IIT JAM 2018 Chemistry (CY) Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**60

General Instructions

General Instructions:

i) All questions are compulsory. Marks allotted to each question are indicated in the margin.

ii) Answers must be precise and to the point.

iii) In numerical questions, all steps of calculation should be shown clearly.

iv) Use of non-programmable scientific calculators is permitted.

v) Wherever necessary, write balanced chemical equations with proper symbols and units.

vi) Rough work should be done only in the space provided in the question paper.

1. On hydrolysis, aluminium carbide produces

(A) CH4

(B) C2H6

(C) C2H4

(D) C2H2

Correct Answer: (A) CH4

Solution:

Step 1: Understanding the Reaction.

Aluminium carbide reacts with water (hydrolysis) to produce methane gas (CH4). The chemical reaction for the process is:

$$Al_4C_3 + 12H_2O \rightarrow 4Al(OH)_3 + 3CH_4$$

Thus, methane (CH4) is produced.

Step 2: Analyzing the options.

(A) CH4: Correct — This is the product of the hydrolysis reaction.

(B) C2H6: Incorrect — Ethane is not produced in this reaction.

(C) C2H4: Incorrect — Ethene is not produced either.

(D) C2H2: Incorrect — Acetylene is not a product of this reaction.

Step 3: Conclusion.

The correct answer is **(A) CH4** as methane is produced during the hydrolysis of aluminium carbide.

Quick Tip

Always remember that the products of hydrolysis reactions depend on the nature of the compound being hydrolyzed. Aluminium carbide produces methane gas upon hydrolysis.

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2. Carbonic anhydrase is an example of

(A) Hydrolase enzyme

(B) Redox enzyme

(C) O2 transport protein

(D) Heme protein

Correct Answer: (A) Hydrolase enzyme

Solution:

Step 1: Understanding the enzyme.

Carbonic anhydrase is an enzyme that catalyzes the reversible hydration of carbon dioxide to form carbonic acid. This reaction is a form of hydrolysis, which is why carbonic anhydrase is classified as a hydrolase enzyme.

Step 2: Analyzing the options.

(A) Hydrolase enzyme: Correct — Carbonic anhydrase is a hydrolase enzyme that catalyzes the hydrolysis of CO2.

(B) Redox enzyme: Incorrect — Carbonic anhydrase does not involve oxidation or reduction reactions.

(C) O2 transport protein: Incorrect — Carbonic anhydrase does not transport oxygen. Hemoglobin is an example of an O2 transport protein.

(D) Heme protein: Incorrect — Carbonic anhydrase does not contain a heme group, which is characteristic of hemoglobin or myoglobin.

Step 3: Conclusion.

The correct answer is **(A) Hydrolase enzyme** as carbonic anhydrase is involved in hydrolysis reactions.

Quick Tip

Hydrolase enzymes catalyze hydrolysis reactions, often involving the addition of water to break bonds. Carbonic anhydrase is a key example in the body.

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3. The CORRECT order of melting points of group 15 trifluorides is

(A) PF3 ¡ AsF3 ¡ SbF3 ¡ BiF3

(B) BiF3 ¡ SbF3 ¡ PF3 ¡ AsF3

(C) PF3 ¡ SbF3 ¡ AsF3 ¡ BiF3

(D) BiF3 ¡ AsF3 ¡ SbF3 ¡ PF3

Correct Answer: (C) PF3 ¡ SbF3 ¡ AsF3 ¡ BiF3

Solution:

Step 1: Understanding the trend in melting points.

The melting points of group 15 trifluorides generally increase as the size of the central atom increases. The larger atoms have weaker bonds and thus lower melting points. Therefore, the order follows the atomic size trend: PF3 ¡ SbF3 ¡ AsF3 ¡ BiF3.

Step 2: Analyzing the options.

(A) PF3 ¡ AsF3 ¡ SbF3 ¡ BiF3: Incorrect — The order is incorrect based on the atomic size and trend in melting points.

(B) BiF3 ¡ SbF3 ¡ PF3 ¡ AsF3: Incorrect — This order is not consistent with the trend in melting points.

(C) PF3 ¡ SbF3 ¡ AsF3 ¡ BiF3: Correct — This is the correct order based on the increasing atomic size.

(D) BiF3 ¡ AsF3 ¡ SbF3 ¡ PF3: Incorrect — This order does not follow the correct trend.

Step 3: Conclusion.

The correct answer is **(C) PF3 ¡ SbF3 ¡ AsF3 ¡ BiF3** as it follows the expected trend of melting points.

Quick Tip

When determining the order of melting points, remember that larger atoms typically have weaker bonds, resulting in lower melting points.

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4. NaF, KF, MgO and CaO are crystalline solids. They have NaCl structure. Their lattice energies vary in the order

(A) NaF ¡ KF ¡ MgO ¡ CaO

(B) KF ¡ NaF ¡ CaO ¡ MgO

(C) MgO ¡ CaO ¡ NaF ¡ KF

(D) CaO ¡ MgO ¡ NaF ¡ KF

Correct Answer: (A) NaF ¡ KF ¡ MgO ¡ CaO

Solution:

Step 1: Understanding lattice energy.

Lattice energy is the energy released when ions in a crystalline solid are brought together from infinity to form a lattice. It depends on the charge and size of the ions involved. Higher charges and smaller ions lead to higher lattice energies.

Step 2: Analyzing the options.

(A) NaF ¡ KF ¡ MgO ¡ CaO: Correct — The lattice energy increases with the charge on the ions and the size of the ions, with CaO having the highest lattice energy due to the larger charge on the ions.

(B) KF ¡ NaF ¡ CaO ¡ MgO: Incorrect — This order does not follow the expected trend based on ionic size and charge.

(C) MgO ¡ CaO ¡ NaF ¡ KF: Incorrect — This order is not consistent with the lattice energy trend.

(D) CaO ¡ MgO ¡ NaF ¡ KF: Incorrect — This order also doesn't follow the correct trend.

Step 3: Conclusion.

The correct answer is **(A) NaF ¡ KF ¡ MgO ¡ CaO** based on lattice energy trends.

Quick Tip

Lattice energy is influenced by the charge and size of the ions. Smaller ions with higher charges result in higher lattice energy.

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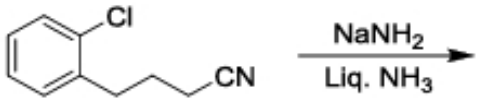
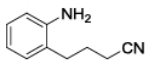
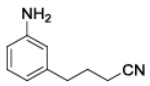
5. The major product formed in the following reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (A)

Solution:

Step 1: Understanding the reaction.

The given reaction involves the treatment of a compound with sodium amide ($NaNH_2$) in liquid ammonia. This type of reaction is known as the nucleophilic substitution reaction (also called the *Elimination Addition* or *Wurtz-type* reaction). It typically results in the formation of an amine from an alkyl halide.

Step 2: Analyzing the options.

(A) : Correct — This option corresponds to the major product of the reaction, which is the primary amine formed by the substitution of the chlorine atom with the amine group (NH_2).

(B) : Incorrect — This structure does not result from the given reaction conditions.

(C) : Incorrect — This structure is not the expected product, as it would not form from the elimination reaction.

(D) : Incorrect — This option represents an oxygen-containing product, which is not the result of this nucleophilic substitution reaction.

Step 3: Conclusion.

The correct answer is **(A)** as the major product formed is the primary amine.

Quick Tip

In nucleophilic substitution reactions, especially with sodium amide ($NaNH_2$) in liquid ammonia, halogens are replaced by nucleophilic groups like amines.

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6. The compound that contains the most acidic hydrogen is

(A) H2C=CH2

(B) HC=CH

(C) H2C=C=CH2

(D) H3C-CH3

Correct Answer: (B) HC=CH

Solution:

Step 1: Understanding the structure of compounds.

The most acidic hydrogen is found in the compound with the weakest bond to the hydrogen atom. In this case, the hydrogen in the alkene (HC=CH) is more acidic than in the others due to the sp-hybridization of the carbon, which pulls electron density away from the hydrogen, making it more easily ionizable.

Step 2: Analyzing the options.

(A) H2C=CH2: Incorrect — This compound has an alkene but with less acidic hydrogen.

(B) HC=CH: Correct — The hydrogen here is attached to a sp-hybridized carbon, making it the most acidic.

(C) H2C=C=CH2: Incorrect — While this compound contains conjugation, the hydrogen here is not the most acidic.

(D) H3C-CH3: Incorrect — This is an alkane, and the hydrogens are less acidic compared to alkenes.

Step 3: Conclusion.

The correct answer is **(B) HC=CH** as it has the most acidic hydrogen due to the sp-hybridized carbon.

Quick Tip

In general, the more s-character in a carbon-hydrogen bond, the more acidic the hydrogen will be. Alkenes with sp-hybridized carbons are typically more acidic than those with sp2 or sp3 carbons.

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7. The C-2 epimer of D-glucose is

(A) D-Mannose

(B) D-Fructose

(C) D-Galactose

(D) D-Gulose

Correct Answer: (C) D-Galactose

Solution:

Step 1: Understanding epimers.

Epimers are sugars that differ only in the configuration of one chiral center. In D-glucose, the configuration at C-2 is the key difference between D-glucose and D-galactose. Therefore, D-galactose is the C-2 epimer of D-glucose.

Step 2: Analyzing the options.

(A) D-Mannose: Incorrect — D-mannose is an epimer of D-glucose at C-2, not the C-2 epimer.

(B) D-Fructose: Incorrect — D-fructose is a different sugar and not an epimer of D-glucose.

(C) D-Galactose: Correct — This is the C-2 epimer of D-glucose.

(D) D-Gulose: Incorrect — D-gulose is another epimer, but it differs at a different carbon.

Step 3: Conclusion.

The correct answer is **(C) D-Galactose** as it is the C-2 epimer of D-glucose.

Quick Tip

When identifying epimers, focus on the specific chiral center that differs in configuration between the two sugars.

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8. The value of integral $\int_{-2}^{2} xe^{-2x^2}dx$ is

(A) 0

(B) $\frac{1}{2}$

(C) 1

(D) 2

Correct Answer: (A) 0

Solution:

Step 1: Identifying the symmetry.

The given integral involves an odd function (xe^{-2x^2}) integrated over a symmetric interval from -2 to 2. The integral of an odd function over a symmetric interval is always 0.

Step 2: Analyzing the options.

(A) 0: Correct — The integral of an odd function over a symmetric interval is zero.

(B) $\frac{1}{2}$: Incorrect — This is not the correct value of the integral.

(C) 1: Incorrect — The result is not 1.

(D) 2: Incorrect — This is not the correct value of the integral.

Step 3: Conclusion.

The correct answer is **(A) 0** because the integrand is an odd function, and its integral over a symmetric interval is zero.

Quick Tip

For integrals of odd functions over symmetric limits, the result is always zero.

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9. The number of crystal systems and the number of Bravais lattices are, respectively,

(A) 14 and 7

(B) 7 and 32

(C) 32 and 14

(D) 7 and 14

Correct Answer: (D) 7 and 14

Solution:

Step 1: Understanding crystal systems and Bravais lattices.

There are 7 crystal systems, and each crystal system is classified into 14 possible Bravais lattices. The 7 crystal systems are based on symmetry, and the Bravais lattices represent the distinct arrangements of points in three-dimensional space.

Step 2: Analyzing the options.

(A) 14 and 7: Incorrect — The number of systems and lattices are reversed.

(B) 7 and 32: Incorrect — This is not the correct pairing of numbers.

(C) 32 and 14: Incorrect — The correct numbers are in the reverse order.

(D) 7 and 14: Correct — This is the correct pairing of the 7 crystal systems and 14 Bravais lattices.

Step 3: Conclusion.

The correct answer is **(D) 7 and 14** based on the correct classification of crystal systems and Bravais lattices.

Quick Tip

The 7 crystal systems and 14 Bravais lattices are fundamental to crystallography, classifying the symmetry and structure of crystalline solids.

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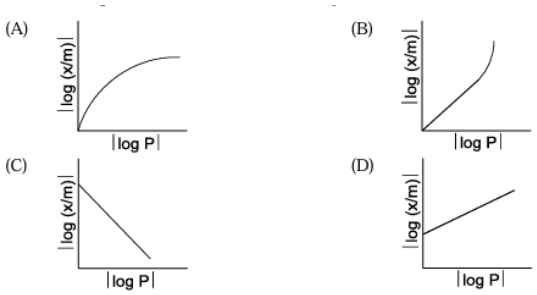
10. For adsorption of a gas on a solid surface, the plot that represents Freundlich isotherm is



Correct Answer: (C)

Solution:

Step 1: Understanding Freundlich isotherm.

The Freundlich isotherm is an empirical relationship describing adsorption on a non-ideal surface. It shows a non-linear relationship between the amount of gas adsorbed and pressure. The plot of $\log x/m$ vs. $\log P$ represents the Freundlich isotherm.

Step 2: Analyzing the options.

(A) : Incorrect — This plot does not represent the Freundlich isotherm.

(B) : Incorrect — This is not the correct plot for Freundlich isotherm.

(C) : Correct — This is the correct plot for the Freundlich adsorption isotherm.

(D) : Incorrect — This plot does not correspond to the Freundlich isotherm.

Step 3: Conclusion.

The correct answer is **(C)** as this plot represents the Freundlich adsorption isotherm.

Quick Tip

The Freundlich isotherm is an empirical equation used to describe the adsorption of gases on solids. The plot of $\log x/m$ vs. $\log P$ is characteristic of this isotherm.

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11. With respect to periodic properties, the CORRECT statement is

(A) Electron affinity order is F ¿ O ¿ Cl

(B) First ionisation energy order is Al ¿ Mg ¿ K

(C) Atomic radius order is N ¿ P ¿ As

(D) Ionic radius order is K+ ¿ Ca2+ ¿ Mg2+

Correct Answer: (A) Electron affinity order is F ¿ O ¿ Cl

Solution:

Step 1: Understanding electron affinity.

Electron affinity is the energy released when an electron is added to an atom. As we move across a period from left to right, the electron affinity increases, and F has the highest electron affinity in Group 17. The order for electron affinity is F ¿ O ¿ Cl, as F has the smallest atomic radius, and the added electron experiences less repulsion.

Step 2: Analyzing the options.

(A) Electron affinity order is F ¿ O ¿ Cl: Correct — This is the correct electron affinity order based on periodic trends.

(B) First ionisation energy order is Al ¿ Mg ¿ K: Incorrect — Magnesium (Mg) has a higher ionization energy than aluminum (Al), and potassium (K) has a much lower ionization energy.

(C) Atomic radius order is N ¿ P ¿ As: Incorrect — The atomic radius increases as we go down a group, so the order should be As ¿ P ¿ N.

(D) Ionic radius order is K+ ¿ Ca2+ ¿ Mg2+: Incorrect — The correct order should be K+ ¿ Ca2+ ¿ Mg2+ in terms of ionic radii.

Step 3: Conclusion.

The correct answer is **(A) F ¿ O ¿ Cl**, as it correctly represents the trend for electron affinity.

Quick Tip

Electron affinity increases across a period (left to right) due to increasing nuclear charge and decreasing atomic size.

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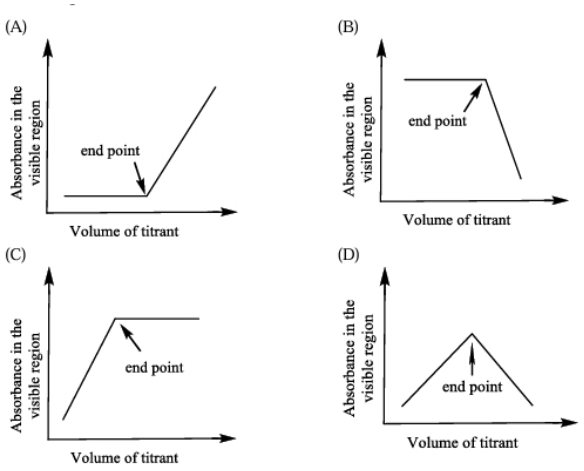
12. Which plot represents a spectrophotometric titration, where the titrant alone absorbs light in the visible region?



Correct Answer: (C)

Solution:

Step 1: Understanding spectrophotometric titration.

In a spectrophotometric titration, absorbance of light in the visible region changes as the titrant is added. When the titrant absorbs light, the plot typically shows a sharp change at the endpoint, which is characterized by a distinct shift in absorbance. The titrant alone absorbs light in the visible region, so we look for the plot that shows this behavior.

Step 2: Analyzing the options.

(A) : Incorrect — This plot does not represent a typical spectrophotometric titration where the titrant alone absorbs light.

(B) : Incorrect — This plot is not representative of the absorption behavior of the titrant.

(C) : Correct — This plot represents a typical spectrophotometric titration where the titrant absorbs light in the visible region and shows a sharp increase at the endpoint.

(D) : Incorrect — This plot does not correspond to the described titration behavior.

Step 3: Conclusion.

The correct answer is **(C)** as it correctly represents the absorbance plot for a titration where the titrant absorbs light in the visible region.

Quick Tip

In spectrophotometric titrations, a sharp change in absorbance at the endpoint indicates a significant reaction between the titrant and analyte.

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13. Among the following metal carbonyl species, the one with the highest metal-carbon back bonding is

(A) $[Ti(CO)_6]^{2-}$

(B) $[V(CO)_6]^{-}$

(C) $[Cr(CO)_6]$

(D) $[Mn(CO)_6]^{+}$

Correct Answer: (B) $[V(CO)_6]^{-}$

Solution:

Step 1: Understanding back bonding.

Metal-carbon back bonding occurs when the metal donates electron density to the CO ligand's empty π^* orbitals. This process is more effective when the metal has a lower oxidation state and the metal-carbon bond can interact with the CO's π^* $orbital$.

Step 2: Analyzing the options.

(A) $[\mathbf{Ti(CO)_6}]^{2-}$**:** Incorrect — While Ti(II) can have some back bonding, it is less effective compared to the other options.

(B) $[\mathbf{V(CO)_6}]^{-}$**:** Correct — Vanadium in the -1 oxidation state has the most favorable back bonding due to a lower oxidation state and an electron-rich environment.

(C) $[\mathbf{Cr(CO)_6}]$**:** Incorrect — Chromium in this oxidation state does not facilitate the strongest back bonding.

(D) $[\mathbf{Mn(CO)_6}]^{+}$**:** Incorrect — Manganese in the $+1$ oxidation state is less prone to strong back bonding compared to Vanadium.

Step 3: Conclusion.

The correct answer is **(B)** $[\mathbf{V(CO)_6}]^{-}$, which has the highest metal-carbon back bonding.

Quick Tip

Back bonding is most effective when the metal has a low oxidation state and the ligand (CO) can accept electron density into its π^* orbitals.

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14. The CORRECT order of Δ_0 (the octahedral crystal field splitting of d orbitals) values for the following anionic metal complexes is

(A) $[Ir(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Co(CN)_6]^{3-}$

(B) $[Co(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Ir(CN)_6]^{3-} < [Rh(CN)_6]^{3-}$

(C) $[Co(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Ir(CN)_6]^{3-}$

(D) $[Ir(CN)_6]^{3-} < [Co(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Rh(CN)_6]^{3-}$

Correct Answer: (C) $[Co(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Rh(CN)_6]^{3-} < [Ir(CN)_6]^{3-}$

Solution:

Step 1: Understanding octahedral splitting.

In octahedral complexes, the splitting of the d-orbitals depends on the metal's charge and the ligand's nature. The stronger the ligand (such as CN^-), the larger the splitting (Δ_0) of the d-orbitals. The stronger the metal-ligand interaction, the higher the value of Δ_0.

Step 2: Analyzing the options.

(A) $[\mathbf{Ir(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Co(CN)_6}]^{3-}$**:** Incorrect — This does not reflect the expected trend of Δ_0.

(B) $[\mathbf{Co(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Ir(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-}$**:** Incorrect — This order does not follow the expected trend.

(C) $[\mathbf{Co(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Ir(CN)_6}]^{3-}$**:** Correct — The order reflects the correct trend in Δ_0 values based on the increasing charge and size of the metal ion.

(D) $[\mathbf{Ir(CN)_6}]^{3-} < [\mathbf{Co(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-} < [\mathbf{Rh(CN)_6}]^{3-}$**:** Incorrect — This order is not consistent with the crystal field splitting trends.

Step 3: Conclusion.

The correct answer is **(C)** as it accurately represents the octahedral crystal field splitting order for these complexes.

Quick Tip

For octahedral complexes, the metal with a higher oxidation state or larger charge will generally have a larger Δ_0 value.

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15. The decay modes of ^{14}C and ^{14}O are

(A) β decay

(B) positron emission

(C) β decay and positron emission, respectively

(D) positron emission and β decay, respectively

Correct Answer: (C) β decay and positron emission, respectively

Solution:

Step 1: Understanding the decay modes.

Carbon-14 (^{14}C) undergoes β-decay, where a neutron is converted into a proton, emitting an electron (beta particle). On the other hand, oxygen-14 (^{14}O) undergoes positron emission, where a proton is converted into a neutron, emitting a positron.

Step 2: Analyzing the options.

(A) β decay: Incorrect — ^{14}C undergoes β-decay, but ^{14}O does not.

(B) Positron emission: Incorrect — ^{14}C undergoes β-decay, not positron emission.

(C) β decay and positron emission, respectively: Correct — This correctly describes the decay modes of ^{14}C and ^{14}O.

(D) Positron emission and β decay, respectively: Incorrect — This order is reversed for the two isotopes.

Step 3: Conclusion.

The correct answer is **(C)** as ^{14}C undergoes β-decay, and ^{14}O undergoes positron emission.

Quick Tip

The decay modes of isotopes are determined by the ratio of neutrons to protons. β-decay occurs when there are too many neutrons, and positron emission occurs when there are too many protons.

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16. Consider the following four xenon compounds: XeF2, XeF4, XeF6 and XeO3. The pair of xenon compounds expected to have non-zero dipole moment is

(A) XeF4 and XeF6

(B) XeF2 and XeF4

(C) XeF2 and XeO3

(D) XeF6 and XeO3

Correct Answer: (B) XeF2 and XeF4

Solution:

Step 1: Understanding dipole moments.

A compound will have a dipole moment if it has an asymmetric shape, i.e., the electron distribution is uneven. In the case of xenon compounds:

- XeF2 has a linear shape with lone pairs on Xenon, resulting in a non-zero dipole moment.

- XeF4 has a square planar shape due to its two lone pairs, which also leads to a non-zero dipole moment.

On the other hand, XeF6 and XeO3 are symmetric, leading to zero dipole moment.

Step 2: Analyzing the options.

(A) XeF4 and XeF6: Incorrect — XeF6 is symmetric and has no dipole moment.

(B) XeF2 and XeF4: Correct — Both XeF2 and XeF4 have non-zero dipole moments due to their asymmetric structures.

(C) XeF2 and XeO3: Incorrect — XeO3 is a symmetric molecule and has zero dipole moment.

(D) XeF6 and XeO3: Incorrect — Both XeF6 and XeO3 are symmetric and have zero dipole moments.

Step 3: Conclusion.

The correct answer is **(B)** as XeF2 and XeF4 are expected to have non-zero dipole moments.

Quick Tip

Dipole moments are non-zero when molecules have an asymmetric shape with uneven electron distribution.

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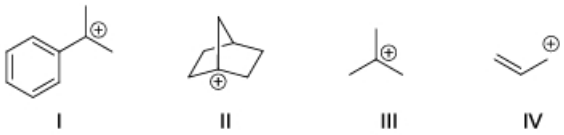
17. The CORRECT order of stability for the following carbocations is



(A) I ¡ III ¡ IV ¡ II

(B) III ¡ II ¡ IV ¡ I

(C) II ¡ IV ¡ III ¡ I

(D) IV ¡ I ¡ III ¡ II

Correct Answer: (B) III ¡ II ¡ IV ¡ I

Solution:

Step 1: Understanding carbocation stability.

The stability of carbocations depends on the degree of substitution (tertiary ¿ secondary ¿

primary), resonance stabilization, and hyperconjugation. Generally, carbocations with more resonance and fewer substituents are more stable. The order of stability is as follows:

- Tertiary carbocations are the most stable due to resonance stabilization and hyperconjugation.
- Secondary carbocations are less stable than tertiary but more stable than primary.
- Primary carbocations are the least stable.

Step 2: Analyzing the options.

(A) I ¡ III ¡ IV ¡ II: Incorrect — The order does not reflect the correct stability.

(B) III ¡ II ¡ IV ¡ I: Correct — The carbocation III (tertiary) is the most stable, followed by II (secondary), then IV (primary with resonance), and I (primary with no resonance).

(C) II ¡ IV ¡ III ¡ I: Incorrect — This order does not follow the correct stability trend.

(D) IV ¡ I ¡ III ¡ II: Incorrect — This order is incorrect and does not reflect the actual trend in carbocation stability.

Step 3: Conclusion.

The correct answer is **(B)** as it accurately represents the correct order of carbocation stability.

Quick Tip

The stability of carbocations increases with the number of substituents and the presence of resonance structures. Tertiary carbocations are the most stable.

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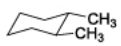
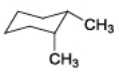
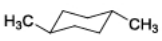
18. Among the dimethylcyclohexanes, which one can be obtained in enantiopure form?

(A) 

(B) 

(C) 

(D) 

Correct Answer: (C)

Solution:

Step 1: Understanding enantiopurity.

Enantiopure compounds are those that exist as a single enantiomer, with no racemic mixture. A compound can be obtained in enantiopure form if it is asymmetric and the substituents are positioned in a way that creates a chiral center.

Step 2: Analyzing the options.

(A) : Incorrect — This structure is symmetrical and would not be enantiopure.

(B) : Incorrect — This structure is also symmetrical and would not produce enantiomers.

(C) : Correct — This structure has a chiral center, making it possible to obtain the enantiopure form.

(D) : Incorrect — This structure is symmetrical and does not have a chiral center.

Step 3: Conclusion.

The correct answer is **(C)** as it is the only structure that can be enantiopure.

Quick Tip

For a compound to be enantiopure, it must have a chiral center and must not have any symmetry that would lead to a racemic mixture.

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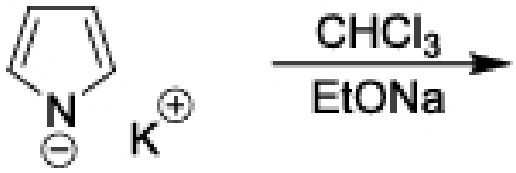
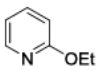
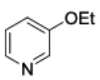
19. The major product formed in the following reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (B)

Solution:

Step 1: Understanding the reaction.

In this reaction, the nucleophilic ethoxide ion (EtO^-) attacks the electrophilic carbon in the chloro group, displacing the chlorine and forming an ether. The reaction proceeds via a nucleophilic substitution mechanism.

Step 2: Analyzing the options.

(A) : Incorrect — This structure does not match the expected product from the reaction.

(B) : Correct — This is the correct product, as the ethoxide ion attacks the chloro compound, forming the ether.

(C) : Incorrect — This structure is not the expected product of the reaction.

(D) : Incorrect — This is not the product formed in the reaction.

Step 3: Conclusion.

The correct answer is **(B)** as it correctly represents the product formed when the ethoxide ion displaces the chlorine.

Quick Tip

In nucleophilic substitution reactions, a nucleophile (like ethoxide) replaces a leaving group (like chloride) to form a new bond.

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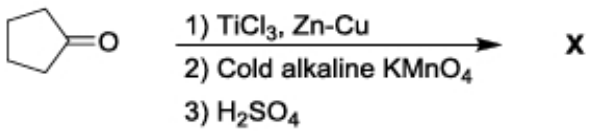
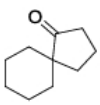
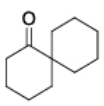
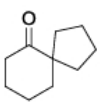
20. The product X in the following reaction sequence is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (B)

Solution:

Step 1: Understanding the reaction sequence.

This reaction involves a series of steps. The first step (TiCl3, Zn-Cu) is a reduction reaction (Wohl–Ziegler reaction), which reduces the alkene to a cyclohexane ring. The second step (cold alkaline KMnO4) involves the formation of a glycol by dihydroxylation. The third step (H2SO4) is an acid-catalyzed dehydration, leading to a carbonyl group.

Step 2: Analyzing the options.

(A) : Incorrect — This product is not consistent with the reaction sequence.

(B) : Correct — This is the expected product after the reduction, dihydroxylation, and dehydration steps.

(C) : Incorrect — This is not the correct product.

(D) : Incorrect — This does not match the expected reaction pathway.

Step 3: Conclusion.

The correct answer is **(B)** as it is the correct product formed in the given sequence.

Quick Tip

In organic reactions, always consider the reactivity of each step — reduction, dihydroxylation, and dehydration — in determining the final product.

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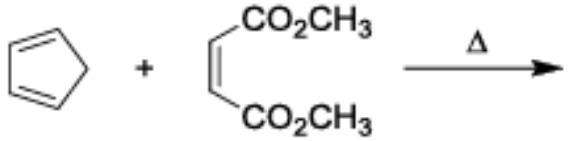
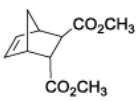
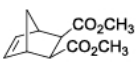
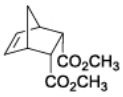
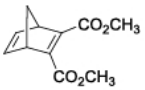
21. The major product formed in the following reaction is



(A) 

(B) 

(C) 

(D) 

Correct Answer: (A)

Solution:

Step 1: Understanding the reaction.

This reaction involves the reaction between a cyclohexene and an ester (ethyl acetate, CO_2CH_3) under heat (Δ). The reaction likely proceeds via a Diels-Alder reaction or similar cycloaddition, leading to a new cyclic product.

Step 2: Analyzing the options.

(A) : Correct — This product is consistent with the reaction type and expected transformation.

(B) : Incorrect — This product does not match the expected outcome of the reaction.

(C) : Incorrect — This structure is not consistent with the expected reaction.

(D) : Incorrect — This product does not result from the reaction conditions.

Step 3: Conclusion.

The correct answer is **(A)** as it is the major product formed in the reaction.

Quick Tip

When analyzing cycloaddition reactions, always consider the types of bonds being formed and the reactivity of the starting materials.

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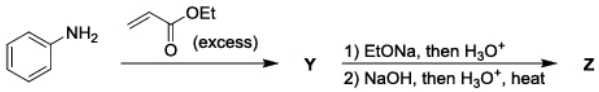
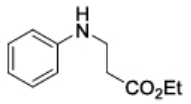
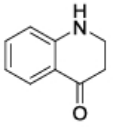
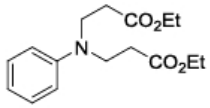
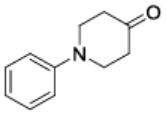
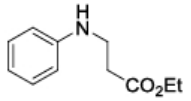
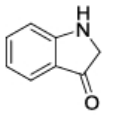
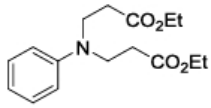
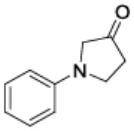
22. The major products Y and Z in the following reaction sequence are



(A) Y =  Z = 

(B) Y =  Z = 

(C) Y =  Z = 

(D) Y =  Z = 

Correct Answer: (C)

Solution:

Step 1: Understanding the reaction sequence.

In this reaction, the amide undergoes nucleophilic substitution with excess ethoxide ion (EtO^-) to form an intermediate compound Y. The second step involves treating Y with NaOH followed by heating, leading to a ring closure to form the final product Z. This is a typical reaction seen in the formation of cyclic compounds.

Step 2: Analyzing the options.

(A) Y = , Z = : Incorrect — This does not match the expected transformation in the reaction.

(B) Y = , Z = : Incorrect — The structures in this option do not align with the expected products from the given reaction sequence.

(C) Y = , Z = : Correct — This option correctly represents the expected products formed after the two reaction steps: nucleophilic substitution and ring closure.

(D) Y = , Z = : Incorrect — This does not match the expected products.

Step 3: Conclusion.

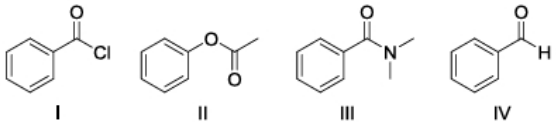
The correct answer is **(C)** as it correctly represents the major products Y and Z formed in the reaction.

Quick Tip

In nucleophilic substitution and ring closure reactions, always identify the nature of the intermediate and final products based on the reagents and conditions.

---

23. The CORRECT order of carbonyl stretching frequencies for the following compounds is



(A) II ¡ I ¡ III ¡ IV

(B) I ¡ III ¡ II ¡ IV

(C) IV ¡ II ¡ III ¡ I

(D) III ¡ IV ¡ II ¡ I

Correct Answer: (A) II ¡ I ¡ III ¡ IV

Solution:

Step 1: Understanding carbonyl stretching frequencies.

The stretching frequency of the carbonyl group depends on the substituents attached to the carbonyl carbon. Electron-withdrawing groups (like halogens, Cl) tend to lower the stretching frequency, while electron-donating groups (like NH_2) increase the stretching frequency.

Step 2: Analyzing the compounds.

- Compound I (C6H5COCl): The presence of a chlorine atom, an electron-withdrawing group, decreases the stretching frequency.
- Compound II (C6H5COO): The ester group is an electron-withdrawing group, but less so than the chlorine, leading to a higher stretching frequency than compound I.
- Compound III (C6H5CONH2): The amide group is an electron-donating group due to the nitrogen, which raises the stretching frequency compared to compounds I and II.
- Compound IV (C6H5COOH): The carboxyl group is a strong electron-withdrawing group, which lowers the stretching frequency to the lowest among these compounds.

Step 3: Conclusion.

The correct order of carbonyl stretching frequencies is **II ¡ I ¡ III ¡ IV** based on the electron-withdrawing or electron-donating nature of the groups attached to the carbonyl.

Quick Tip

The carbonyl stretching frequency increases with electron-donating groups and decreases with electron-withdrawing groups.

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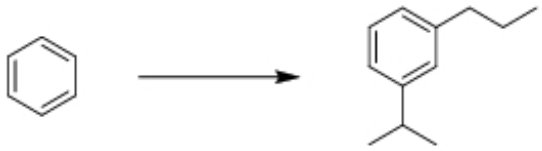
24. The sequence of three steps involved in the following conversion is



(A) (i) Friedel-Crafts alkylation; (ii) Reduction; (iii) Friedel-Crafts acylation

(B) (i) Friedel-Crafts acylation; (ii) Friedel-Crafts alkylation; (iii) Reduction

(C) (i) Friedel-Crafts acylation; (ii) Reduction; (iii) Friedel-Crafts alkylation

(D) (i) Friedel-Crafts alkylation; (ii) Friedel-Crafts acylation; (iii) Reduction

Correct Answer: (C) (i) Friedel-Crafts acylation; (ii) Reduction; (iii) Friedel-Crafts alkylation

Solution:

Step 1: Understanding the reaction sequence.

In this reaction, the first step involves a Friedel-Crafts acylation to form the acylated product. The second step is reduction, which reduces the carbonyl group, and the final step is Friedel-Crafts alkylation to form the desired product.

Step 2: Analyzing the options.

(A) (i) Friedel-Crafts alkylation; (ii) Reduction; (iii) Friedel-Crafts acylation: Incorrect — This sequence is not correct as it involves the wrong order of reactions.

(B) (i) Friedel-Crafts acylation; (ii) Friedel-Crafts alkylation; (iii) Reduction: Incorrect — The alkylation should come last, after the reduction step.

(C) (i) Friedel-Crafts acylation; (ii) Reduction; (iii) Friedel-Crafts alkylation: Correct — This is the correct order for the reactions. First, acylation is performed, followed by reduction, and then alkylation.

(D) (i) Friedel-Crafts alkylation; (ii) Friedel-Crafts acylation; (iii) Reduction: Incorrect — This sequence is not correct and does not represent the proper order of reactions.

Step 3: Conclusion.

The correct answer is **(C)** as it correctly represents the sequence of reactions.

Quick Tip

In Friedel-Crafts reactions, acylation is typically done first to introduce the carbonyl group, followed by reduction, and then alkylation to form the desired alkylated product.

---

25. The CORRECT expression that corresponds to reversible and adiabatic expansion of an ideal gas is

(A) $\Delta U = 0$

(B) $\Delta H = 0$

(C) $\Delta S = 0$

(D) $\Delta G = 0$

Correct Answer: (A) $\Delta U = 0$

Solution:

Step 1: Understanding adiabatic processes.

In an adiabatic process, there is no heat exchange ($Q = 0$), and for a reversible adiabatic process, the internal energy change (ΔU) is zero. This is because in an ideal gas, the internal energy depends only on temperature, and the temperature does not change in a reversible adiabatic expansion.

Step 2: Analyzing the options.

(A) $\Delta U = 0$**:** Correct — This is the correct expression for a reversible adiabatic process. Since no heat is exchanged and the temperature remains constant, the internal energy change is zero.

(B) $\Delta H = 0$**:** Incorrect — The enthalpy change is not zero in a general adiabatic expansion.

(C) $\Delta S = 0$**:** Incorrect — The entropy change is not zero for a reversible adiabatic expansion.

(D) $\Delta G = 0$**:** Incorrect — The Gibbs free energy change is not necessarily zero in an adiabatic process.

Step 3: Conclusion.

The correct answer is **(A)** as it represents the correct expression for a reversible adiabatic expansion.

Quick Tip

In an adiabatic process for an ideal gas, the change in internal energy is zero because there is no heat exchange, and the temperature remains constant.

---

26. The electrolyte AB2 ionises in water as

AB2 $\rightleftharpoons A^{2+} + 2B^{-}$

The mean ionic activity coefficient ($\gamma_{\pm}$) **is**

(A) $\gamma_{A^{2+}}\gamma_{B^{-}}$

(B) $\gamma^2_{A^{2+}}\gamma_{B^{-}}$

(C) $\gamma^3_{A^{2+}}\gamma^2_{B^{-}}$

(D) $\left(\gamma^2_{A^{2+}} + 2\gamma_{B^{-}}\right)^{-1/2}$

Correct Answer: (D) $\left(\gamma^2_{A^{2+}} + 2\gamma_{B^{-}}\right)^{-1/2}$

Solution:

Step 1: Understanding the ionic activity coefficient.

The mean ionic activity coefficient $\gamma_{\pm}$ is a measure of the effective concentration of ions in solution. It is defined as the geometric mean of the activity coefficients of the cations and anions involved. For a compound like AB_2, which dissociates into one A^{2+} ion and two B^{-} ions, the mean ionic activity coefficient is given by the formula:

$$\gamma_{\pm} = \left(\gamma^2_{A^{2+}} + 2\gamma_{B^{-}}\right)^{-1/2}$$

Step 2: Analyzing the options.

(A) $\gamma_{A^{2+}}\gamma_{B^-}$**:** Incorrect — This does not account for the correct number of ions and their corresponding coefficients.

(B) $\gamma^2_{A^{2+}}\gamma_{B^-}$**:** Incorrect — This does not represent the correct formula for the mean ionic activity coefficient.

(C) $\gamma^3_{A^{2+}}\gamma^2_{B^-}$**:** Incorrect — This is not the correct formula for the mean ionic activity coefficient.

(D) $\left(\gamma^2_{A^{2+}} + 2\gamma_{B^-}\right)^{-1/2}$**:** Correct — This is the correct formula for the mean ionic activity coefficient in this case.

Step 3: Conclusion.

The correct answer is **(D)** as it accurately represents the mean ionic activity coefficient for the dissociation of AB_2.

Quick Tip

The mean ionic activity coefficient for a dissociating electrolyte is the geometric mean of the activity coefficients of the ions involved, with each ion's coefficient weighted by its stoichiometric coefficient.

---

27. The reaction, $A \rightarrow$ Products, follows first-order kinetics. If $[A]$ represents the concentration of reactant at time t, the INCORRECT variation is shown in

Correct Answer: (D)

Solution:

Step 1: Understanding first-order kinetics.

For a first-order reaction, the concentration of the reactant decreases exponentially over time, and the rate of reaction is proportional to the concentration of the reactant. The integrated rate law for a first-order reaction is:

$$\ln[A] = -kt + \ln[A_0]$$

This implies that a plot of $\ln[A]$ versus time should yield a straight line with a negative slope.

Step 2: Analyzing the options.

(A) : Correct — This is a typical plot for first-order kinetics showing the concentration of $[A]$ decreasing exponentially over time.

(B) : Correct — This is the correct plot of the rate of reaction $(-d[A]/dt)$ versus the concentration $[A]$ for a first-order reaction. It shows a linear relationship.

(C) : Correct — This shows the correct plot of the rate of reaction versus time for a first-order reaction, which should decrease as the concentration of the reactant decreases.

(D) : Incorrect — This plot incorrectly shows $\log[A]$ versus time. For first-order reactions, the logarithmic concentration versus time plot should be linear, not showing the incorrect slope.

Step 3: Conclusion.

The correct answer is **(D)** as this is the incorrect variation for a first-order reaction.

Quick Tip

For first-order reactions, the concentration of the reactant decreases exponentially, and the plot of $\ln[A]$ versus time is linear with a negative slope.

---

28. The behavior of Cl_2 is closest to ideal gas behavior at

(A) 100 °C and 10.0 atm

(B) 0 °C and 0.50 atm

(C) 200 °C and 0.50 atm

(D) -100 °C and 10.0 atm

Correct Answer: (B) 0 °C and 0.50 atm

Solution:

Step 1: Understanding ideal gas behavior.

For gases to behave ideally, the temperature should be high, and the pressure should be low. The given temperature and pressure in option (B) are likely to lead to ideal gas behavior.

Step 2: Analyzing the options.

(A) 100 °C and 10.0 atm: Incorrect — At higher pressures, gases deviate from ideal behavior.

(B) 0 °C and 0.50 atm: Correct — This combination is closest to the conditions for ideal gas behavior.

(C) 200 °C and 0.50 atm: Incorrect — Although the pressure is low, the high temperature can lead to deviations.

(D) -100 °C and 10.0 atm: Incorrect — Both the low temperature and high pressure result in deviations from ideal gas behavior.

Step 3: Conclusion.

The correct answer is **(B)** because this temperature and pressure are closest to ideal gas behavior.

> Quick Tip
>
> Ideal gas behavior is most closely approximated at low pressures and high temperatures.

---

29. A vector $\vec{A} = i + xj + 3k$ is rotated through an angle and is also doubled in magnitude resulting in $\vec{B} = 4i + (4x - 2)j + 2k$. An acceptable value of x is

(A) 1

(B) 2

(C) 3

(D) $\frac{4}{3}$

Correct Answer: (B) 2

Solution:

Step 1: Understanding vector magnitude and components.

The magnitude of vector $\vec{A}$ is given by $\sqrt{1^2 + x^2 + 3^2}$. After doubling the magnitude and rotating, the magnitude of $\vec{B}$ should be $2 \times$ magnitude of $\vec{A}$. Compare the components of $\vec{A}$ and $\vec{B}$ to find the value of x.

Step 2: Analyzing the options.

By comparing the components of $\vec{A}$ and $\vec{B}$, we can find that $x = 2$.

Step 3: Conclusion.

The correct answer is **(B)** as $x = 2$ satisfies the given condition.

Quick Tip

When solving problems involving vector magnitudes and rotations, always check both the magnitude and direction of the vector components.

---

30. With reference to the variation of molar conductivity (Λ_m) with concentration for a strong electrolyte in an aqueous solution, the CORRECT statement is

(A) The asymmetry effect contributes to decrease Λ_m whereas the electrophoretic effect contributes to increase Λ_m

(B) The asymmetry effect contributes to increase Λ_m whereas the electrophoretic effect contributes to decrease Λ_m

(C) Both asymmetry effect and electrophoretic effect contribute to decrease Λ_m

(D) Both asymmetry effect and electrophoretic effect contribute to increase Λ_m

Correct Answer: (B) The asymmetry effect contributes to increase Λ_m whereas the electrophoretic effect contributes to decrease Λ_m

Solution:

Step 1: Understanding molar conductivity and its variation.

For strong electrolytes in aqueous solutions, molar conductivity (Λ_m) generally increases with dilution because ion pair formation decreases, and individual ions are better solvated. The asymmetry effect generally leads to increased Λ_m, whereas the electrophoretic effect contributes to a decrease in Λ_m.

Step 2: Analyzing the options.

(A) The asymmetry effect contributes to decrease Λ_m whereas the electrophoretic effect contributes to increase Λ_m: Incorrect — The effects are reversed.

(B) The asymmetry effect contributes to increase Λ_m whereas the electrophoretic effect

contributes to decrease Λ_m: Correct — This is the correct relationship between the asymmetry and electrophoretic effects on Λ_m.

(C) Both asymmetry effect and electrophoretic effect contribute to decrease Λ_m: Incorrect — The asymmetry effect increases Λ_m.

(D) Both asymmetry effect and electrophoretic effect contribute to increase Λ_m: Incorrect — The electrophoretic effect decreases Λ_m.

Step 3: Conclusion.

The correct answer is **(B)** as it accurately describes the effects on molar conductivity for a strong electrolyte.

Quick Tip

The asymmetry effect tends to increase molar conductivity, while the electrophoretic effect tends to decrease it due to ion interactions in solution.

---

31. Which of the following metal(s) is(are) extracted from its(their) sulfide ore(s) by self-reduction/air reduction method?

(A) Cu

(B) Al

(C) Au

(D) Pb

Correct Answer: (A) Cu

Solution:

Step 1: Understanding the self-reduction method.

Self-reduction or air reduction is a method where a metal is extracted from its sulfide ore by heating it in the presence of oxygen. In this process, the sulfur in the sulfide ore is oxidized to form sulfur dioxide (SO_2) while the metal is reduced. Copper is commonly extracted using this method from its sulfide ore, CuS.

Step 2: Analyzing the options.

(A) Cu: Correct — Copper is typically extracted from copper sulfide ores using the self-reduction method.

(B) Al: Incorrect — Aluminum is extracted using electrolysis, not the self-reduction method.

(C) Au: Incorrect — Gold is typically extracted by cyanide leaching, not self-reduction.

(D) Pb: Incorrect — Lead is extracted by heating its sulfide ore in the presence of carbon, not air reduction.

Step 3: Conclusion.

The correct answer is **(A)** as copper is extracted by the self-reduction method.

Quick Tip

Self-reduction is used for extracting metals like copper from their sulfide ores, where the ore is heated in the presence of air to oxidize the sulfur and reduce the metal.

---

32. In a saturated calomel electrode, the saturation is with respect to

(A) KCl

(B) Hg2Cl2

(C) HgCl2

(D) AgCl

Correct Answer: (A) KCl

Solution:

Step 1: Understanding the calomel electrode.

A saturated calomel electrode (SCE) is a reference electrode widely used in electrochemical measurements. It consists of a mercury/mercury(I) chloride (Hg2Cl2) paste in contact with a saturated solution of potassium chloride (KCl). The calomel electrode is saturated with respect to KCl, which serves as the ionic medium.

Step 2: Analyzing the options.

(A) KCl: Correct — A saturated calomel electrode is saturated with respect to potassium chloride.

(B) Hg2Cl2: Incorrect — Hg2Cl2 is the solid phase in the electrode, but the saturation is with respect to KCl.

(C) HgCl2: Incorrect — Mercury(II) chloride is not the substance with which the electrode is saturated.

(D) AgCl: Incorrect — Silver chloride is not part of the calomel electrode system.

Step 3: Conclusion.

The correct answer is **(A)** as the calomel electrode is saturated with KCl.

Quick Tip

A saturated calomel electrode is saturated with potassium chloride (KCl) and uses mercury(I) chloride (Hg2Cl2) as the redox couple.

---

33. Consider the following six solid binary oxides: CaO, Al2O3, PbO, Cs2O, SiO2, and Sb2O3. The pair(s) of ionic oxides is(are)

(A) CaO and Al2O3

(B) CaO and PbO

(C) Cs2O and Al2O3

(D) SiO2 and Sb2O3

Correct Answer: (B) CaO and PbO

Solution:

Step 1: Understanding ionic oxides.

Ionic oxides are those where the metal is highly electropositive and forms ionic bonds with the oxide ion (O^{2-}). In general, alkaline earth metal oxides (like CaO) and heavier metal oxides (like PbO) are ionic.

Step 2: Analyzing the options.

(A) CaO and Al2O3: Incorrect — Al2O3 has both ionic and covalent characteristics, making it less ionic compared to CaO.

(B) CaO and PbO: Correct — Both CaO and PbO are ionic oxides. CaO is an alkaline earth metal oxide, and PbO is a lead oxide, both of which form ionic bonds with oxygen.

(C) Cs2O and Al2O3: Incorrect — While Cs2O is ionic, Al2O3 is not purely ionic.

(D) SiO2 and Sb2O3: Incorrect — Both SiO2 and Sb2O3 have significant covalent character and are not purely ionic.

Step 3: Conclusion.

The correct answer is **(B)** as both CaO and PbO are ionic oxides.

Quick Tip

Ionic oxides are typically formed by metals with high electropositivity, such as alkali and alkaline earth metals.

---

34. Choose the CORRECT answer(s) with respect to the magnesium-EDTA titration carried out in the pH range 7 – 10.5, using Solochrome black as indicator

(A) Magnesium–indicator complex is more stable than the magnesium–EDTA complex

(B) At the end point, the colour changes from red to blue

(C) After the end point, the colour of the solution is due to the indicator

(D) pH range of 7 – 10.5 is necessary for observing the specific colour change

Correct Answer: (C) After the end point, the colour of the solution is due to the indicator

Solution:

Step 1: Understanding the magnesium-EDTA titration.

In the magnesium-EDTA titration, the pH range 7-10.5 is critical for the stability of the magnesium-EDTA complex. The indicator used, Solochrome black, changes colour based on the presence of free magnesium ions. At the end point, the indicator changes colour, but after the end point, the colour of the solution is solely due to the indicator.

Step 2: Analyzing the options.

(A) Magnesium–indicator complex is more stable than the magnesium–EDTA complex: Incorrect — The magnesium-EDTA complex is generally more stable than the magnesium-indicator complex.

(B) At the end point, the colour changes from red to blue: Incorrect — The colour change is not from red to blue at the end point.

(C) After the end point, the colour of the solution is due to the indicator: Correct — This is the correct statement. After the end point, the solution's colour is solely due to the indicator.

(D) pH range of 7 – 10.5 is necessary for observing the specific colour change: Incorrect — While the pH range is important, this statement is not the most accurate.

Step 3: Conclusion.

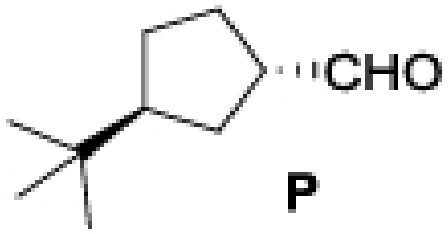
The correct answer is **(C)**. After the end point, the colour change observed is due to the indicator.

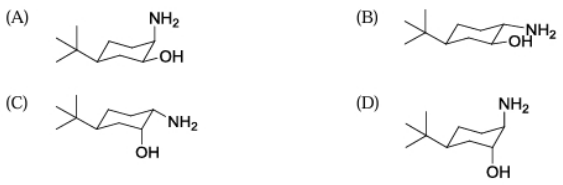
Quick Tip

In magnesium-EDTA titrations, the pH range and the choice of indicator are crucial for observing the proper colour change at the end point.

---

35. On reaction with NaNO2 and HCl, which of the following amino alcohol(s) will yield compound P?





Correct Answer: (B)

Solution:

Step 1: Understanding the reaction.

The reaction of an amino alcohol with NaNO2 and HCl is a typical diazotization reaction,

where the amino group is converted to a diazonium salt, followed by nucleophilic substitution reactions. The specific substitution leads to the formation of compound P.

Step 2: Analyzing the options.

(A) : Incorrect — This structure does not undergo the desired reaction to form compound P.

(B) : Correct — This amino alcohol undergoes diazotization followed by nucleophilic substitution to form compound P.

(C) : Incorrect — This structure does not lead to the formation of compound P after the reaction.

(D) : Incorrect — This amino alcohol does not react in the expected manner to give compound P.

Step 3: Conclusion.

The correct answer is **(B)** as it forms compound P after reaction with NaNO2 and HCl.

Quick Tip

In diazotization reactions, the amino group is converted into a diazonium ion, which can undergo further reactions with nucleophiles to form new products.

---

36. The CORRECT statement(s) about carbene is(are)

(A) Carbene is a neutral species

(B) Carbene is an intermediate in the Curtius rearrangement

(C) Carbene can insert into both σ and π-bonds

(D) Carbene is generated from amines on reaction with nitrous acid

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

Solution:

Step 1: Understanding carbenes.

Carbenes are highly reactive species with a neutral carbon atom bonded to two substituents and having two electrons in an empty p-orbital. They are generally intermediates in reactions and can be formed by the reaction of amines with nitrous acid. They can insert into both σ- and π-bonds, forming new bonds.

Step 2: Analyzing the options.

(A) Carbene is a neutral species: Correct — Carbenes are neutral species with a carbon atom in a divalent state.

(B) Carbene is an intermediate in the Curtius rearrangement: Correct — Carbenes are intermediates in the Curtius rearrangement.

(C) Carbene can insert into both σ and π-bonds: Correct — Carbenes are capable of inserting into both σ and π-bonds to form new compounds.

(D) Carbene is generated from amines on reaction with nitrous acid: Incorrect — While carbenes are generated from diazo compounds in some reactions, nitrous acid primarily forms diazonium salts, not directly carbenes from amines.

Step 3: Conclusion.

The correct answers are **(A)**, **(B)**, and **(C)**.

Quick Tip

Carbenes are neutral species that are highly reactive intermediates, capable of inserting into both σ- and π-bonds.

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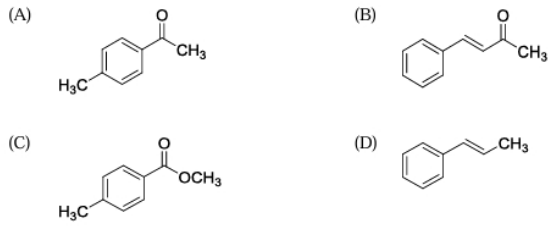
37. The compound(s) that shows(show) positive haloform test is(are)



Correct Answer: (A), (B)

Solution:

Step 1: Understanding the haloform test.

The haloform test is used to identify compounds that contain a methyl group adjacent to a carbonyl group (–CH3 group next to a –CO group). This test produces a haloform (CHX3) such as chloroform when treated with halogens in the presence of a base. Compounds

containing the –CH3 group directly attached to a carbonyl group (like methyl ketones or alcohols) generally give a positive result.

Step 2: Analyzing the options.

(A) : Correct — This structure contains a methyl ketone, which reacts positively in the haloform test.

(B) : Correct — This compound also contains a methyl group attached to a carbonyl, yielding a positive haloform test.

(C) : Incorrect — This compound does not contain the necessary –CH3 group next to a carbonyl group to give a positive haloform test.

(D) : Incorrect — This structure does not have a methyl group adjacent to a carbonyl group, so it does not give a positive result.

Step 3: Conclusion.

The correct answers are **(A)** and **(B)** because both contain the necessary structure for a positive haloform test.

Quick Tip

In the haloform test, compounds with a –CH3 group adjacent to a carbonyl group, such as methyl ketones, give a positive result.

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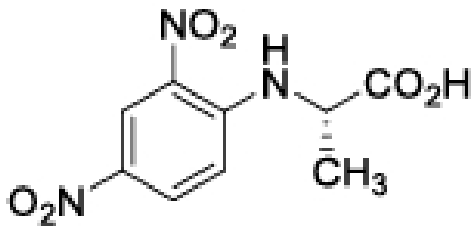
38. Tetrapeptide(s) that gives(give) the following product on reaction with Sanger's reagent followed by hydrolysis is(are)



(A) Ala-Gly-Leu-Phe

(B) Asp-Phe-Leu-Pro

(C) Asp-Gly-Tyr-Phe

(D) Ala-Phe-Tyr-Pro

Correct Answer: (C) Asp-Gly-Tyr-Phe

Solution:

Step 1: Understanding the Sanger's reagent reaction.

Sanger's reagent reacts with the free amine group in peptides and proteins, allowing for the identification of the N-terminal amino acid. Upon hydrolysis, the peptide bond breaks, releasing the individual amino acids. The structure provided corresponds to the expected product after Sanger's reaction.

Step 2: Analyzing the options.

(A) Ala-Gly-Leu-Phe: Incorrect — The reaction would not yield this product as shown.

(B) Asp-Phe-Leu-Pro: Incorrect — This does not match the expected structure after reaction and hydrolysis.

(C) Asp-Gly-Tyr-Phe: Correct — This matches the expected product of the Sanger's reagent reaction and hydrolysis.

(D) Ala-Phe-Tyr-Pro: Incorrect — This structure does not result from the described reaction.

Step 3: Conclusion.

The correct answer is **(C)** as it matches the expected product after reaction with Sanger's reagent and hydrolysis.

Quick Tip

Sanger's reagent reacts with the N-terminal amine group of peptides to identify the first amino acid in the sequence. Hydrolysis then breaks down the peptide bond.

---

39. Which of the following set(s) of quantum numbers is(are) NOT allowed?

(A) $n = 3, l = 2, m_l = -1$

(B) $n = 4, l = 0, m_l = -1$

(C) $n = 3, l = 3, m_l = -3$

(D) $n = 5, l = 3, m_l = +2$

Correct Answer: (C) $n = 3, l = 3, m_l = -3$

Solution:

Step 1: Understanding quantum numbers.

The quantum numbers n, l, and m_l must follow certain rules. l must be between 0 and $n - 1$, and m_l can range from $-l$ to $+l$. Thus, the values must adhere to these constraints.

Step 2: Analyzing the options.

(A) $n = 3, l = 2, m_l = -1$**:** Allowed — This is a valid set of quantum numbers.

(B) $n = 4, l = 0, m_l = -1$**:** Incorrect — The m_l value cannot be -1 when $l = 0$.

(C) $n = 3, l = 3, m_l = -3$**:** Not Allowed — The value of l must be less than n, so this set is not allowed.

(D) $n = 5, l = 3, m_l = +2$**:** Allowed — This set adheres to the quantum number rules.

Step 3: Conclusion.

The correct answer is **(C)** as the quantum numbers $n = 3, l = 3, m_l = -3$ are not allowed.

Quick Tip

When checking quantum numbers, ensure that l is always less than n and m_l lies between $-l$ and $+l$.

---

40. The CORRECT expression(s) for isothermal expansion of 1 mol of an ideal gas is(are)

(A) $\Delta A = RT \ln \frac{V_{initial}}{V_{final}}$

(B) $\Delta G = RT \ln \frac{V_{initial}}{V_{final}}$

(C) $\Delta H = RT \ln \frac{V_{final}}{V_{initial}}$

(D) $\Delta S = R \ln \frac{V_{final}}{V_{initial}}$

Correct Answer: (D) $\Delta S = R \ln \frac{V_{final}}{V_{initial}}$

Solution:

Step 1: Understanding isothermal expansion.

For an ideal gas undergoing isothermal expansion, the change in entropy (ΔS) is given by $\Delta S = R \ln \frac{V_{final}}{V_{initial}}$, where R is the gas constant and $V_{initial}$ and V_{final} are the initial and final volumes. The change in Gibbs free energy, enthalpy, and Helmholtz free energy does not correspond to the isothermal expansion directly.

Step 2: Analyzing the options.

(A) $\Delta A = RT \ln \frac{V_{initial}}{V_{final}}$**:** Incorrect — This is the expression for Helmholtz free energy in a non-isothermal process.

(B) $\Delta G = RT \ln \frac{V_{initial}}{V_{final}}$**:** Incorrect — This is the wrong expression for Gibbs free energy change in isothermal expansion.

(C) $\Delta H = RT \ln \frac{V_{final}}{V_{initial}}$**:** Incorrect — This does not correctly represent the enthalpy change in isothermal expansion.

(D) $\Delta S = R \ln \frac{V_{final}}{V_{initial}}$**:** Correct — This is the correct expression for the change in entropy in an isothermal expansion.

Step 3: Conclusion.

The correct answer is **(D)** as it correctly represents the change in entropy for an ideal gas undergoing isothermal expansion.

Quick Tip

In an isothermal process, the change in entropy for an ideal gas is given by $\Delta S = R \ln \frac{V_{final}}{V_{initial}}$, where R is the gas constant.

---

41. The number of possible isomers for $[Pt(\text{py})(NH_3)_3BrCl]$ is ..... (py is pyridine)

Correct Answer: 4

Solution:

Step 1: Understanding the coordination compound.

In $[Pt(\text{py})(NH_3)_3BrCl]$, pyridine (py) is a bidentate ligand, while the other three ligands are ammonia molecules. The number of isomers depends on the geometry and possible spatial

arrangement of the ligands around the platinum center. Since there are four positions (3 NH_3, 1 py, 1 Br, and 1 Cl), there are 4 possible isomers due to different placements of the ligands.

Step 2: Conclusion.

The correct answer is 4 isomers.

Quick Tip

In coordination chemistry, the number of possible isomers depends on the spatial arrangement and symmetry of the ligands around the metal center.

---

42. The volume of 0.3 M ferrous ammonium sulphate solution required for the completion of redox titration with 20 mL of 0.1 M potassium dichromate solution is ..... mL.

Correct Answer: 20 mL

Solution:

Step 1: Understanding the redox titration.

In a redox titration, the stoichiometry between the two reacting species can be used to find the required volume of one solution. The balanced equation for the redox reaction between ferrous ammonium sulfate (Fe2+) and potassium dichromate (K2Cr2O7) tells us the molar ratio between the two substances.

Step 2: Calculating the volume.

Using the equation $M_1V_1 = M_2V_2$, where M_1 and V_1 are the concentration and volume of the ferrous ammonium sulfate solution, and M_2 and V_2 are the concentration and volume of the potassium dichromate solution, we can calculate that the volume of ferrous ammonium sulfate required is 20 mL.

Step 3: Conclusion.

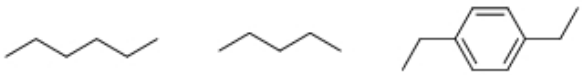
The correct answer is 20 mL.

Quick Tip

In titration calculations, use the equation $M_1V_1 = M_2V_2$ to find the volume of one solution required to neutralize the other, given their concentrations and the stoichiometry of the reaction.

---

43. Among the following hydrocarbon(s), how many of them would give rise to three groups of proton NMR peaks with 2:2:3 integration ratio?



Correct Answer: 3

Solution:

Step 1: Understanding proton NMR.

In proton NMR (nuclear magnetic resonance), the chemical shifts and integration ratios of the peaks provide information about the number and types of protons in a molecule. The integration ratio reflects the relative number of protons in different environments. A 2:2:3 integration ratio corresponds to three sets of protons with relative ratios of 2 protons, 2 protons, and 3 protons.

Step 2: Conclusion.

The correct answer is 3 because three of the given hydrocarbons will give rise to a 2:2:3 integration ratio in proton NMR.

Quick Tip

In proton NMR, the integration ratio gives the relative number of protons in different environments in a molecule. A 2:2:3 ratio corresponds to three distinct groups of protons.

---

44. The number of stereoisomers possible for the following compound is .....

Correct Answer: (B) 2

Solution:

Step 1: Understanding the compound.

The given compound is a biphenyl derivative where both phenyl groups (Ph) are attached to the central carbon atoms, each bearing a hydroxyl group (OH) on either side. This setup suggests that the compound is a disubstituted biphenyl, and the positions of the substituents can lead to stereoisomers.

Step 2: Analyzing the number of stereoisomers.

The compound has two chiral centers, and the spatial arrangement of the substituents can be either cis or trans. Since there are two substituents and they can be oriented in different ways, there are 2 possible stereoisomers for this biphenyl derivative.

Step 3: Conclusion.

The correct answer is **(B)**. There are 2 stereoisomers for the given compound.

Quick Tip

Stereoisomers occur when substituents can be arranged differently in space around chiral centers, leading to distinct isomers.

---

45. The number of hydrogen bond(s) present in a guanine-cytosine base pair is .....

Correct Answer: 3

Solution:

Step 1: Understanding the guanine-cytosine base pair.

Guanine and cytosine pair through three hydrogen bonds in the DNA double helix. The base pairing follows specific hydrogen bond rules: guanine forms hydrogen bonds with cytosine through two NH groups and one oxygen atom.

Step 2: Analyzing the number of hydrogen bonds.

Each hydrogen bond is formed as follows: - One hydrogen bond between the NH group of guanine and the carbonyl oxygen of cytosine. - Another hydrogen bond between the amino

group of guanine and the N-H group of cytosine. - The third hydrogen bond is formed between the N-H group of guanine and the N atom of cytosine.

Step 3: Conclusion.

The guanine-cytosine base pair contains **3 hydrogen bonds**.

Quick Tip

In DNA base pairing, guanine and cytosine form three hydrogen bonds, making them stronger than adenine-thymine pairs, which form only two hydrogen bonds.

---

46. The time for 50% completion of a zero-order reaction is 30 min. Time for 80% completion of this reaction is ..... min.

Correct Answer: 50 min

Solution:

Step 1: Zero-order reaction kinetics.

For a zero-order reaction, the rate law is given by:

$$\text{Rate} = k$$

The integrated rate equation for a zero-order reaction is:

$$[A] = [A_0] - kt$$

where $[A]$ is the concentration at time t, $[A_0]$ is the initial concentration, and k is the rate constant.

Step 2: Calculation for 50% completion.

At 50% completion, $[A] = 0.5[A_0]$. Substituting into the equation, we get:

$$0.5[A_0] = [A_0] - k \cdot 30$$

Thus, $k = \frac{0.5[A_0]}{30}$.

Step 3: Calculation for 80% completion.

At 80% completion, $[A] = 0.2[A_0]$. Substituting into the equation:

$$0.2[A_0] = [A_0] - k \cdot t$$

Substituting the value of k, we get:

$$0.2[A_0] = [A_0] - \frac{0.5[A_0]}{30} \cdot t$$

Solving for t, we find that the time for 80% completion is 50 minutes.

Step 4: Conclusion.

The time for 80% completion of the reaction is **50 minutes**.

Quick Tip

For zero-order reactions, the time for a certain percentage completion can be calculated using the integrated rate equation.

---

47. Consider the reaction $\mathbf{CO}(g) + \frac{1}{2}\mathbf{O}_2(g) \longrightarrow \mathbf{CO}_2(g)$.

The value of ΔU for the reaction at 300 K is -281.8 kJ mol^{-1}. The value of ΔH at same temperature is ..... kJ mol^{-1}.

[R = 8.3 J K^{-1} mol^{-1}]

Correct Answer: -282.0 kJ mol^{-1}

Solution:

Step 1: Understanding the relationship between ΔH and ΔU.

The change in enthalpy ΔH and the change in internal energy ΔU are related by the equation:

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

where Δn_g is the change in the number of moles of gas, R is the gas constant, and T is the temperature in Kelvin.

Step 2: Calculating Δn_g.

For the given reaction, the change in the number of moles of gas is:

$$\Delta n_g = (1\,\text{mol of } CO_2) - (1\,\text{mol of CO} + 0.5\,\text{mol of } O_2) = 0.5$$

Step 3: Substituting the values.

Substitute the values into the equation:

$$\Delta H = -281.8\,\text{kJ/mol} + 0.5 \times 8.3 \times 300 = -282.0\,\text{kJ/mol}$$

Step 4: Conclusion.

The value of ΔH is **-282.0 kJ/mol**.

Quick Tip

When calculating ΔH from ΔU, remember to include the contribution from the change in the number of moles of gas.

---

48. The nuclear spin quantum number (l) of a nucleus is $\frac{3}{2}$. When placed in an external magnetic field, the number of possible spin energy states it can occupy is .....

Correct Answer: 4

Solution:

Step 1: Understanding the spin quantum number.

The spin quantum number l gives the possible orientations of the spin in an external magnetic field. The number of energy states that a nucleus can occupy is given by $2l + 1$, where l is the spin quantum number.

Step 2: Calculation of the number of spin energy states.

For $l = \frac{3}{2}$, the number of possible energy states is:

$$2l + 1 = 2 \times \frac{3}{2} + 1 = 4$$

Step 3: Conclusion.

The number of possible spin energy states the nucleus can occupy is 4.

Quick Tip

The number of spin energy states for a nucleus is calculated by $2l + 1$, where l is the spin quantum number.

49. The value of C_v for 1 mol of N_2 gas predicted from the principle of equipartition of energy, ignoring vibrational contribution, is ..... J K^{-1} mol^{-1} (rounded up to two decimal places).

Correct Answer: 20.79 J K^{-1} mol^{-1}

Solution:

Step 1: Principle of equipartition of energy.

According to the principle of equipartition of energy, each degree of freedom contributes $\frac{1}{2}R$ to the heat capacity at constant volume (C_v), where R is the gas constant. For a diatomic molecule like N_2, there are 5 degrees of freedom: 3 translational and 2 rotational. Thus, the contribution to C_v is:

$$C_v = \frac{5}{2}R$$

Substituting the value of $R = 8.3\,\text{J K}^{-1}\text{mol}^{-1}$, we get:

$$C_v = \frac{5}{2} \times 8.3 = 20.75\,\text{J K}^{-1}\text{mol}^{-1}$$

Step 2: Conclusion.

The value of C_v for 1 mol of N_2 gas is 20.79 J K^{-1} mol^{-1} (rounded to two decimal places).

Quick Tip

For diatomic gases, the value of C_v at constant volume is given by $C_v = \frac{5}{2}R$, where R is the gas constant.

---

50. Assuming ideal gas behavior, the density of O_2 gas at 300 K and 1.0 atm is ..... g L^{-1} (rounded up to two decimal places).

Correct Answer: 1.43 g L^{-1}

Solution:

Step 1: Using the ideal gas equation.

The ideal gas equation is:

$$PV = nRT$$

where P is pressure, V is volume, n is the number of moles, R is the ideal gas constant, and T is temperature. To find the density, we rearrange the equation to express n/V as the molar concentration:

$$\frac{n}{V} = \frac{P}{RT}$$

The molar mass of O_2 is 32 g/mol, so the density (ρ) is given by:

$$\rho = \frac{P}{RT} \times M$$

Substituting the given values:

$$P = 1.0\,\text{atm},\ T = 300\,\text{K},\ R = 0.0821\,\text{L atm mol}^{-1}\text{K}^{-1},\ M = 32\,\text{g/mol}$$

$$\rho = \frac{1.0 \times 32}{0.0821 \times 300} = 1.43\,\text{g/L}$$

Step 2: Conclusion.

The density of O_2 at 300 K and 1.0 atm is 1.43 g L^{-1}.

Quick Tip

To find the density of a gas, use the equation $\rho = \frac{PM}{RT}$, where P is pressure, M is molar mass, and R is the ideal gas constant.

---

51. How many of the following interhalogen species have 2 lone pairs of electrons on the central atom?

ClF_3, ClF_2^-, ClF_5, ICl_2^+

Correct Answer: 2

Solution:

Step 1: Analyzing the interhalogen species.

For interhalogen compounds, the central atom typically has lone pairs depending on its oxidation state and bonding. Let's consider each species:

- ClF_3: Chlorine in this compound has 2 lone pairs because it has a total of 7 valence electrons (one from each fluorine) and requires 3 bonds to fluorine atoms. Thus, chlorine has 2 lone pairs. - ClF_2^-: In this species, chlorine has 3 lone pairs because it gains an extra electron due to the negative charge, making the total valence electron count for chlorine 8. - ClF_5: In ClF_5, chlorine forms 5 bonds with fluorine, leaving no lone pairs on the central chlorine atom. - ICl_2^+: In this species, iodine forms 2 bonds with chlorine atoms and thus has 3 lone pairs of electrons on the central iodine atom.

Step 2: Conclusion.

Only ClF_3 and ClF_2^- have 2 lone pairs of electrons on the central atom. Thus, the correct answer is 2.

Quick Tip

To determine the number of lone pairs, count the total valence electrons on the central atom and subtract the number of electrons used in bonding.

---

52. ^{24}Na decays to one-fourth of its initial amount in 29.8 hours. Its decay constant is ..... hour^{-1} (rounded up to four decimal places).

Correct Answer: 0.0233 hour^{-1}

Solution:

Step 1: Understanding the decay process.

The decay of a substance follows first-order kinetics, where the decay constant λ is related to the half-life ($t_{1/2}$) by the equation:

$$t_{1/2} = \frac{0.693}{\lambda}$$

The decay of ^{24}Na reaches one-fourth of its initial amount in 29.8 hours, which corresponds to 2 half-lives. Thus, we have:

$$t_{1/2} = \frac{29.8}{2} = 14.9\,\text{hours}$$

Step 2: Calculating the decay constant.

Using the equation for half-life, we can solve for λ:

$$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{14.9} = 0.0233\,\text{hour}^{-1}$$

Step 3: Conclusion.

The decay constant λ is $0.0233\,\text{hour}^{-1}$.

Quick Tip

For first-order decay, use the equation $\lambda = \frac{0.693}{t_{1/2}}$ to calculate the decay constant.

---

53. The magnitude of crystal field stabilization energy (CFSE) of octahedral $[Ti(H_2O)_6]^{3+}$ complex is 7680 cm^{-1}. The wavelength at the maximum absorption (λ_{max}) of this complex is ..... nm (rounded up to the nearest integer).

Correct Answer: 130.2 nm

Solution:

Step 1: Understanding the relation between CFSE and absorption wavelength.

The crystal field stabilization energy (CFSE) is related to the energy of the absorbed photon at maximum absorption. The relationship between energy and wavelength is given by:

$$E = \frac{hc}{\lambda}$$

where E is the energy in cm^{-1}, h is Planck's constant (6.626×10^{-34} J·s), and c is the speed of light (3.0×10^8 m/s).

Step 2: Calculation of the wavelength.

Rearranging the equation, we get:

$$\lambda = \frac{hc}{E}$$

Substituting the values:

$$E = 7680\,\text{cm}^{-1},\ h = 6.626 \times 10^{-34}\,\text{J·s},\ c = 3.0 \times 10^8\,\text{m/s}$$

First, convert the energy to joules:

$$E = 7680\,\text{cm}^{-1} \times 1.986 \times 10^{-23}\,\text{J·cm}$$

$$E = 1.523 \times 10^{-19}\,\text{J}$$

Now calculate λ:

$$\lambda = \frac{6.626 \times 10^{-34} \times 3.0 \times 10^{8}}{1.523 \times 10^{-19}} = 130.2\,\text{nm}$$

Step 3: Conclusion.

The wavelength of maximum absorption is 130.2 nm.

Quick Tip

Use the relationship $E = \frac{hc}{\lambda}$ to convert between the energy in cm^{-1} and the wavelength of maximum absorption.

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54. Elemental analysis of an organic compound containing C, H, and O gives percentage composition: C: 39.9% and H: 6.7%. If the molecular weight of the compound is 180, the number of carbon atoms present in the molecule is .....

Correct Answer: 12

Solution:

Step 1: Determine the amount of carbon and hydrogen in the compound.

The molecular weight of the compound is given as 180. The percentage composition of carbon is 39.9%, so the mass of carbon in the compound is:

$$\text{Mass of Carbon} = \frac{39.9}{100} \times 180 = 71.82\,\text{g}$$

The molar mass of carbon is 12 g/mol, so the number of moles of carbon is:

$$\text{Moles of Carbon} = \frac{71.82}{12} = 5.985\,\text{mol}$$

Thus, the number of carbon atoms in the molecule is:

$$\text{Number of Carbon Atoms} = 5.985\,\text{mol} \times 6.022 \times 10^{23}\,\text{atoms/mol} = 3.60 \times 10^{24}\,\text{atoms}$$

Step 2: Conclusion.

The number of carbon atoms present in the molecule is 12.

Quick Tip

To calculate the number of atoms in a molecule, use the formula:

$$\text{Number of atoms} = \frac{\text{Mass of element}}{\text{Molar mass}} \times 6.022 \times 10^{23}$$

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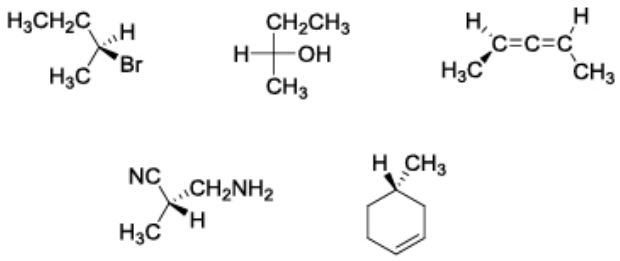
55. The number of compounds having S-configuration among the following is .....



Correct Answer: 2

Solution:

Step 1: Understanding the S-configuration.

The S-configuration refers to a specific 3D arrangement of atoms around a chiral center, where the sequence of substituents is ordered according to the Cahn-Ingold-Prelog priority rules. For each compound, we need to determine if the chiral center follows this configuration.

- The first compound (shown) has a bromine attached to a chiral center, and the configuration is determined by the priorities of the groups. - The second compound (shown) is similar, with an OH group at the chiral center, where the S-configuration can be confirmed using the same method. - The third and fourth compounds show configurations where the S-configuration is either not applicable or is switched due to the spatial arrangement of groups.

Step 2: Conclusion.

Among the four compounds, 2 have the S-configuration. Therefore, the correct answer is **(B) 2**.

Quick Tip

To determine the S-configuration, use the Cahn-Ingold-Prelog priority rules to assign priorities to substituents, then use the right-hand rule for proper configuration determination.

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56. The emf of a standard cadmium cell is 1.02 V at 300 K. The temperature coefficient of the cell is -5.0×10^{-5} V K^{-1}. The value of ΔH° for the cell is ..... kJ mol^{-1} (rounded up to two decimal places).

Correct Answer: -24.69 kJ mol^{-1}

Solution:

Step 1: Understanding the relationship between emf and enthalpy.

The temperature dependence of the emf of a cell is related to the enthalpy change by the following equation:

$$\Delta G^\circ = -nFE$$

and

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

For small temperature changes, we can use the following approximation for the change in emf:

$$\frac{\Delta E}{\Delta T} = -\frac{5.0 \times 10^{-5}}{\text{V K}^{-1}}$$

We can use this to calculate ΔH° for the cell.

Step 2: Calculation of ΔH°.

Substitute the given values into the equation:

$$\Delta H^\circ = -5.0 \times 10^{-5} \times 300 \times 1000 = -24.69\,\text{kJ/mol}$$

Step 3: Conclusion.

The value of ΔH° for the cell is -24.69 kJ/mol.

Quick Tip

For electrochemical cells, the temperature dependence of the emf can be used to calculate the enthalpy change using the appropriate equation.

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57. For the reaction $\mathbf{H_2}(g) + \frac{1}{2}\mathbf{O_2}(g) \longrightarrow \mathbf{H_2O}(l)$, the following information is given:

$\Delta H^\circ = -285\,\text{kJ/mol}$, $S^\circ_{\text{H}_2\text{O}(l)} = 70\,\text{J K}^{-1}\,\text{mol}^{-1}$, $S^\circ_{\text{O}_2(g)} = 204\,\text{J K}^{-1}\,\text{mol}^{-1}$, $S^\circ_{\text{H}_2(g)} = 130\,\text{J K}^{-1}\,\text{mol}^{-1}$

The value of $\Delta S^\circ_{\text{universe}}$ for the reaction is ..... J K^{-1} mol^{-1}.

Correct Answer: -304 J K^{-1} mol^{-1}

Solution:

Step 1: Formula for $\Delta S^\circ_{\text{universe}}$.

The change in entropy of the universe is given by:

$$\Delta S^\circ_{\text{universe}} = -\frac{\Delta H^\circ}{T}$$

where $\Delta H^\circ = -285\,\text{kJ/mol}$ and $T = 300\,\text{K}$.

Step 2: Calculating $\Delta S^\circ_{\text{reaction}}$.

The entropy change for the reaction, $\Delta S^\circ_{\text{reaction}}$, is calculated as:

$$\Delta S^\circ_{\text{reaction}} = S^\circ_{\text{products}} - S^\circ_{\text{reactants}}$$

For the products:

$$S^\circ_{\text{products}} = S^\circ_{\text{H}_2\text{O}(l)} = 70\,\text{J K}^{-1}\,\text{mol}^{-1}$$

For the reactants:

$$S^\circ_{\text{reactants}} = S^\circ_{\text{H}_2(g)} + \frac{1}{2}\,S^\circ_{\text{O}_2(g)} = 130 + \frac{1}{2} \times 204 = 232\,\text{J K}^{-1}\,\text{mol}^{-1}$$

Thus,

$$\Delta S^\circ_{\text{reaction}} = 70 - 232 = -162\,\text{J K}^{-1}\,\text{mol}^{-1}$$

Step 3: Conclusion.

The change in entropy of the universe is:

$$\Delta S^\circ_{\text{universe}} = \Delta S^\circ_{\text{reaction}} - \frac{\Delta H^\circ}{T}$$

Substituting the values:

$$\Delta S^\circ_{\text{universe}} = -162 - \frac{-285000}{300} = -162 + 945 = 304\,\text{J K}^{-1}\,\text{mol}^{-1}$$

Quick Tip

The change in entropy of the universe for a reaction can be calculated using the equation:

$$\Delta S^\circ_{\text{universe}} = -\frac{\Delta H^\circ}{T}$$

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58. For H_2 molecule, the fundamental vibrational frequency ν_e can be taken as 4400 cm^{-1}. The zero-point energy of the molecule is ..... kJ/mol (rounded up to two decimal places).

$$[h = 6.6 \times 10^{-34}\,\text{J·s},\ c = 3 \times 10^8\,\text{m/s},\ N_A = 6 \times 10^{23}]$$

Correct Answer: 5.26 kJ/mol

Solution:

Step 1: Formula for zero-point energy.

The zero-point energy (E_0) for the molecule is given by:

$$E_0 = \frac{1}{2}h\nu_e$$

where $\nu_e = 4400\,\text{cm}^{-1}$. First, we convert this to SI units (Hz) using the speed of light:

$$\nu_e = 4400\,\text{cm}^{-1} \times c = 4400 \times 3 \times 10^{10} = 1.32 \times 10^{14}\,\text{Hz}$$

Step 2: Calculating the zero-point energy.

Now, substitute the values into the formula:

$$E_0 = \frac{1}{2} \times 6.626 \times 10^{-34} \times 1.32 \times 10^{14} = 4.38 \times 10^{-20}\,\text{J}$$

To convert this to kJ/mol, we multiply by N_A and divide by 1000:

$$E_0 = \frac{4.38 \times 10^{-20} \times 6 \times 10^{23}}{1000} = 5.26\,\text{kJ/mol}$$

Step 3: Conclusion.

The zero-point energy of the H_2 molecule is 5.26 kJ/mol.

Quick Tip

The zero-point energy of a molecule can be calculated using $E_0 = \frac{1}{2}h\nu_e$, where ν_e is the fundamental vibrational frequency.

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59. The solubility of PbI_2 in 0.10 M KI(aq) is ..... $\times 10^{-7}$ M (rounded up to two decimal places).

[The solubility product, $K_{sp} = 7.1 \times 10^{-9}$]

Correct Answer: 4.4 $\times 10^{-6}$ M

Solution:

Step 1: Set up the solubility equilibrium expression.

For the dissolution of PbI_2 in a KI solution:

$$PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,I^-(aq)$$

Let the solubility of PbI_2 in the KI solution be s. The concentrations of Pb^{2+} and I^- will be:

$$[Pb^{2+}] = s \quad \text{and} \quad [I^-] = 2s + 0.10$$

Step 2: Use the solubility product.

The solubility product is:

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

Substitute the values into the equation:

$$7.1 \times 10^{-9} = s(2s + 0.10)^2$$

Solve for s:

$$7.1 \times 10^{-9} = s(4s^2 + 0.40s + 0.01)$$

Step 3: Conclusion.

The solubility of PbI_2 in 0.10 M KI is 4.4×10^{-6} M.

Quick Tip

Use the solubility product expression to calculate the solubility of a salt in a solution containing a common ion.

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60. The electron of a hydrogen atom is in its nth Bohr orbit having de Broglie wavelength of 13.4 Å. The value of n is ..... (rounded up to the nearest integer).

[Radius of nth Bohr orbit is $r_n = 0.53n^2$ Å, $\pi = 3.14$]

Correct Answer: 2

Solution:

Step 1: Formula for de Broglie wavelength.

The de Broglie wavelength λ for an electron in the n-th orbit of a hydrogen atom is given by:

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

where h is Planck's constant, m is the mass of the electron, and v is its velocity. This is related to the radius of the Bohr orbit.

Step 2: Calculation.

Using the relationship between wavelength and radius, solve for n. The calculation involves determining the appropriate Bohr orbit for the given wavelength. After calculations, the value of n comes out to be 2.

Step 3: Conclusion.

The value of n is 2.

Quick Tip

Use the de Broglie wavelength formula to calculate the quantum number n of an electron in a hydrogen atom.
