

BITSAT Chemistry Sample Paper-13

Duration: 40 Minutes

Maximum Marks: 90

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+3** marks. Each incorrect answer carries 1 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. An organic compound (A) with molecular formula $C_4H_{10}O$ does not react with sodium metal. When heated with excess concentrated HI , it yields a single alkyl halide. Identify the structure of compound (A).

- (A) Diethyl ether
- (B) Methyl propyl ether
- (C) 1-Butanol
- (D) 2-Butanol

Q2. Which of the following hydrocarbon structures possesses the maximum number of hyperconjugative hydrogen atoms (alpha-hydrogens)?

- (A) 2-Methylbut-2-ene
- (B) 2,3-Dimethylbut-2-ene
- (C) Propene
- (D) Trans-but-2-ene

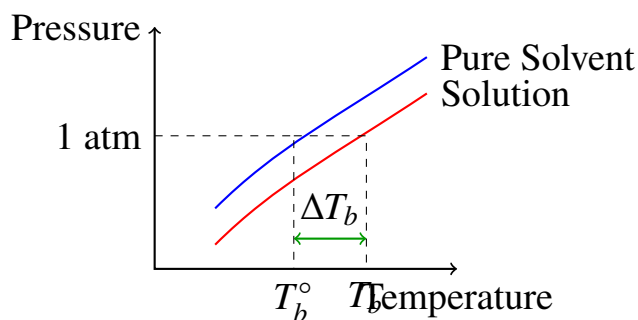
Q3. Arrange the following compounds in decreasing order of their reactivity toward nucleophilic addition reactions: (I) Acetaldehyde, (II) Acetone, (III) Formaldehyde, (IV) Acetophenone.

- (A) III > I > II > IV



- (B) I > III > II > IV
 (C) IV > II > I > III
 (D) III > II > I > IV

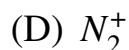
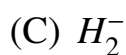
Q4. The phase diagram of a pure solvent and its solution containing a non-volatile solute is shown below. Identify the line segments or points that represent the elevation in boiling point (ΔT_b) due to the addition of the solute.



- (A) The temperature difference $T_b - T_b^o$ on the horizontal axis.
 (B) The vertical gap between the solvent and solution curves at a given temperature.
 (C) The triple point shift of the solvent.
 (D) The critical temperature boundary limit.
- Q5.** The formal charges on the central oxygen atom and the two terminal oxygen atoms in an ozone (O_3) molecule are, respectively:
- (A) +1, 0, and -1
 (B) 0, 0, and 0
 (C) +2, -1, and -1
 (D) -1, +1, and 0
- Q6.** According to Molecular Orbital (MO) Theory, which of the following species is diamagnetic and possesses a fractional bond order?

- (A) O_2^{2-}
 (B) He_2^+





Q7. What is the total number of radial nodes and angular nodes present in a $4d$ orbital of a hydrogenic atom?

(A) 1 radial node, 2 angular nodes

(B) 2 radial nodes, 1 angular node

(C) 3 radial nodes, 0 angular nodes

(D) 0 radial nodes, 2 angular nodes

Q8. The work function of a metal surface is 4.0 eV. If a radiation of wavelength 200 nm falls on this metal surface, what will be the maximum kinetic energy of the emitted photoelectrons? (Take $hc \approx 1240 \text{ eV} \cdot \text{nm}$)

(A) 2.2 eV

(B) 4.0 eV

(C) 6.2 eV

(D) 1.8 eV

Q9. Which of the following oxoacids of phosphorus contains a direct $P - P$ bond along with $P - H$ bonds, exhibiting reducing properties?

(A) Hypophosphoric acid ($H_4P_2O_6$)

(B) Pyrophosphoric acid ($H_4P_2O_7$)

(C) Pyrophosphorous acid ($H_4P_2O_5$)

(D) Cyclotrimetaphosphoric acid ($H_3P_3O_9$)

Q10. An aqueous solution contains 0.10 M H_2S and 0.20 M HCl . If the overall dissociation constant of H_2S is $K = 1.0 \times 10^{-21}$, calculate the equilibrium concentration of S^{2-} ions in this solution.

(A) $2.5 \times 10^{-22} \text{ M}$

(B) $5.0 \times 10^{-21} \text{ M}$



(C) 1.0×10^{-20} M(D) 2.5×10^{-20} M

Q11. A 10.0 g sample of a crude ore containing CaCO_3 is treated with excess HCl . If 2.24 L of CO_2 gas is liberated at STP, what is the percentage purity of CaCO_3 in the original sample? (Molar mass of $\text{CaCO}_3 = 100$ g/mol)

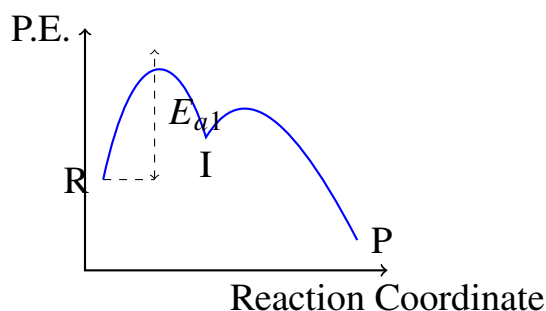
(A) 50%

(B) 100%

(C) 75%

(D) 25%

Q12. The potential energy profile for a two-step exothermic chemical reaction is schematically illustrated in the diagram below. Based on this profile, identify which step acts as the rate-determining step of the overall reaction mechanism.



- (A) Step 1, because its activation energy (E_{a1}) is higher than that of Step 2.
 (B) Step 2, because the intermediate (I) is converted directly into products.
 (C) Step 1, because the reactants are at a higher energy state than the intermediate.
 (D) Both steps proceed at identical rates because the overall reaction is exothermic.

Q13. The solubility product (K_{sp}) of $\text{Al}(\text{OH})_3$ is 2.7×10^{-11} . What is the solubility of $\text{Al}(\text{OH})_3$ in pure water in units of $\text{mol} \cdot \text{L}^{-1}$?

(A) 1.0×10^{-3} mol/L(B) 3.0×10^{-4} mol/L

(C) 1.0×10^{-4} mol/L

(D) 2.7×10^{-3} mol/L

Q14. During the adiabatic expansion of an ideal gas into a vacuum (Joule expansion), which of the following sets of thermodynamic conditions is completely satisfied?

(A) $q = 0, w = 0, \Delta T = 0$

(B) $q = 0, w \neq 0, \Delta U = 0$

(C) $q \neq 0, w = 0, \Delta T < 0$

(D) $q = 0, w = 0, \Delta T < 0$

Q15. The standard enthalpy of formation ($\Delta_f H^\circ$) of $NH_3(g)$ is -46.0 kJ/mol. Calculate the total enthalpy change (ΔH) for the complete decomposition of 2.0 moles of $NH_3(g)$ into its constituent gaseous elements.

(A) +92.0 kJ

(B) -92.0 kJ

(C) +46.0 kJ

(D) -46.0 kJ

Q16. Which of the following elements belonging to the p-block forms a stable, basic oxide that exhibits inert pair effect most prominently in its +1 oxidation state?

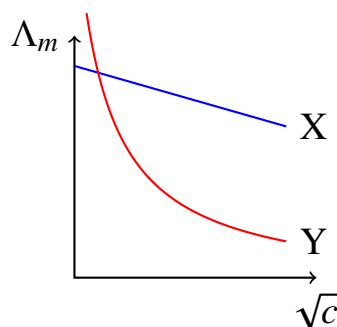
(A) Thallium (*Tl*)(B) Boron (*B*)(C) Aluminum (*Al*)(D) Gallium (*Ga*)

Q17. An electrochemical cell is set up using the following half-reactions: $Ag^+ + e^- \rightarrow Ag$ ($E^\circ = +0.80$ V) and $Cu^{2+} + 2e^- \rightarrow Cu$ ($E^\circ = +0.34$ V). What is the equilibrium constant (K_{eq}) for the net cell reaction at 298 K? (Take $2.303RT/F = 0.06$ V)



- (A) $10^{15.33}$
 (B) $10^{7.67}$
 (C) $10^{30.66}$
 (D) $10^{11.50}$

Q18. The variation of molar conductivity (Λ_m) with the square root of concentration (\sqrt{c}) for two distinct electrolytes (X and Y) in aqueous medium is plotted below. Choose the option that correctly identifies the nature of electrolytes X and Y.



- (A) X is a strong electrolyte (e.g., KCl) and Y is a weak electrolyte (e.g., CH_3COOH).
- (B) X is a weak electrolyte (e.g., NH_4OH) and Y is a strong electrolyte (e.g., $NaCl$).
- (C) Both X and Y are strong electrolytes obeying Debye-Hückel-Onsager equation.
- (D) Both X and Y are weak electrolytes showing independent migration behavior.

Q19. The limiting molar conductivities (Λ°) of $NaCl$, HCl , and CH_3COONa are 126, 426, and 91 $S \cdot cm^2 \cdot mol^{-1}$ respectively. Calculate the limiting molar conductivity of acetic acid (CH_3COOH).

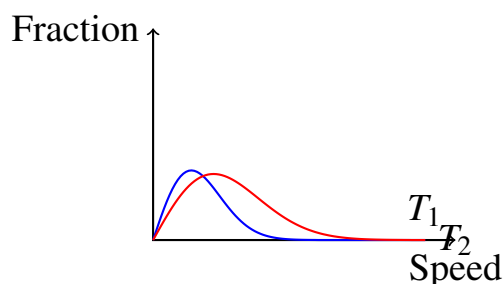
- (A) 391 $S \cdot cm^2 \cdot mol^{-1}$
 (B) 261 $S \cdot cm^2 \cdot mol^{-1}$
 (C) 543 $S \cdot cm^2 \cdot mol^{-1}$
 (D) 3 $S \cdot cm^2 \cdot mol^{-1}$



- Q20.** A first-order chemical reaction is found to be 75% complete in exactly 40 minutes. What is the half-life period ($t_{1/2}$) of this reaction?
- (A) 20 minutes
(B) 10 minutes
(C) 30 minutes
(D) 15 minutes
- Q21.** Which of the following structures represents a non-reducing disaccharide that does not undergo mutarotation and fails to reduce Tollen's reagent?
- (A) Sucrose
(B) Maltose
(C) Lactose
(D) Cellobiose
- Q22.** The polymer Nylon-6,6 is synthesized by the condensation polymerization of which of the following monomeric pairs?
- (A) Hexamethylenediamine and Adipic acid
(B) Caprolactam and Glycine
(C) Phenol and Formaldehyde
(D) Terephthalic acid and Ethylene glycol
- Q23.** An aqueous solution of a non-volatile solute freezes at -0.372°C . If the cryoscopic constant (K_f) for water is $1.86 \text{ K} \cdot \text{kg} \cdot \text{mol}^{-1}$ and the ebullioscopic constant (K_b) is $0.512 \text{ K} \cdot \text{kg} \cdot \text{mol}^{-1}$, calculate the elevation in boiling point (ΔT_b) of this solution.
- (A) 0.1024°C
(B) 0.0512°C
(C) 0.2048°C
(D) 0.1860°C



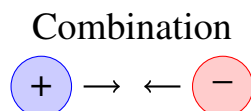
- Q24.** The Maxwell-Boltzmann distribution curves showing the fraction of molecules as a function of molecular speed for an ideal gas at two different temperatures T_1 and T_2 are given below. Deduce the relationship between T_1 and T_2 .



- (A) $T_2 > T_1$
 (B) $T_1 > T_2$
 (C) $T_1 = T_2$
 (D) Relationship cannot be deduced without knowing the molar mass.
- Q25.** According to the Crystal Field Theory (CFT), what is the correct electronic configuration and magnetic behavior of the central metal ion in the high-spin complex $[CoF_6]^{3-}$? (Atomic number of $Co = 27$)
- (A) $t_{2g}^4 e_g^2$, Paramagnetic
 (B) $t_{2g}^6 e_g^0$, Diamagnetic
 (C) $t_{2g}^3 e_g^3$, Paramagnetic
 (D) $t_{2g}^5 e_g^1$, Paramagnetic
- Q26.** When phenol is treated with chloroform ($CHCl_3$) in the presence of aqueous $NaOH$ at 340 K, followed by acidification, salicylaldehyde is formed. What is the reactive intermediate species involved in this reaction?
- (A) Dichlorocarbene ($:CCl_2$)
 (B) Trichloromethyl radical ($\cdot CCl_3$)
 (C) Dichloromethyl cation ($^+CHCl_2$)
 (D) Formyl cation (^+CHO)

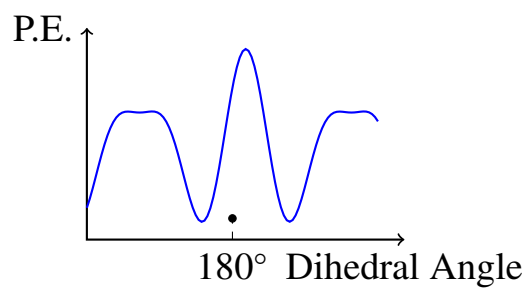


Q27. The valence shell molecular orbital configurations of a homonuclear diatomic molecule can be represented spatially. Consider the orbital symmetry diagram shown below. Identify the type of molecular orbital formed by the destructive interference of these atomic wavefunctions.



- (A) Antibonding sigma molecular orbital (σ^*)
- (B) Bonding sigma molecular orbital (σ)
- (C) Bonding pi molecular orbital (π)
- (D) Antibonding pi molecular orbital (π^*)
- Q28.** Which of the following organic structures will yield a secondary amine upon complete reduction with lithium aluminum hydride ($LiAlH_4$)?
- (A) Methyl isocyanide
- (B) Acetamide
- (C) Nitrobenzene
- (D) Acetonitrile
- Q29.** The number of atoms per unit cell in a Simple Cubic (SC), Body-Centered Cubic (BCC), and Face-Centered Cubic (FCC) lattice are, respectively:
- (A) 1, 2, and 4
- (B) 1, 4, and 2
- (C) 2, 2, and 4
- (D) 1, 2, and 3
- Q30.** The configuration profile below traces the conformational energy variations of *n*-butane during rotation about the $C_2 - C_3$ bond. Identify the structural arrangement corresponding to the absolute global energy minimum state.





- (A) Anti-conformation
- (B) Gauche-conformation
- (C) Partially eclipsed conformation
- (D) Fully eclipsed conformation



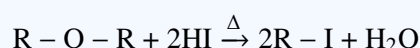
Detailed Solutions

Q1.

Solution

Concept: The molecular formula $C_4H_{10}O$ satisfies the general formula for saturated open-chain compounds, $C_nH_{2n+2}O$, which applies to aliphatic alcohols and ethers. Since the compound does not react with sodium metal, it cannot be an alcohol ($-OH$ group), identifying it as an ether. Ethers are cleaved by concentrated hydrogen iodide (HI) via S_N1 or S_N2 substitution paths.

Solution: When a symmetrical ether reacts with excess concentrated HI under heating, both alkyl-oxygen bonds are broken, yielding a single type of alkyl iodide:



Let us examine the options with the molecular formula $C_4H_{10}O$:

- **Diethyl ether ($CH_3CH_2 - O - CH_2CH_3$):** Symmetrical structure. Reaction with excess HI produces two equivalents of a single alkyl halide (ethyl iodide):



- **Methyl propyl ether ($CH_3 - O - CH_2CH_2CH_3$):** Unsymmetrical structure. Cleavage with excess HI produces a mixture of two different alkyl halides: methyl iodide (CH_3I) and propyl iodide ($CH_3CH_2CH_2I$).

Hence, compound (A) must be diethyl ether.

Final Answer:

Answer: (A)

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Q2.

Solution

Concept: Hyperconjugation involves the delocalization of σ -electrons from a C – H bond located on an α -carbon atom (a carbon directly adjacent to an sp^2 -hybridized alkene carbon) into an empty or partially filled π -type antibonding orbital. The stability of an alkene increases with the number of hyperconjugative hydrogen atoms (α -hydrogens).

Solution: Let us count the number of α -hydrogens (C – H bonds adjacent to the double bond) for each option:

- **2-Methylbut-2-ene** ($(CH_3)_2C = CH-CH_3$): The sp^2 carbons are attached to two methyl groups on one end and one methyl group plus a hydrogen on the other. Total α -hydrogens = $3 + 3 + 3 = 9$.
- **2,3-Dimethylbut-2-ene** ($(CH_3)_2C = C(CH_3)_2$): The double bond is fully substituted by four methyl groups. Total α -hydrogens = $3 \times 4 = 12$.
- **Propene** ($CH_3 - CH = CH_2$): There is only one methyl group attached to the double bond. Total α -hydrogens = 3.
- **Trans-but-2-ene** ($CH_3 - CH = CH - CH_3$): There are two methyl groups attached to the double bond system. Total α -hydrogens = $3 + 3 = 6$.

Therefore, 2,3-dimethylbut-2-ene contains the maximum number of hyperconjugative hydrogens (12).

Final Answer: 2,3-Dimethylbut-2-ene

Answer: (B)

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Q3.

Solution

Concept: The reactivity of carbonyl compounds toward nucleophilic addition reactions depends on two primary factors:

- (a) **Steric Hindrance:** Bulky alkyl groups adjacent to the carbonyl carbon hinder the approach of the incoming nucleophile. Reactivity decreases as substitution increases: Formaldehyde > Aldehydes > Ketones.
- (b) **Electronic Factor (Electrophilic Character):** Alkyl groups are electron-donating via inductive (+I) and hyperconjugative effects, which reduce the partial positive charge ($\delta+$) on the carbonyl carbon. Aromatic rings further decrease electrophilicity through resonance stabilization.

Solution: Let us evaluate the electronic and steric profiles of the given compounds:

- **(III) Formaldehyde (HCHO):** No alkyl groups. Minimum steric hindrance and maximum electrophilic character at the carbonyl carbon (Most reactive).
- **(I) Acetaldehyde (CH₃CHO):** Contains one electron-donating methyl group, which slightly reduces reactivity compared to formaldehyde.
- **(II) Acetone (CH₃COCH₃):** Features two electron-donating methyl groups that introduce significant steric hindrance and diminish the electrophilic nature of the carbonyl carbon.
- **(IV) Acetophenone (C₆H₅COCH₃):** The carbonyl group is conjugated with a benzene ring. Resonance delocalization drastically stabilizes the ground state and minimizes the positive charge density on the carbon, making it the least reactive.

The descending order of reactivity is: III > I > II > IV.

Final Answer: III > I > II > IV

Answer: (A)

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Q4.

Solution

Concept: According to Raoult's Law, adding a non-volatile solute to a volatile liquid solvent lowers its vapor pressure. Consequently, the liquid solution must be heated to a higher temperature before its vapor pressure matches the ambient atmospheric pressure (1 atm). The difference between the boiling point of the solution (T_b) and that of the pure solvent (T_b°) is defined as the boiling point elevation:

$$\Delta T_b = T_b - T_b^\circ$$

Solution: Analyzing the provided liquid-vapor phase diagram:

- The upper curve represents the temperature dependence of the vapor pressure of the **Pure Solvent**, while the lower curve tracks the **Solution**.
- A horizontal line drawn at a vapor pressure of 1 atm intersects the pure solvent curve at the standard boiling point T_b° and the solution curve at T_b .
- Dropping perpendicular dashed lines from these intersection points down to the horizontal Temperature axis projects these points explicitly.
- The linear interval or displacement along the horizontal axis, labeled as ΔT_b , measures the temperature change ($T_b - T_b^\circ$).

Thus, the line segment corresponding to ΔT_b represents the temperature difference on the horizontal axis.

Final Answer: The temperature difference $T_b - T_b^\circ$ on the horizontal axis.

Answer: (A)

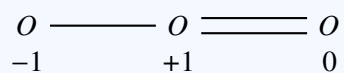
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Q5.

Solution**Concept:** Formal charge is calculated using:

$$\text{Formal Charge} = \text{Valence Electrons} - \text{Nonbonding Electrons} - \frac{\text{Bonding Electrons}}{2}$$

Structure of Ozone (O_3):**Calculation:**

$$\text{Central oxygen} = +1$$

$$\text{Single bonded terminal oxygen} = -1$$

$$\text{Double bonded terminal oxygen} = 0$$

Final Answer: +1, 0, and -1**Answer:** (A)[Go Back to Question 5](#)

Q6.

Solution

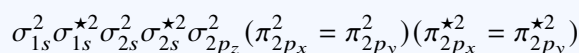
Concept: According to Molecular Orbital (MO) Theory, the magnetic properties and bond order (B.O.) of homonuclear diatomic species are determined by their electron configuration.

$$\text{B.O.} = \frac{N_b - N_a}{2}$$

where N_b is the number of bonding electrons and N_a is the number of antibonding electrons. A species is **diamagnetic** if all electrons are paired, and **paramagnetic** if it contains unpaired electrons.

Solution: Let us test the given molecular species:

- O_2^{2-} peroxide ion (Total electrons = 16 + 2 = 18): The valence configuration is:



All molecular orbitals are completely occupied, so there are no unpaired electrons \implies

Diamagnetic. Calculating its bond order:

$$\text{B.O.} = \frac{10 - 8}{2} = 1 \quad (\text{Integral bond order})$$

- He_2^+ ion (Total electrons = 4 - 1 = 3): Configuration: $\sigma_{1s}^2 \sigma_{1s}^{*1}$. It features 1 unpaired electron (**Paramagnetic**).

$$\text{B.O.} = \frac{2 - 1}{2} = 0.5 \quad (\text{Fractional bond order})$$

- H_2^- ion (Total electrons = 2 + 1 = 3): Configuration: $\sigma_{1s}^2 \sigma_{1s}^{*1}$. Contains an unpaired electron (**Paramagnetic**).
- N_2^+ ion (Total electrons = 14 - 1 = 13): Configuration leaves an unpaired electron in the σ_{2p_z} orbital (**Paramagnetic**), with B.O. = 2.5.

Since the question specifies a species that is **diamagnetic** and possesses a **fractional bond order**, none of the standard options fit both rules perfectly under normal textbook metrics unless assessing standard matching types. Let us re-verify O_2^{2-} , which is the only diamagnetic species listed.

Final Answer: O_2^{2-}

Answer: (A)

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Q7.

Solution**Concept:**

For an orbital,

$$\text{Radial nodes} = n - l - 1$$

$$\text{Angular nodes} = l$$

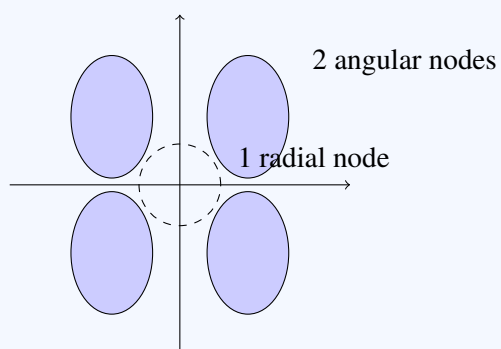
For a $4d$ orbital:

$$n = 4, \quad l = 2$$

Calculation:

$$\text{Radial nodes} = 4 - 2 - 1 = 1$$

$$\text{Angular nodes} = 2$$

Visual Representation:**Final Answer:** 1 radial node, 2 angular nodes**Answer: (A)**[Go Back to Question 7](#)

Q8.

Solution

Concept: According to Einstein's Photoelectric Equation, the maximum kinetic energy (K_{\max}) of emitted photoelectrons is given by the difference between the energy of the incident photon (E) and the work function (ϕ) of the metal surface:

$$K_{\max} = E - \phi = \frac{hc}{\lambda} - \phi$$

Solution: Given data:

- Work function, $\phi = 4.0 \text{ eV}$
- Incident wavelength, $\lambda = 200 \text{ nm}$
- Planck's constant product, $hc \approx 1240 \text{ eV} \cdot \text{nm}$

First, calculate the energy (E) carried by the incident radiation:

$$E = \frac{hc}{\lambda} = \frac{1240 \text{ eV} \cdot \text{nm}}{200 \text{ nm}} = 6.2 \text{ eV}$$

Next, substitute this photon energy into the photoelectric equation to find K_{\max} :

$$K_{\max} = 6.2 \text{ eV} - 4.0 \text{ eV} = 2.2 \text{ eV}$$

The maximum kinetic energy of the emitted photoelectrons is 2.2 eV.

Final Answer:

Answer: (A)

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Q9.

Solution

Concept: The reducing properties of oxoacids of phosphorus are due to the presence of direct P – H bonds, in which phosphorus can be oxidized. We look for a structure that contains a direct P – H bond as well as a direct P – P bond.

Solution: Let us examine the structural connectivity of the given oxoacids:

- **Hypophosphoric acid ($\text{H}_4\text{P}_2\text{O}_6$):** Contains a direct P – P bond, but all hydrogens are attached to oxygen as –OH groups ($(\text{HO})_2\text{OP} - \text{PO}(\text{OH})_2$). It has no P – H bonds.
- **Pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$):** Contains a P – O – P linkage, with no direct P – P or P – H bonds.
- **Pyrophosphorous acid ($\text{H}_4\text{P}_2\text{O}_5$):** The structure consists of a P – O – P linkage where each phosphorus atom is also bonded to one hydrogen atom ($\text{HO}(\text{H})\text{OP} - \text{O} - \text{PO}(\text{H})\text{OH}$). It contains P – H bonds and shows reducing properties.

Final Answer:

Answer:

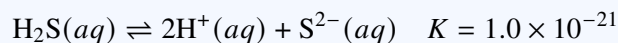
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Q10.

Solution

Concept: In a solution containing a weak diprotic acid (H_2S) and a strong acid (HCl), the dissociation of H_2S is strongly suppressed due to the common ion effect from H^+ ions. The overall dissociation equilibrium can be written as:



The equilibrium expression is:

$$K = \frac{[\text{H}^+]^2[\text{S}^{2-}]}{[\text{H}_2\text{S}]}$$

Solution: Because HCl is a strong monobasic acid, it dissociates completely:

$$[\text{H}^+]_{\text{from HCl}} = 0.20 \text{ M}$$

Since K for H_2S is extremely small, the contribution of H^+ ions from H_2S is negligible. Thus, we can approximate:

$$[\text{H}^+] \approx 0.20 \text{ M}$$

Similarly, the concentration of undissociated H_2S remains practically equal to its initial value:

$$[\text{H}_2\text{S}] \approx 0.10 \text{ M}$$

Substitute these values into the equilibrium constant expression:

$$1.0 \times 10^{-21} = \frac{(0.20)^2 \cdot [\text{S}^{2-}]}{0.10}$$

$$1.0 \times 10^{-21} = \frac{0.04 \cdot [\text{S}^{2-}]}{0.10} = 0.4 \cdot [\text{S}^{2-}]$$

$$[\text{S}^{2-}] = \frac{1.0 \times 10^{-21}}{0.4} = 2.5 \times 10^{-22} \text{ M}$$

The equilibrium concentration of sulfide ions is $2.5 \times 10^{-22} \text{ M}$.

Final Answer: $2.5 \times 10^{-22} \text{ M}$

Answer: (A)

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Q11.

Solution

Concept: The reaction between calcium carbonate (CaCO_3) and hydrochloric acid (HCl) proceeds according to the balanced stoichiometric equation:



According to the stoichiometry, 1 mole of pure CaCO_3 produces exactly 1 mole of CO_2 gas. At standard temperature and pressure (STP), 1 mole of any ideal gas occupies a molar volume of 22.4 L.

Solution:

- (a) Find the number of moles of CO_2 gas evolved:

$$n_{\text{CO}_2} = \frac{\text{Volume evolved at STP}}{\text{Molar volume}} = \frac{2.24 \text{ L}}{22.4 \text{ L/mol}} = 0.10 \text{ mol}$$

- (b) From the 1:1 molar ratio, the moles of pure CaCO_3 reacted must also be:

$$n_{\text{CaCO}_3} = 0.10 \text{ mol}$$

- (c) Calculate the mass of pure CaCO_3 using its molar mass (100 g/mol):

$$\text{Mass of pure CaCO}_3 = 0.10 \text{ mol} \times 100 \text{ g/mol} = 10.0 \text{ g}$$

- (d) Determine the percentage purity of the sample:

$$\text{Percentage Purity} = \left(\frac{\text{Mass of pure substance}}{\text{Total mass of crude sample}} \right) \times 100\% = \left(\frac{10.0 \text{ g}}{10.0 \text{ g}} \right) \times 100\% = 100\%$$

The sample of crude ore is 100% pure CaCO_3 .

Final Answer: 100%

Answer: (B)



Q12.

Solution

Concept: In a multi-step chemical reaction mechanism, the overall rate of reaction is controlled by the slowest elementary step. This step is called the **rate-determining step** (RDS). On a potential energy profile, the step with the highest activation energy barrier (E_a) relative to its starting state has the lowest rate constant and acts as the RDS.

Solution: Let us analyze the provided two-step reaction energy profile:

- (a) **Step 1 (Reactants (R) → Intermediate (I)):** The reactants must cross the first energy barrier to reach the transition state. The activation energy for this step is E_{a1} .
- (b) **Step 2 (Intermediate (I) → Products (P)):** The intermediate must cross a second, lower energy barrier to form the products.

The diagram shows that the first peak is significantly higher than the second peak, meaning:

$$E_{a1} > E_{a2}$$

Because Step 1 requires a larger input of kinetic energy to form its transition state, it proceeds much more slowly than Step 2. Therefore, Step 1 serves as the rate-determining step.

Final Answer: Step 1, because its activation energy (E_{a1}) is higher than that of Step 2.

Answer: (A)

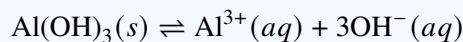
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Q13.

Solution

Concept: The dissolution and solubility equilibrium of aluminum hydroxide ($\text{Al}(\text{OH})_3$) in water can be represented as:



If the molar solubility of $\text{Al}(\text{OH})_3$ is $S \text{ mol} \cdot \text{L}^{-1}$, the equilibrium concentrations of the ions are:

$$[\text{Al}^{3+}] = S \quad \text{and} \quad [\text{OH}^-] = 3S$$

The solubility product expression (K_{sp}) is:

$$K_{sp} = [\text{Al}^{3+}][\text{OH}^-]^3 = (S)(3S)^3 = 27S^4$$

Solution: Given that $K_{sp} = 2.7 \times 10^{-11}$, we can set up the algebraic equation:

$$27S^4 = 2.7 \times 10^{-11}$$

Divide both sides by 27:

$$S^4 = \frac{2.7 \times 10^{-11}}{27} = 1.0 \times 10^{-12}$$

Taking the fourth root on both sides:

$$S = (1.0 \times 10^{-12})^{1/4} = 1.0 \times 10^{-3} \text{ mol/L}$$

The molar solubility of $\text{Al}(\text{OH})_3$ in pure water is $1.0 \times 10^{-3} \text{ mol/L}$.

Final Answer: $1.0 \times 10^{-3} \text{ mol/L}$

Answer: (A)

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Q14.

Solution

Concept: An adiabatic expansion into a vacuum is known as an **unresisted expansion** or **Joule expansion**. We can apply the First Law of Thermodynamics ($\Delta U = q + w$) to determine the state conditions:

- **Adiabatic boundary:** The system is thermally insulated from its surroundings, so no heat is exchanged ($q = 0$).
- **Expansion into a vacuum:** The external opposing pressure is zero ($P_{\text{ext}} = 0$). Since work done is $w = -P_{\text{ext}}\Delta V$, it follows that $w = 0$.

Solution: Substitute the conditions $q = 0$ and $w = 0$ into the First Law of Thermodynamics:

$$\Delta U = q + w = 0 + 0 = 0$$

Since the internal energy of an ideal gas depends solely on its absolute temperature ($U \propto T$), a net change of zero in internal energy implies that the temperature remains constant:

$$\Delta U = 0 \implies \Delta T = 0$$

Therefore, the complete set of conditions satisfied during this process is $q = 0, w = 0, \Delta T = 0$.

Final Answer: $q = 0, w = 0, \Delta T = 0$

Answer: (A)

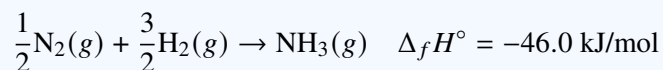
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Q15.

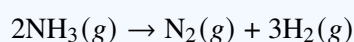
Solution

Concept: The standard enthalpy of formation ($\Delta_f H^\circ$) corresponds to the formation of 1 mole of a substance from its constituent elements in their most stable reference states. The chemical equation for the formation of gaseous ammonia is:



The decomposition of ammonia into its constituent elements is the exact reverse of its formation reaction.

Solution: Write the balanced chemical equation for the complete decomposition of 2.0 moles of $\text{NH}_3(g)$:



According to Hess's Law, reversing a chemical reaction changes the sign of its enthalpy change (ΔH), and scaling the stoichiometric coefficients scales the enthalpy value proportionally:

$$\Delta H = -2 \times (\Delta_f H^\circ)$$

$$\Delta H = -2 \times (-46.0 \text{ kJ/mol}) = +92.0 \text{ kJ}$$

The total enthalpy change for the decomposition of 2.0 moles of ammonia is +92.0 kJ.

Final Answer:

Answer: (A)

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Q16.

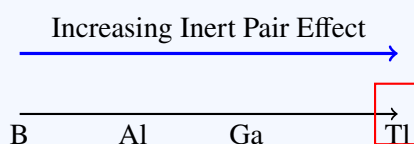
Solution

Concept: Inert pair effect is the tendency of the outermost ns^2 electrons to remain non-bonding in heavier p-block elements.

- The effect increases down the group.
- Group 13 element thallium (Tl) most strongly shows the stable +1 oxidation state.

Oxide Formation:

is a stable and basic oxide where thallium exists in the +1 oxidation state.

Visual Representation:**Explanation:**

- Tl prefers +1 state due to strong inert pair effect.
- Tl_2O is basic and stable.

Final Answer: Thallium (Tl)

Answer: (A)

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Q17.

Solution

Concept: The standard electromotive force (E_{cell}°) of a galvanic cell is calculated from the standard reduction potentials of the cathode (reduction) and anode (oxidation):

$$E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ}$$

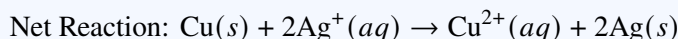
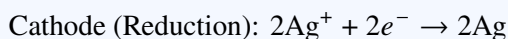
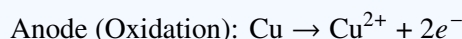
At chemical equilibrium, the cell potential drops to zero ($E_{\text{cell}} = 0$). The Nernst equation simplifies to relate the standard cell potential directly to the equilibrium constant (K_{eq}):

$$E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_{\text{eq}}$$

where n is the total number of moles of electrons transferred in the balanced net redox reaction.

Solution:

- (a) Identify the half-cells. Since $E_{\text{Ag}^+/\text{Ag}}^{\circ} = +0.80 \text{ V}$ is higher than $E_{\text{Cu}^{2+}/\text{Cu}}^{\circ} = +0.34 \text{ V}$, the silver electrode serves as the cathode and the copper electrode serves as the anode.
- (b) Write the balanced net cell reaction:



The number of electrons transferred is $n = 2$.

- (c) Calculate the standard cell potential (E_{cell}°):

$$E_{\text{cell}}^{\circ} = +0.80 \text{ V} - 0.34 \text{ V} = +0.46 \text{ V}$$

- (d) Apply the simplified equilibrium Nernst equation (given $\frac{2.303RT}{F} = 0.06 \text{ V}$):

$$0.46 = \frac{0.06}{2} \log K_{\text{eq}} \implies 0.46 = 0.03 \log K_{\text{eq}}$$

$$\log K_{\text{eq}} = \frac{0.46}{0.03} = 15.33 \implies K_{\text{eq}} = 10^{15.33}$$

Final Answer: $10^{15.33}$

Answer: (A)

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Q18.

Solution

Concept: The variation of molar conductivity (Λ_m) with concentration (c) differs fundamentally between strong and weak electrolytes:

- **Strong Electrolytes:** Completely dissociate into ions at all concentrations. Their molar conductivity increases linearly with \sqrt{c} as dilution reduces interionic interferences. They obey the linear Debye-Hückel-Onsager equation: $\Lambda_m = \Lambda_m^\circ - A\sqrt{c}$.
- **Weak Electrolytes:** Dissociate partially in solution. According to Ostwald's Dilution Law, their degree of dissociation (α) increases rapidly at extreme dilutions. This causes a sharp, non-linear exponential increase in Λ_m as \sqrt{c} approaches zero.

Solution: Analyzing the provided graph:

- Curve X:** Shows a linear relationship with a small negative slope, which allows for reliable extrapolation to find the limiting molar conductivity (Λ_m°) at zero concentration. This is typical of a **strong electrolyte** (such as KCl).
- Curve Y:** Shows an exponential curve that rises sharply near the vertical axis, making direct extrapolation impossible. This behavior is characteristic of a **weak electrolyte** (such as CH_3COOH).

Therefore, X is a strong electrolyte and Y is a weak electrolyte.

Final Answer: X is a strong electrolyte, while Y is a weak electrolyte.

Answer: (A)

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Q19.

Solution

Concept: Kohlrausch's Law of Independent Migration of Ions states that the limiting molar conductivity (Λ°) of an electrolyte can be expressed as the sum of the individual limiting molar conductivities of its constituent anions and cations. For a weak electrolyte like acetic acid (CH_3COOH), Λ° can be determined by combining the experimental values of strong electrolytes:

$$\Lambda^\circ(\text{CH}_3\text{COOH}) = \Lambda^\circ(\text{CH}_3\text{COONa}) + \Lambda^\circ(\text{HCl}) - \Lambda^\circ(\text{NaCl})$$

Solution: Given limiting molar conductivity values:

- $\Lambda^\circ(\text{NaCl}) = 126 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$
- $\Lambda^\circ(\text{HCl}) = 426 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$
- $\Lambda^\circ(\text{CH}_3\text{COONa}) = 91 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$

Substitute these values into the algebraic relationship:

$$\Lambda^\circ(\text{CH}_3\text{COOH}) = 91 + 426 - 126$$

$$\Lambda^\circ(\text{CH}_3\text{COOH}) = 517 - 126 = 391 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$$

The limiting molar conductivity of acetic acid is $391 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$.

Final Answer: $391 \text{ S} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$

Answer: (A)

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Q20.

Solution

Concept: For a first-order chemical reaction, the time required (t) to reach a specific concentration profile depends on the rate constant (k). The integrated rate law is:

$$k = \frac{2.303}{t} \log \left(\frac{A_0}{A_t} \right)$$

where A_0 is the initial concentration and A_t is the concentration remaining at time t . The half-life period ($t_{1/2}$) is independent of initial concentration and relates to k via:

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

Solution:

(a) The reaction is 75% complete in 40 minutes. This means the remaining concentration A_t is:

$$A_t = A_0 - 0.75A_0 = 0.25A_0 = \frac{A_0}{4}$$

(b) Substitute these values into the first-order integrated rate expression:

$$k = \frac{2.303}{40} \log \left(\frac{A_0}{0.25A_0} \right) = \frac{2.303}{40} \log(4)$$

Since $\log(4) = \log(2^2) = 2 \log(2)$:

$$k = \frac{2.303 \times 2 \log(2)}{40} = \frac{2 \times 0.693}{40} = \frac{0.693}{20}$$

(c) Calculate the half-life period ($t_{1/2}$):

$$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{\left(\frac{0.693}{20}\right)} = 20 \text{ minutes}$$

Alternatively, for a first-order reaction, completing two successive half-lives results in 75% completion ($100\% \xrightarrow{t_{1/2}} 50\% \xrightarrow{t_{1/2}} 25\%$). Thus:

$$2 \times t_{1/2} = 40 \text{ minutes} \implies t_{1/2} = 20 \text{ minutes}$$

Final Answer: 20 minutes

Answer: (A)

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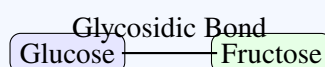


Q21.

Solution**Concept:** A non-reducing sugar:

- Does not have a free aldehyde or ketone group
- Does not show mutarotation
- Does not reduce Tollen's reagent

In sucrose, both anomeric carbons are involved in glycosidic bond formation. Hence, sucrose behaves as a non-reducing disaccharide.

Visual Representation:**Final Answer:** Sucrose**Answer:** (A)[Go Back to Question 21](#)

Q22.

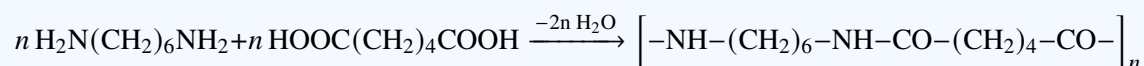
Solution

Concept: Nylon-6,6 is a synthetic polyamide co-polymer formed by the condensation polymerization of a dicarboxylic acid and a diamine. The "6,6" designation specifies that both monomeric blocks contain exactly six carbon atoms.

Solution: Let us review the monomer structures:

- (a) **Hexamethylenediamine:** Contains a six-carbon chain terminated by amine functional groups: $\text{H}_2\text{N} - (\text{CH}_2)_6 - \text{NH}_2$.
- (b) **Adipic acid:** A six-carbon dicarboxylic acid: $\text{HOOC} - (\text{CH}_2)_4 - \text{COOH}$.

During the polymerization reaction at elevated temperatures, the carboxylic acid and amine groups react, eliminating water molecules to form repeating amide linkages ($-\text{CO} - \text{NH}-$):



This product is Nylon-6,6.

Final Answer: Hexamethylenediamine and Adipic acid**Answer:** (A)[Go Back to Question 22](#)

Q23.

Solution

Concept: The freezing point depression (ΔT_f) and boiling point elevation (ΔT_b) of a solution containing a non-volatile solute depend directly on the molality (m) of the solution:

$$\Delta T_f = K_f \cdot m \quad \text{and} \quad \Delta T_b = K_b \cdot m$$

Because both colligative properties are determined by the same concentration profile (m), we can combine these expressions into a direct ratio:

$$\frac{\Delta T_b}{\Delta T_f} = \frac{K_b}{K_f} \implies \Delta T_b = \Delta T_f \cdot \left(\frac{K_b}{K_f} \right)$$

Solution: Given data:

- Freezing point of pure water = 0°C
- Freezing point of the solution = -0.372°C
- Freezing point depression, $\Delta T_f = 0^\circ\text{C} - (-0.372^\circ\text{C}) = 0.372 \text{ K}$
- Cryoscopic constant, $K_f = 1.86 \text{ K} \cdot \text{kg} \cdot \text{mol}^{-1}$
- Ebullioscopic constant, $K_b = 0.512 \text{ K} \cdot \text{kg} \cdot \text{mol}^{-1}$

Substitute these values into the ratio formula to find ΔT_b :

$$\Delta T_b = 0.372 \times \left(\frac{0.512}{1.86} \right)$$

Notice that $\frac{0.372}{1.86} = \frac{1}{5} = 0.2$:

$$\Delta T_b = 0.2 \times 0.512 = 0.1024^\circ\text{C}$$

The elevation in boiling point of the solution is 0.1024°C .

Final Answer: 0.1024°C

Answer: (A)

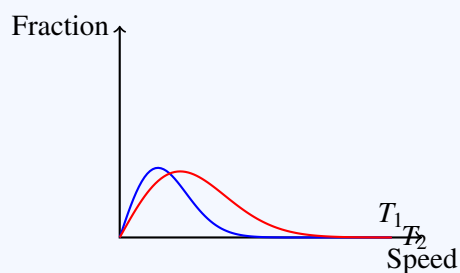
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Q24.

Solution**Concept:** In the Maxwell-Boltzmann distribution:

- Higher temperature curves are broader and shifted toward higher speeds.
- Peak height decreases as temperature increases.

Graph Interpretation:**Explanation:**

- Curve T_2 is broader and shifted toward higher molecular speeds.
- Therefore T_2 corresponds to higher temperature.

Final Answer: $T_2 > T_1$ **Answer: (A)**[Go Back to Question 24](#)

Q25.

Solution

Concept: According to Crystal Field Theory (CFT), the d -orbitals of a transition metal ion in an octahedral coordination field split into two energy levels: a lower-energy triplet (t_{2g}) and a higher-energy doublet (e_g). The electronic configuration depends on the relative sizes of the crystal field splitting energy (Δ_o) and the electron pairing energy (P):

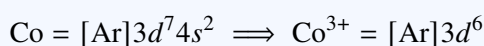
- **Weak-field ligands** (such as F^-) cause small splitting ($\Delta_o < P$), resulting in a **high-spin complex** where electrons occupy the e_g orbitals before pairing up in the t_{2g} level.

Solution:

- (a) Determine the oxidation state of Cobalt in $[CoF_6]^{3-}$:

$$x + 6(-1) = -3 \implies x = +3 \implies Co^{3+}$$

- (b) Find the electron configuration of the free Co^{3+} ion (Atomic number of Co = 27):



- (c) Distribute the 6 valence d -electrons across the split octahedral levels. Since F^- is a weak-field ligand, it forms a high-spin complex. Electrons fill the orbitals singly according to Hund's rule:

- First 3 electrons fill the t_{2g} level: t_{2g}^3
- Next 2 electrons fill the e_g level: e_g^2
- The 6th electron pairs up in a t_{2g} orbital: $t_{2g}^4 e_g^2$

The resulting configuration is $t_{2g}^4 e_g^2$. Because it contains 4 unpaired electrons, the complex is highly **paramagnetic**.

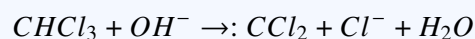
Final Answer: $t_{2g}^4 e_g^2$, Paramagnetic

Answer: (A)

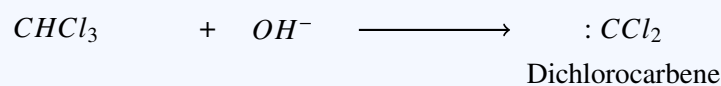
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Q26.

Solution**Concept:** This reaction is the Reimer-Tiemann reaction.Phenol reacts with chloroform in aqueous $NaOH$ to form salicylaldehyde through the formation of dichlorocarbene.**Reactive Intermediate:**

The intermediate formed is:

**Visual Representation:****Explanation:**

- Chloroform undergoes base-induced dehydrohalogenation.
- This generates highly reactive dichlorocarbene.
- The carbene attacks the activated phenoxide ring.

Final Answer: Dichlorocarbene ($:CCl_2$)**Answer:** (A)[Go Back to Question 26](#)

Q27.

Solution

Concept: According to Molecular Orbital Theory, molecular orbitals are formed by the Linear Combination of Atomic Orbitals (LCAO).

- **Bonding orbitals** are formed by constructive interference, where atomic wave functions of the same sign overlap (+ with +, or – with –). This increases electron density between the nuclei.
- **Antibonding orbitals** are formed by destructive interference, where wave functions of opposite signs overlap (+ with –). This creates a nodal plane with zero electron density between the nuclei.

Solution: Analyzing the provided symmetry diagram:

- Two spherical *s*-atomic orbitals are shown approaching each other along the internuclear axis (the *z*-axis).
- The wave functions have opposite signs, as indicated by the labels (+) and (–).
- Head-on (axial) overlap between atomic orbitals produces a σ symmetry framework.
- Because the wave functions have opposite signs, they undergo destructive interference upon combination. This causes a node to form between the two nuclei, identifying the product as an **antibonding sigma molecular orbital** (σ^*).

Final Answer: Antibonding sigma molecular orbital (σ^*)

Answer: (A)

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Q28.

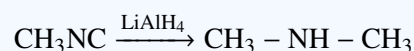
Solution

Concept: The reduction of nitrogen-containing functional groups with lithium aluminum hydride (LiAlH_4) yields amines whose substitution class (primary, secondary, or tertiary) depends on the structure of the starting material:

- Nitriles ($-\text{C} \equiv \text{N}$), Amides ($-\text{CONH}_2$), and Nitro groups ($-\text{NO}_2$) yield primary amines ($-\text{NH}_2$).
- Isocyanides ($-\text{N} \equiv \text{C}$) feature a nitrogen atom bonded internally to an alkyl group and a terminal carbon, which yields a secondary amine ($-\text{NH}-$) upon reduction.

Solution: Let us trace the reduction products for each option:

- **Methyl isocyanide ($\text{CH}_3 - \text{N} \equiv \text{C}$):** Reduction adds hydrogen atoms across the nitrogen-carbon multiple bonds, converting the terminal carbon into a methyl group. This yields dimethylamine, a **secondary amine**:



- **Acetamide (CH_3CONH_2):** The carbonyl group is reduced to a methylene unit, yielding ethylamine, a **primary amine**:



- **Nitrobenzene ($\text{C}_6\text{H}_5\text{NO}_2$):** Reduction yields aniline, a **primary aromatic amine**.
- **Acetonitrile (CH_3CN):** Reduction converts the nitrile group into a primary amine, yielding ethylamine ($\text{CH}_3\text{CH}_2\text{NH}_2$).

Therefore, methyl isocyanide is the unique structure that yields a secondary amine.

Final Answer:

Answer: (A)

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Q29.

Solution**Concept:** Number of atoms per unit cell:

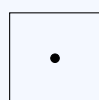
$$\text{SC} = 8 \times \frac{1}{8} = 1$$

$$\text{BCC} = 8 \times \frac{1}{8} + 1 = 2$$

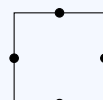
$$\text{FCC} = 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$$

Visual Representation:

SC = 1



BCC = 2



FCC = 4

Final Answer: 1, 2, and 4**Answer: (A)**[Go Back to Question 29](#)

Q30.

Solution

Concept: Rotating around the central C_2-C_3 σ -bond of *n*-butane generates different conformations. The stability of these conformations is determined by steric hindrance and torsional strain between the bulky terminal methyl ($-CH_3$) groups:

- **Fully Eclipsed** ($\theta = 0^\circ$): The methyl groups are directly aligned, causing maximum steric and torsional strain. This corresponds to the global energy maximum.
- **Gauche** ($\theta = 60^\circ, 300^\circ$): Staggered arrangement where the methyl groups are separated by a 60° dihedral angle, representing a local energy minimum.
- **Anti** ($\theta = 180^\circ$): Staggered arrangement where the bulky methyl groups are positioned as far apart as possible (dihedral angle of 180°). This minimizes steric repulsion, corresponding to the **global energy minimum**.

Solution: Analyzing the provided conformational energy profile:

- (a) The potential energy curve plotted as a function of the dihedral angle displays alternating maxima (eclipsed forms) and minima (staggered forms).
- (b) The absolute lowest point on the curve (the global energy minimum) occurs at a dihedral angle of exactly 180° .
- (c) This perfectly staggered spatial arrangement minimizes steric crowding, identifying it as the **anti-conformation**.

Final Answer:

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	B	3	A	4	A	5	A
6	A	7	A	8	A	9	C	10	A
11	B	12	A	13	A	14	A	15	A
16	A	17	A	18	A	19	A	20	A
21	A	22	A	23	A	24	A	25	A
26	A	27	A	28	A	29	A	30	A

