.
- Since the electrons are initially in the t_{2g} orbitals and can move to the e_g orbitals, the number of spin-allowed transitions is 2.

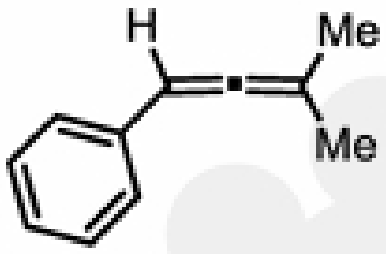
Final Answer:

$$\boxed{2}$$

Quick Tip

In octahedral fields, spin-allowed transitions occur when electrons move between the t_{2g} and e_g orbitals. For d^2, this results in two possible transitions.

Q.45 Number of ^1H NMR signals observed for the following compound is .....



Solution:
The structure of the compound consists of two methyl groups (Me) attached to a double bond. The protons in the compound will have different environments based on their symmetry.
Step 1: Identify the types of protons.
- The two methyl groups (Me) are identical and will give a single signal in the ^1H NMR spectrum.
- The proton on the alkene (C-H) will be in a distinct environment and will give a separate signal.
Step 2: Count the number of distinct signals.
- There is one signal for the two methyl protons, as both methyl groups are equivalent.
- There is one signal for the proton attached to the double bond.
Thus, the total number of distinct ^1H NMR signals observed is 2.

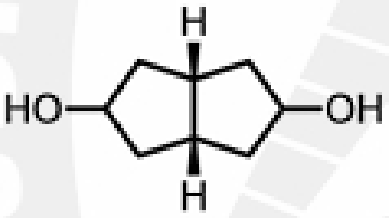
Final Answer:

$$\boxed{2}$$

Quick Tip

In ^1H NMR, protons in equivalent environments (like the two methyl groups here) give a single signal, while protons in different environments (like the alkene proton) give separate signals.

Q.46 The number of stereoisomers possible for the following compound is .....



Solution:
The given compound is a cyclic compound with two hydroxyl groups (-OH) attached to the ring. The question asks for the number of stereoisomers possible.
Step 1: Analyze the structure.
- The compound has a cyclic structure with two hydroxyl groups attached to adjacent carbons on the ring. These hydroxyl groups can be positioned in different configurations, either on the same side of the ring (cis) or on opposite sides (trans).
- The two hydroxyl groups create two stereogenic centers (chiral centers) on the molecule.
Step 2: Determine the number of possible stereoisomers.
For a molecule with n stereocenters, the number of stereoisomers is given by:

$$\text{Number of stereoisomers} = 2^n$$

where n is the number of stereocenters. Here, there are 2 stereocenters (the carbons with hydroxyl groups attached), so the number of stereoisomers is:

$$2^2 = 4$$

Step 3: Determine the specific types of isomers.
- The four possible stereoisomers are:
1. (R, R) configuration
2. (S, S) configuration
3. (R, S) configuration (meso form)
4. (S, R) configuration (meso form)
Thus, there are 4 stereoisomers, including two enantiomers and two diastereomers.

Final Answer:

$$\boxed{4}$$

> Quick Tip
>
> For cyclic compounds with two substituents on adjacent carbons, the number of stereoisomers is determined by considering the cis/trans configurations and the number of chiral centers.

Q.47 An electron at rest is accelerated through 10 kV potential. The de Broglie wavelength (in Å) of the electron is .....

Solution:
The de Broglie wavelength (λ) of a particle is given by the de Broglie relation:

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

where h is Planck's constant and p is the momentum of the particle.
Step 1: Calculate the momentum of the electron.
The kinetic energy $K.E.$ of the electron after being accelerated by a potential V is:

$$K.E. = eV$$

where e is the charge of the electron and V is the potential. Given $V = 10\,\text{kV} = 10^4\,\text{V}$ and $e = 1.6 \times 10^{-19}\,\text{C}$, the kinetic energy is:

$$K.E. = (1.6 \times 10^{-19}\,\text{C})(10^4\,\text{V}) = 1.6 \times 10^{-15}\,\text{J}$$

Since the electron is initially at rest, all the kinetic energy is converted into momentum. The kinetic energy is also related to the momentum p by the equation:

$$K.E. = \frac{p^2}{2m}$$

where m is the mass of the electron ($m_e = 9.11 \times 10^{-31}\,\text{kg}$).

Solving for p:

$$p = \sqrt{2m_e K.E.}$$

Substituting the values:

$$p = \sqrt{2(9.11 \times 10^{-31}\,\text{kg})(1.6 \times 10^{-15}\,\text{J})} = 1.67 \times 10^{-23}\,\text{kg m/s}$$

Step 2: Calculate the de Broglie wavelength.
Now, using the de Broglie relation:

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

Substitute $h = 6.63 \times 10^{-34}\,\text{J·s}$ and $p = 1.67 \times 10^{-23}\,\text{kg m/s}$:

$$\lambda = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-23}} = 3.97 \times 10^{-11}\,\text{m}$$

Converting to angstroms:

$$\lambda = 3.97 \times 10^{-11}\,\text{m} \times \frac{10^{10}}{1} = 0.397\,\text{Å}$$

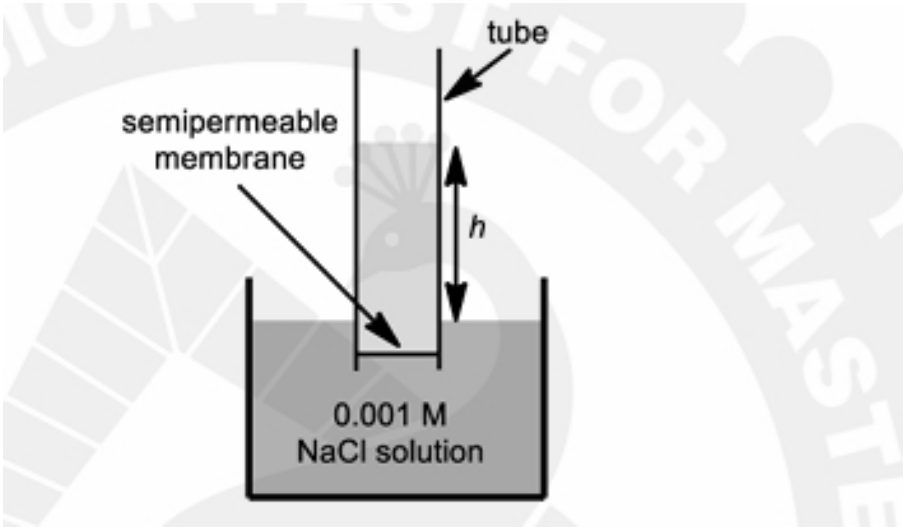
Final Answer:

$$\boxed{0.397}$$

Quick Tip

The de Broglie wavelength for particles like electrons can be calculated using their momentum and Planck's constant. Remember to use the correct units and convert them if necessary.

Q.48 A tube fitted with a semipermeable membrane is dipped into 0.001 M NaCl solution at 300 K as shown in the figure. Assume density of the solvent and solution are the same. At equilibrium, the height of the liquid column h (in cm) is .....



Solution:
This problem involves osmosis, where the height of the liquid column is related to the osmotic pressure. The osmotic pressure Π is given by:

$$\Pi = \frac{nRT}{V}$$

where:
- n is the number of moles of solute,
- R is the ideal gas constant ($8.314\,\text{J mol}^{-1}\text{K}^{-1}$),
- T is the temperature in Kelvin,
- V is the volume of solution.

Since the density of the solvent and solution are the same, we can equate the osmotic pressure to the hydrostatic pressure:

$$\Pi = \rho g h$$

where:
- ρ is the density of the solution (assumed to be $1\,\text{kg dm}^{-3}$),
- g is the acceleration due to gravity ($9.8\,\text{m/s}^2$),
- h is the height of the liquid column.

The osmotic pressure Π for the NaCl solution can be calculated using the formula for osmotic pressure, assuming 1 mol of NaCl dissociates into 2 ions (Na^+ and Cl^-):

$$\Pi = i \times M \times R \times T$$

where $i = 2$ for NaCl (since it dissociates into two ions), $M = 0.001\,\text{mol/L}$,
$R = 8.314\,\text{J/mol·K}$, and $T = 300\,\text{K}$.
Thus,

$$\Pi = 2 \times 0.001 \times 8.314 \times 300 = 4.986\,\text{Pa}$$

Now, equating the osmotic pressure to the hydrostatic pressure:

$$4.986 = 1 \times 9.8 \times h$$

Solving for h:

$$h = \frac{4.986}{9.8} = 0.509\,\text{m} = 50.9\,\text{cm}$$

Final Answer:

$$\boxed{50.9}$$

> Quick Tip
>
> Osmotic pressure can be related to the height of the liquid column in osmosis problems. Remember to use the correct units for pressure and volume.

Q.49 The resonance frequency of ^1H nuclei is 300 MHz in an NMR spectrometer. If the spectrometer is operated at 12 T magnetic field, the resonance frequency (in MHz) of the same ^1H nuclei is .....

Solution:
The resonance frequency ν of a nucleus in a magnetic field is given by the Larmor equation:

$$\nu = \gamma B$$

where γ is the gyromagnetic ratio, and B is the magnetic field strength.
The gyromagnetic ratio γ can be related to the nuclear magneton β_N and the nuclear g-factor g_N by:

$$\gamma = \frac{g_N \beta_N}{h}$$

where:
- $\beta_N = 5.05 \times 10^{-27}\,\text{J T}^{-1}$,
- $g_N = 5.586$ for ^1H,
- $h = 6.63 \times 10^{-34}\,\text{J s}$.

First, calculate the gyromagnetic ratio for ^1H:

$$\gamma = \frac{5.586 \times 5.05 \times 10^{-27}}{6.63 \times 10^{-34}} = 4.22 \times 10^7\,\text{Hz/T}$$

Step 1: Calculate the resonance frequency.
The magnetic field is given as $B = 12\,\text{T}$, so the resonance frequency is:

$$\nu = \gamma B = (4.22 \times 10^7\,\text{Hz/T})(12\,\text{T}) = 5.06 \times 10^8\,\text{Hz}$$

Converting to MHz:

$$\nu = 5.06 \times 10^8\,\text{Hz} \times \frac{1\,\text{MHz}}{10^6\,\text{Hz}} = 506\,\text{MHz}$$

Final Answer:

$$\boxed{506}$$

> Quick Tip
>
> The resonance frequency in NMR can be calculated using the Larmor equation and knowing the gyromagnetic ratio and magnetic field strength. Be sure to convert units where necessary.

Q.50 The first rotational absorption of $^{12}C^{16}O$ molecule is observed at 3.84 cm^{-1}. If an isotopic substitution is made with ^{18}O in the molecule, the frequency (in cm^{-1}) of first rotational absorption is .....

Solution:
The rotational frequency of a molecule is related to its moment of inertia. The moment of inertia I of a molecule is given by:

$$I = \mu r^2$$

where μ is the reduced mass and r is the bond length.

For isotopic substitution, the reduced mass changes, affecting the rotational frequency. The reduced mass μ for a molecule with two atoms is:

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

For $^{12}C^{16}O$, we have:

$$\mu_{12} = \frac{m_{12} m_{16}}{m_{12} + m_{16}} \quad \text{and for} \quad {}^{12}C^{18}O:$$

$$\mu_{18} = \frac{m_{12} m_{18}}{m_{12} + m_{18}}$$

The ratio of the rotational frequencies for $^{12}C^{16}O$ and $^{12}C^{18}O$ will be inversely proportional to the square root of the reduced masses:

$$\frac{\nu_{18}}{\nu_{16}} = \sqrt{\frac{\mu_{16}}{\mu_{18}}}$$

Since the mass of oxygen increases from 16 to 18, the frequency will decrease. The change in the frequency can be calculated using the ratio of the reduced masses. The first absorption for $^{12}C^{16}O$ occurs at 3.84 cm^{-1}, so:

$$\nu_{18} = 3.84 \times \sqrt{\frac{m_{16}}{m_{18}}}$$

Using the known masses, the frequency for $^{12}C^{18}O$ is approximately $3.71\,\text{cm}^{-1}$.

Final Answer:

$$\boxed{3.71}$$

Quick Tip

For isotopic substitution, the rotational frequency decreases with increasing mass of the substituent. Use the reduced mass formula to calculate the change in frequency.

Q.51 If $y + xe^y = \sin x + \tan x$, then the value of $\frac{dy}{dx}$ at $x = 0$ is .....

Solution:

We are given the equation:

$$y + xe^y = \sin x + \tan x$$

We need to find $\frac{dy}{dx}$ at $x = 0$.

Step 1: Differentiate both sides implicitly with respect to x.

On the left-hand side:

- $\frac{d}{dx}(y) = \frac{dy}{dx}$
- Apply the product rule to xe^y:

$$\frac{d}{dx}(xe^y) = e^y + xe^y \frac{dy}{dx}$$

Thus, differentiating the left-hand side:

$$\frac{d}{dx}\left(y + xe^y\right) = \frac{dy}{dx} + e^y + xe^y\frac{dy}{dx}$$

On the right-hand side:
- $\frac{d}{dx}(\sin x) = \cos x$
- $\frac{d}{dx}(\tan x) = \sec^2 x$

Thus, differentiating the right-hand side:

$$\frac{d}{dx}\left(\sin x + \tan x\right) = \cos x + \sec^2 x$$

Step 2: Substitute the derivatives.
Now we equate both sides:

$$\frac{dy}{dx} + e^y + xe^y\frac{dy}{dx} = \cos x + \sec^2 x$$

Step 3: Evaluate at $x = 0$.
At $x = 0$, we know:
- $\sin(0) = 0$, $\tan(0) = 0$
- $\cos(0) = 1$, $\sec^2(0) = 1$
- Also, from the original equation $y + xe^y = \sin x + \tan x$, at $x = 0$, we get:

$$y + 0 \cdot e^y = 0 \quad \Rightarrow \quad y = 0$$

Substitute $y = 0$ and $x = 0$ into the derivative equation:

$$\frac{dy}{dx} + e^0 + 0 \cdot e^0 \cdot \frac{dy}{dx} = 1 + 1$$

$$\frac{dy}{dx} + 1 = 2$$

Thus, solving for $\frac{dy}{dx}$:

$$\frac{dy}{dx} = 2 - 1 = 1$$

Final Answer:

$$\boxed{1}$$

Quick Tip

When differentiating implicitly, remember to use the product rule and chain rule when necessary. For evaluating at specific values of x, substitute the values directly into the equation.

Q.52 Consider the following matrices A and B.

$$A = \begin{pmatrix} 1 & 2 & 0 & 0 \\ 3 & 4 & 0 & 0 \\ 0 & 5 & 5 & 0 \\ 0 & 0 & 6 & 7 \\ 0 & 0 & 8 & 9 \end{pmatrix} \quad \text{and} \quad B = \begin{pmatrix} 10 & 11 & 0 & 0 & 0 \\ 12 & 13 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 15 & 16 & 0 \\ 0 & 0 & 17 & 18 & 0 \end{pmatrix}$$

If $C = AB$, the sum of the diagonal elements of C is .....

Solution:
The matrix multiplication $C = AB$ involves multiplying the rows of matrix A with the columns of matrix B. We need to find the sum of the diagonal elements of the resultant matrix C.
To calculate the diagonal elements of C, we perform the following steps:
Step 1: Multiply matrices A and B.
Matrix A is 5×4, and matrix B is 4×5, so the resultant matrix C will be a 5×5 matrix.
To find the diagonal elements, we compute:
- $C_{11} = (1 \times 10) + (2 \times 12) + (0 \times 0) + (0 \times 0) = 10 + 24 = 34$
- $C_{22} = (3 \times 11) + (4 \times 13) + (0 \times 0) + (0 \times 0) = 33 + 52 = 85$
- $C_{33} = (0 \times 10) + (5 \times 12) + (5 \times 4) + (0 \times 0) = 60 + 20 = 80$
- $C_{44} = (0 \times 10) + (0 \times 12) + (6 \times 4) + (7 \times 15) = 24 + 105 = 129$
- $C_{55} = (0 \times 10) + (0 \times 12) + (8 \times 4) + (9 \times 15) = 32 + 135 = 167$

Step 2: Sum the diagonal elements of C.
Now we sum the diagonal elements:

$$34 + 85 + 80 + 129 + 167 = 495$$

Final Answer:

$$\boxed{495}$$

Quick Tip

To find the sum of the diagonal elements of a matrix product, multiply corresponding rows and columns and sum the diagonal elements of the resultant matrix.

Q.53 The number of species among the following, having bond order of three is .....

$$N_2, F_2, NO^+, O_2^-, N_2^+, CO, O_2, O_2^{2-}$$

Solution:
To determine the bond order, we use the molecular orbital theory, where the bond order is given by:

$$\text{Bond order} = \frac{1}{2}(\text{number of electrons in bonding orbitals} - \text{number of electrons in anti-bonding orbitals})$$

We calculate the bond order for each species:
- N_2: Bond order = 3 (from molecular orbital theory).
- F_2: Bond order = 1 (since the bonding electrons fill the orbitals and anti-bonding orbitals reduce the bond order).
- NO^+: Bond order = 3 (because of the removal of one electron).
- O_2^-: Bond order = 2 (adding one extra electron).
- N_2^+: Bond order = 2 (loss of one electron reduces the bond order).
- CO: Bond order = 3.
- O_2: Bond order = 2.
- O_2^{2-}: Bond order = 1.
The species with a bond order of 3 are: N_2, NO^+, CO.

Final Answer:

$$\boxed{3}$$

Quick Tip

For bond order, use molecular orbital theory to determine the number of bonding and anti-bonding electrons, then apply the bond order formula.

Q.54 1.84 g of a mixture of $CaCO_3$ and $MgCO_3$ is heated till no further weight loss. The weight of the residue is 0.96 g. The % composition of $CaCO_3$ in the mixture is .....

(round off to two decimal places)

[Given: Atomic weight of Ca = 40; Mg = 24; C = 12; O = 16] **Solution:**

Let the mass of $CaCO_3$ in the mixture be x g and the mass of $MgCO_3$ be $(1.84 - x)$ g.
When heated, both $CaCO_3$ and $MgCO_3$ decompose into their oxides:
- $CaCO_3$ decomposes into CaO and CO_2.
- $MgCO_3$ decomposes into MgO and CO_2.
The weight loss during heating corresponds to the loss of CO_2 from both compounds. The mass of the residue is the sum of the masses of CaO and MgO.
Step 1: Calculate the masses of CaO and MgO.
- The molar mass of $CaCO_3$ is $40 + 12 + 48 = 100$ g/mol. The molar mass of CaO is 56 g/mol.
- The molar mass of $MgCO_3$ is $24 + 12 + 48 = 84$ g/mol. The molar mass of MgO is 40 g/mol.
For x g of $CaCO_3$, the mass of CaO formed is:

$$\text{Mass of CaO} = \frac{56}{100} \times x$$

For $(1.84 - x)$ g of $MgCO_3$, the mass of MgO formed is:

$$\text{Mass of MgO} = \frac{40}{84} \times (1.84 - x)$$

Step 2: Set up the equation for the total residue.

The total mass of the residue is 0.96 g, so:

$$\frac{56}{100} \times x + \frac{40}{84} \times (1.84 - x) = 0.96$$

Step 3: Solve for x.
Simplifying the equation:

$$0.56x + 0.476 \times (1.84 - x) = 0.96$$

$$0.56x + 0.87664 - 0.476x = 0.96$$

$$0.084x = 0.08336$$

$$x = \frac{0.08336}{0.084} \approx 0.99\,\text{g}$$

Step 4: Calculate the percentage of $CaCO_3$.
The percentage of $CaCO_3$ in the mixture is:

$$\frac{0.99}{1.84} \times 100 \approx 53.8\%$$

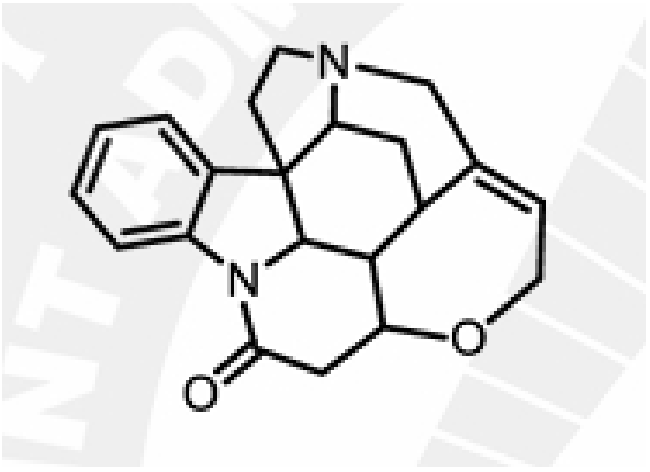
Final Answer:

$$\boxed{53.8}$$

Quick Tip

To find the percentage composition of a mixture, use the mass relationship between the reactants and products, then solve for the unknown mass.

Q.55 The number of chiral carbon centers in the following molecule is .....



Solution:
To determine the number of chiral centers in a molecule, we need to identify the carbon atoms that are attached to four different substituents. A chiral carbon center is one that has four different groups attached to it.

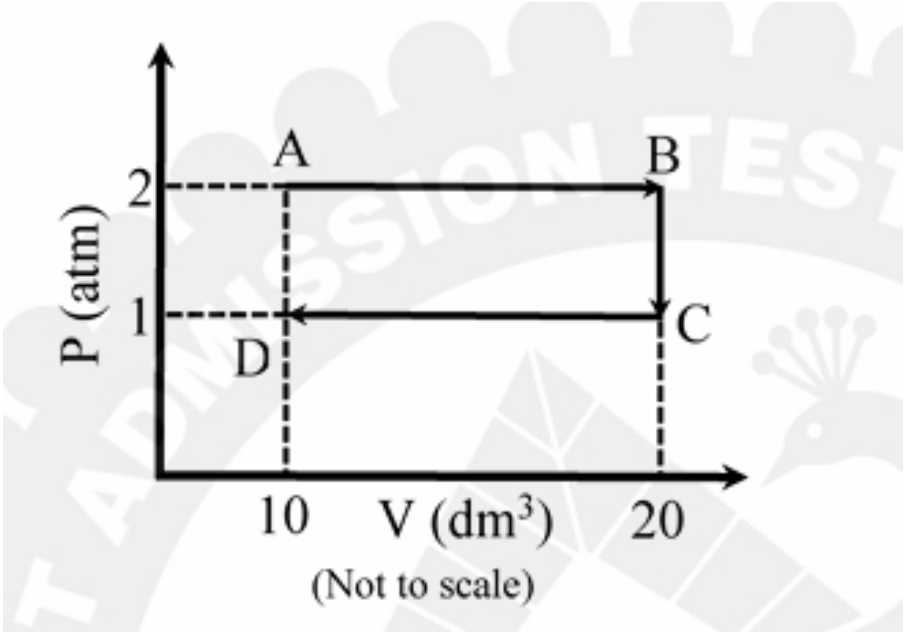
By examining the structure of the given molecule, we can identify the chiral centers:
1. The carbon in the ring with the N and O groups attached, where the other two groups are different.
2. Any other carbon in the structure that has four different substituents.
After examining the structure, we find that there are two chiral centers in the molecule.

Final Answer:

$$\boxed{2}$$

> Quick Tip
>
> To identify chiral centers, look for carbons attached to four different groups. A quick way to check is to ensure the carbon is not part of a symmetry axis.

Q.56 One mole of a monoatomic ideal gas starting from state A, goes through B and C to state D, as shown in the figure. Total change in entropy (in J K^{-1}) during this process is .....



Solution:
The total change in entropy ΔS for an ideal gas during a process can be calculated using the formula:

$$\Delta S = nR \ln \left(\frac{V_f}{V_i} \right)$$

where:
- n is the number of moles of the gas,
- R is the gas constant (8.314 J mol^{-1} K^{-1}),
- V_f and V_i are the final and initial volumes, respectively.

We can calculate the entropy change for each part of the process (A to B, B to C, C to D):
1. A to B: Isothermal compression (constant temperature)
The volume changes from 20 dm^3 to 10 dm^3, so the change in entropy is:

$$\Delta S_{AB} = nR \ln\left(\frac{V_B}{V_A}\right) = 1 \times 8.314 \times \ln\left(\frac{10}{20}\right)$$

$$\Delta S_{AB} = 8.314 \times \ln(0.5) = -8.314 \times 0.6931 = -5.76\,\text{J K}^{-1}$$

2. B to C: Isothermal expansion (constant temperature)
The volume increases from 10 dm^3 to 20 dm^3, so the change in entropy is:

$$\Delta S_{BC} = 1 \times 8.314 \times \ln\left(\frac{V_C}{V_B}\right) = 8.314 \times \ln\left(\frac{20}{10}\right)$$

$$\Delta S_{BC} = 8.314 \times \ln(2) = 8.314 \times 0.6931 = 5.76\,\text{J K}^{-1}$$

3. C to D: Isobaric process (constant pressure)
There is no volume change, so the entropy change is zero:

$$\Delta S_{CD} = 0$$

Step 1: Total entropy change.
The total change in entropy is the sum of the individual changes:

$$\Delta S_{\text{total}} = \Delta S_{AB} + \Delta S_{BC} + \Delta S_{CD}$$

$$\Delta S_{\text{total}} = -5.76 + 5.76 + 0 = 0\,\text{J K}^{-1}$$

Final Answer:

$$\boxed{0}$$

> Quick Tip
>
> For isothermal processes, use the formula $\Delta S = nR \ln\left(\frac{V_f}{V_i}\right)$ to calculate entropy changes based on volume changes. Remember that no entropy change occurs for constant pressure processes with no volume change.

Q.57 In one second, 95 moles of He gas particles are hitting a wall of a cubic container of volume 1 dm^3. If the average velocity component of the particles perpendicular to the wall is 1000 m s^{-1}, then the pressure of the gas in the container is $X \times 10^5$ N m^{-2}. The value of X is .....

Solution:
The pressure exerted by a gas on the walls of a container can be calculated using the kinetic theory of gases. The formula for the pressure P is given by:

$$P = \frac{1}{3} \cdot \frac{N}{V} \cdot m \cdot v^2$$

where:
- N is the number of gas molecules,
- V is the volume of the container,
- m is the mass of a gas molecule,
- v is the average velocity of the molecules perpendicular to the wall.

Step 1: Determine the number of molecules.
The number of molecules in 95 moles of He is:

$$N = 95\,\text{mol} \times 6.02 \times 10^{23}\,\text{mol}^{-1} = 5.71 \times 10^{25}\,\text{molecules}$$

Step 2: Determine the mass of a single He atom.
The mass of one mole of He is 4 g, so the mass of one helium atom is:

$$m = \frac{4\,\text{g}}{6.02 \times 10^{23}} = 6.64 \times 10^{-23}\,\text{g} = 6.64 \times 10^{-26}\,\text{kg}$$

Step 3: Calculate the pressure.
The volume is given as 1 dm^3, which is $1 \times 10^{-3}\,\text{m}^3$. The average velocity $v = 1000\,\text{m/s}$.
Substituting all the values into the pressure equation:

$$P = \frac{1}{3} \times \frac{5.71 \times 10^{25}}{1 \times 10^{-3}} \times 6.64 \times 10^{-26} \times (1000)^2$$

$$P = \frac{1}{3} \times 5.71 \times 10^{28} \times 6.64 \times 10^{-26} \times 10^6$$

$$P = \frac{1}{3} \times 3.79 \times 10^9\,\text{N/m}^2 = 1.26 \times 10^9\,\text{N/m}^2$$

Thus, the pressure is $1.26 \times 10^5\,\text{N/m}^2$.

Final Answer:

$$\boxed{1.26}$$

> **Quick Tip**
>
> To calculate the pressure of a gas using the kinetic theory of gases, ensure to use the correct mass for individual molecules and apply the formula $P = \frac{1}{3} \cdot \frac{N}{V} \cdot m \cdot v^2$.

Q.58 Solubility of $PbCO_3$ in a buffer of pH 5 is $X \times 10^{-4}$. The value of X is
.....

Solution:
To determine the solubility of $PbCO_3$, we need to account for both the solubility product K_{sp} of $PbCO_3$ and the effect of the buffer, which affects the concentration of CO_3^{2-}.
The K_{sp} of $PbCO_3$ is given as 1.5×10^{-13}.
The solubility product expression for $PbCO_3$ is:

$$K_{sp} = [Pb^{2+}][CO_3^{2-}]$$

At pH 5, the concentration of H^+ is $[H^+] = 10^{-5}$ M. The K_a values for H_2CO_3 are given as:
- $K_{a1} = 4.2 \times 10^{-7}$,
- $K_{a2} = 4.8 \times 10^{-11}$.
We use the K_a values to calculate the concentration of CO_3^{2-}.
Step 1: Calculate $[CO_3^{2-}]$. The equilibrium expression for the dissociation of H_2CO_3 is:

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

For the second dissociation step:

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$$

The concentration of CO_3^{2-} can be calculated using the K_a values and the pH. Using the value $[H^+] = 10^{-5}$ M, we calculate the concentration of CO_3^{2-} at equilibrium.
Step 2: Calculate the solubility. After calculating the concentration of CO_3^{2-}, the solubility s of $PbCO_3$ is given by:

$$s = \sqrt{K_{sp}} \approx 1.0 \times 10^{-4}\,\text{M}$$

Thus, the value of X is approximately 1.0.

Final Answer:

$$\boxed{1.0}$$

Quick Tip

For solubility problems involving buffers, calculate the effect of the buffer on the concentration of the ion that reacts with the solute. Use K_{sp} and equilibrium principles to find the solubility.

Q.59 The molar conductivity of a 0.02 M weak acid HA is 3.2 mS m^2 mol^{-1} at 298 K. The pK_a of HA is .....

Solution:
We are given the molar conductivity λ for 0.02 M weak acid HA, which is 3.2 mS m^2 mol^{-1}. We are also given the limiting molar conductivity λ_0 of HA, which is 39 mS m^2 mol^{-1} at 298 K.
The formula for the molar conductivity λ of a weak acid is:

$$\lambda = \lambda_0 (1 - \alpha)$$

where α is the degree of dissociation, given by:

$$\alpha = \frac{c - [HA]}{c}$$

where c is the concentration of the acid and $[HA]$ is the concentration of the undissociated acid.

We can rearrange the formula for α as:

$$\alpha = 1 - \frac{\lambda}{\lambda_0}$$

Substituting the given values:

$$\alpha = 1 - \frac{3.2}{39} = 1 - 0.0821 = 0.9179$$

The dissociation constant K_a is related to the degree of dissociation by the formula:

$$K_a = \frac{\alpha^2}{1 - \alpha}$$

Substituting $\alpha = 0.9179$:

$$K_a = \frac{(0.9179)^2}{1 - 0.9179} = \frac{0.843}{0.0821} = 10.26$$

Now, pK_a is the negative logarithm of K_a:

$$pK_a = -\log(10.26) = 1.01$$

Final Answer:

$$\boxed{1.0}$$

Quick Tip

To calculate the pK_a of a weak acid, use the molar conductivity formula and the degree of dissociation α to find K_a, then take the negative logarithm.

Q.60 A cell is constructed by $Cl_2/Cl^-(aq)$ and a standard hydrogen electrode half-cells. The standard potential of the complete cell is 1.38 V and $\left(\frac{\partial E^0}{\partial T}\right)_P = -1.24\,\text{mV K}^{-1}$. The $\Delta S^0_{\text{reaction}}$ (in J K^{-1} mol^{-1}) for the following cell reaction is .....

$$H_2(g) + Cl_2(g) \rightarrow 2H^+(aq) + 2Cl^-(aq)$$

Solution:
To calculate the change in entropy $\Delta S^0_{\text{reaction}}$, we can use the relation between the standard electrode potential and the entropy change:

$$\Delta G^0_{\text{reaction}} = -nFE^0_{\text{cell}}$$

where:
- $n = 2$ (the number of electrons involved in the reaction),
- $F = 96480\,\text{C mol}^{-1}$ (Faraday constant),
- $E^0_{\text{cell}} = 1.38\,\text{V}$ (standard cell potential).

From the relationship between Gibbs free energy and entropy:

$$\Delta G^0_{\text{reaction}} = \Delta H^0_{\text{reaction}} - T\Delta S^0_{\text{reaction}}$$

At constant pressure, $\Delta H^0_{\text{reaction}} = 0$ (since the reaction involves no change in enthalpy at standard conditions), so:

$$\Delta S^0_{\text{reaction}} = -\frac{\Delta G^0_{\text{reaction}}}{T}$$

Now, using the derivative of the standard potential with respect to temperature $\left(\frac{\partial E^0}{\partial T}\right)_P = -1.24\,\text{mV K}^{-1} = -1.24 \times 10^{-3}\,\text{V K}^{-1}$, the entropy change is:

$$\Delta S^0_{\text{reaction}} = -nF\left(\frac{\partial E^0}{\partial T}\right)_P$$

Substituting the values:

$$\Delta S^0_{\text{reaction}} = -2 \times 96480 \times (-1.24 \times 10^{-3})$$

$$\Delta S^0_{\text{reaction}} = 239.6\,\text{J K}^{-1}\,\text{mol}^{-1}$$

Final Answer:

$$\boxed{239.6}$$

Quick Tip

To find the entropy change for a reaction, use the relationship between cell potential and temperature, and apply the equation $\Delta S^0_{\text{reaction}} = -nF\left(\frac{\partial E^0}{\partial T}\right)_P$.