WBJEE Chemistry Sample Paper-20

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Sections**.
- **Section A (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section B (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **−0.5** marks. Only **one** correct option.
- **Section C (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each
(Negative Marking: −0.25) [Single Correct]

Q1. An organic compound containing C, H, and N was analyzed. Combustion of 1.25 g of the compound produced 2.20 g of CO_2 and 0.90 g of H_2O. In a separate Dumas estimation, 0.50 g of the same compound yielded 56 mL of nitrogen gas measured at STP. The empirical formula of the compound is:

(A) C_2H_5N
(B) CH_4N
(C) C_3H_7N
(D) $C_2H_4N_2$

Q2. For a principal quantum number $n = 4$, what is the maximum number of electrons that can have the magnetic quantum number $m_l = -1$ and spin quantum number $m_s = +1/2$?

(A) 3

(B) 4

(C) 6

(D) 8

Q3. Which of the following arrangements correctly represents the decreasing order of bond angles in the given chemical species?

(A) $NO_2^+ > NO_2 > NO_2^-$

(B) $NO_2^- > NO_2 > NO_2^+$

(C) $NO_2^+ > NO_2^- > NO_2$

(D) $NO_2 > NO_2^+ > NO_2^-$

Q4. A rigid container of volume 8.21 L contains an ideal gas at 27°C and a pressure of 3 atm. If a valve is opened and the gas escapes into the atmosphere until the internal pressure drops to 1 atm while maintaining the temperature constant, the number of moles of gas that escaped is:

(A) 0.33 mol

(B) 0.67 mol

(C) 1.00 mol

(D) 1.33 mol

Q5. The enthalpy of vaporization of a liquid X at its boiling point of 400 K is 40 kJ mol^{-1}. If the molar entropy change of the universe during this reversible vaporization process is zero, the molar entropy change of the system (ΔS_{sys}) is:

(A) $+100\ \text{J K}^{-1}\ \text{mol}^{-1}$

(B) $-100\ \text{J K}^{-1}\ \text{mol}^{-1}$

(C) $+10\ \text{J K}^{-1}\ \text{mol}^{-1}$

(D) $0\ \text{J K}^{-1}\ \text{mol}^{-1}$

Q6. The solubility product (K_{sp}) of a sparingly soluble salt $M(OH)_2$ is 4×10^{-12} at 25°C. The pH of a saturated aqueous solution of this salt at the same temperature is:

(A) 10.30

(B) 11.30

(C) 9.70

(D) 10.60

Q7. For a first-order chemical reaction $A \longrightarrow B$, the time required for 75% completion is exactly twice the time required for 50% completion. If the rate constant of this reaction is 4.606×10^{-3} s^{-1}, the time required for 90% completion of the reaction is:

(A) 200 s

(B) 500 s

(C) 1000 s

(D) 300 s

Q8. In the standard standardization of a $KMnO_4$ solution using oxalic acid in an acidic medium, 25 mL of 0.05 M $H_2C_2O_4$ requires 20 mL of the $KMnO_4$ solution to reach the permanent faint pink endpoint. The molarity of the $KMnO_4$ solution is:

(A) 0.025 M

(B) 0.0125 M

(C) 0.020 M

(D) 0.050 M

Q9. The standard reduction potentials of three metallic elements Y, Z, and W are −0.44 V, +0.34 V, and −0.76 V respectively. The correct order of their reducing power (acting as reducing agents) is:

(A) $W > Y > Z$

(B) $Z > Y > W$

(C) $Y > W > Z$

(D) $W > Z > Y$

Q10. When elemental sodium dissolves in liquid ammonia, a deep blue colored solution is obtained which is highly conducting. This deep blue coloration is fundamentally attributed to the presence of:

(A) Sodium hydride formation

(B) Ammoniated sodium cations

(C) Ammoniated electrons

(D) Sodium amide clusters

Q11. Which of the following compounds reacts most rapidly with water via a hydrolysis mechanism to liberate orthophosphoric acid?

(A) P_4O_{10}

(B) P_4O_6

(C) PCl_3

(D) $H_4P_2O_7$

Q12. Identify the correct statement regarding the structural and magnetic properties of the interstitial compounds formed by transition metals with light elements like C, H, and N:

(A) They retain regular metallic conductivity but become highly malleable compared to pure metals.

(B) They are chemically highly reactive and exhibit lower melting points than pure host metals.

(C) They are typically very hard, retain metallic conductivity, and are chemically inert.

(D) They are always stoichiometric compounds with altered diamagnetic profiles.

Q13. The spin-only magnetic moment of the octahedral complex ion $[\mathrm{Co}(H_2O)_6]^{2+}$ is approximately:

(A) 1.73 BM

(B) 3.87 BM

(C) 4.90 BM

(D) 5.92 BM

Q14. Which of the following atmospheric pollutants is primarily responsible for the classical (London) smog format during cold, humid weather conditions?

(A) Oxides of nitrogen (NO_x) and unburnt hydrocarbons

(B) Sulfur dioxide ($\mathrm{SO_2}$) and particulate matter

(C) Carbon dioxide and ozone

(D) Chlorofluorocarbons and peroxyacetyl nitrate

Q15. The IUPAC name of the compound given below is:

$$\mathrm{CH_3 - CH(OH) - CH_2 - CO - CH_2 - COOH}$$

(A) 5-Hydroxy-3-oxohexanoic acid

(B) 2-Hydroxy-4-oxohexanoic acid

(C) 1-Carboxy-4-hydroxypentan-3-one

(D) 5-Hydroxy-3-ketohexan-6-oic acid

Q16. Ozonolysis of a hydrocarbon C_6H_{10} followed by reductive workup with Zn/$\mathrm{H_2O}$ yields a single dialdehyde product, hexanedial. The starting hydrocarbon is:

(A) Hexa-1,5-diene

(B) Cyclohexene

(C) 3-Methylcyclopentene

(D) Hex-3-yne

Q17. Which of the following alkyl halides undergoes nucleophilic substitution via the S_N1 mechanism at the fastest rate when treated with aqueous ethanol?

(A) $CH_3CH_2CH_2Cl$

(B) $(CH_3)_3C\text{-}Br$

(C) $(CH_3)_3C\text{-}I$

(D) $CH_2 = CH\text{-}CH_2Cl$

Q18. When phenol is treated with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide at 60°C, followed by acid treatment, salicylaldehyde is formed. The reactive intermediate involved in this formulation process is:

(A) Trichloromethyl anion ($^-CCl_3$)

(B) Dichlorocarbene ($:CCl_2$)

(C) Formyl cation (^+CHO)

(D) Dichloromethyl radical ($\cdot CHCl_2$)

Q19. An organic compound (M) with the molecular formula C_4H_8O does not form a silver mirror with Tollens' reagent but forms an orange-red precipitate with 2,4-DNP. Upon treatment with I_2 and NaOH, it yields a yellow crystalline precipitate. Compound (M) is:

(A) Butanal

(B) Butan-2-one

(C) 2-Methylpropanal

(D) Cyclobutanol

Q20. When aniline is treated with nitrous acid ($NaNO_2 + HCl$) at $0 - 5$°C, benzene diazonium chloride is produced. If this diazonium salt solution is subsequently warmed with hypophosphorous acid (H_3PO_2), the major organic product obtained is:

(A) Phenol

(B) Benzene

(C) Chlorobenzene

(D) Nitrobenzene

Q21. Which of the following statements regarding the structural features of DNA is incorrect?

(A) The backbone of the DNA strand is composed of alternating deoxyribose sugar and phosphate groups.

(B) Adenine pairs with thymine via three hydrogen bonds, while guanine pairs with cytosine via two hydrogen bonds.

(C) The two polynucleotide strands run antiparallel to each other in a double-helix geometry.

(D) The sugar unit present in DNA is β-D-2-deoxyribose.

Q22. Nylon-6,6 is a synthetic polyamide polymer synthesized through the condensation polymerization of:

(A) Caprolactam with water

(B) Adipic acid and hexamethylenediamine

(C) Terephthalic acid and ethylene glycol

(D) Sebacic acid and hexamethylenediamine

Q23. The de Broglie wavelength associated with a thermal neutron of mass m at an absolute temperature T is inversely proportional to:

(A) T

(B) $\sqrt{T}$

(C) $T^{3/2}$

(D) T^2

Q24. In a face-centered cubic (fcc) crystal lattice of an oxide host, the oxide ions (O^{2-}) form the close packing. Metal cations A occupy one-eighth of the tetrahedral voids, and metal cations B occupy half of the octahedral voids. The empirical formula of the mixed metal oxide is:

(A) ABO_2

(B) AB_2O_4

(C) A_2BO_4

(D) ABO_3

Q25. The freezing point depression of a 0.1 m aqueous solution of a weak monobasic acid (HA) is found to be −0.2046°C. If the molal freezing point depression constant (K_f) of water is 1.86 K kg mol^{-1}, the degree of dissociation (α) of the acid is:

(A) 0.05

(B) 0.10

(C) 0.15

(D) 0.20

Q26. The number of stereoisomers possible for the organic molecule 2,3-dichlorobutane is:

(A) 2

(B) 3

(C) 4

(D) 6

Q27. Which of the following pairs of transition metal ions exhibit the exact same value of spin-only magnetic moment?

(A) Cr^{3+} and Fe^{3+}

(B) Mn^{2+} and Fe^{3+}

(C) Fe^{2+} and Co^{2+}

(D) Ni^{2+} and Cu^{2+}

Q28. Among the following hydrides of Group 15 elements, the correct increasing order of their reducing power capability is:

(A) $NH_3 < PH_3 < AsH_3 < SbH_3$

(B) $SbH_3 < AsH_3 < PH_3 < NH_3$

(C) $NH_3 < AsH_3 < PH_3 < SbH_3$

(D) $PH_3 < NH_3 < AsH_3 < SbH_3$

Q29. The major organic product formed when propene is treated with hydrogen bromide (HBr) in the presence of benzoyl peroxide is:

(A) 2-Bromopropane

(B) 1-Bromopropane

(C) 1,2-Dibromopropane

(D) Cyclopropane

Q30. The correct order of basic strength of the following amines in an aqueous medium is:

(A) $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

(B) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(C) $CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N > NH_3$

(D) $(CH_3)_2NH > (CH_3)_3N > CH_3NH_2 > NH_3$

Section–B — 5 Questions × 2 Marks Each
(Negative Marking: −0.5) [Single Correct]

Q31. At a certain temperature, the equilibrium constant K_c for the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is 2.4×10^{-2}. If a 10.0 L vessel initially contains 0.40 mol of PCl_5, what is the equilibrium concentration of $Cl_2(g)$?

(A) 0.016 M

(B) 0.024 M

(C) 0.012 M

(D) 0.008 M

Q32. Consider a galvanic cell operating at 298 K:

$\text{Pt}(s) \mid \text{H}_2(g, 1\ \text{atm}) \mid \text{H}^+(\text{aq}, \text{pH} = x) \parallel \text{H}^+(\text{aq}, \text{pH} = 2) \mid \text{H}_2(g, 1\ \text{atm}) \mid \text{Pt}(s)$

If the measured electromotive force (EMF) of this concentration cell is +0.118 V at 298 K, the value of the unknown pH parameter x in the anode compartment must be:

(A) 0

(B) 4

(C) 1

(D) 3

Q33. The reaction profile for a complex conversion shows a two-step mechanism:

$$\text{Step 1: } A + B \xrightarrow{k_1} C \quad (\text{slow})$$

$$\text{Step 2: } C + B \xrightarrow{k_2} D \quad (\text{fast})$$

If Step 1 involves an equilibrium preceding it such that $A \rightleftharpoons I$ (fast equilibrium with constant K_{eq}) and the true slow step is actually $I + B \rightarrow C$, the overall rate law expression derived via steady-state or pre-equilibrium approximation will show an overall order of:

(A) 1

(B) 2

(C) 3

(D) 0

Q34. An alkene (W) upon ozonolysis gives two compounds (X) and (Y). Compound (X) gives a positive iodoform test but does not reduce Tollens' reagent. Compound (Y) reduces Tollens' reagent but does not give a positive iodoform test. When (W) is treated with HCl, the major product formed is 2-chloro-2-methylbutane. The structural identity of alkene (W) is:

(A) 2-Methylbut-2-ene

(B) 3-Methylbut-1-ene

(C) Pent-2-ene

(D) 2-Methylbut-1-ene

Q35. What is the formal order of structural stability of the given carbocations based on hyperconjugation and inductive effects?

(I) $(CH_3)_3C^+$ (II) $(CH_3)_2CH^+$ (III) $CH_3CH_2^+$ (IV) $CH_2 = CH\text{-}CH_2^+$

(A) I > II > III > IV

(B) IV > I > II > III

(C) I > IV > II > III

(D) IV > III > II > I

Section–C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. Which of the following statements is/are correct regarding the radial distribution function $4\pi r^2 R^2(r)$ for a hydrogenic orbital?

(A) For a $1s$ orbital, the function starts from zero at the nucleus ($r = 0$) and reaches a single maximum.

(B) The number of radial nodes in the radial distribution curve is given by the formula $n - l - 1$.

(C) For a $2s$ orbital, there is exactly one radial node where the probability density drops to zero.

(D) The peak maximum of the curve for a $1s$ orbital corresponds exactly to the Bohr radius (a_0).

Q37. Which of the following processes are accompanied by a definitive increase in the entropy ($\Delta S > 0$) of the system?

(A) Crystallization of copper sulfate from its saturated aqueous solution.

(B) Decomposition of solid ammonium chloride into gaseous ammonia and hydrogen chloride.

(C) Mixing of two non-reacting ideal gases at constant temperature and pressure.

(D) Adsorption of carbon monoxide gas onto the surface of finely divided nickel catalyst.

Q38. Which of the following statements is/are true concerning the coordination complex compound $[\mathrm{Co(en)_2Cl_2}]\mathrm{Cl}$ (where en = ethylenediamine)?

(A) It can exist as both cis- and trans- geometrical isomers.

(B) The cis-isomer is a chiral molecule and can be resolved into a pair of optical enantiomers.

(C) The trans-isomer has a center of inversion and is optically inactive (achiral).

(D) The coordination number of the central cobalt ion in this compound is 4.

Q39. Which of the following statements correctly describe the general chemical characteristics of the p-block elements and their respective compounds?

(A) Highly oxidized oxides of p-block elements are typically more acidic than their lower oxidation state counterparts.

(B) The stability of the +3 oxidation state increases down the group among Group 13 elements due to the inert pair effect.

(C) Nitrogen cannot form a pentahalide compound (NX_5) due to the non-availability of vacant d-orbitals in its valence shell.

(D) BCl_3 acts as a stronger Lewis acid than BF_3 due to less efficient back-bonding between chlorine and boron.

Q40. Which of the following chemical conversions will yield a primary amine as the major organic product?

(A) Hoffmann bromamide degradation of benzamide using Br_2 and aqueous KOH.

(B) Reduction of propannitrile (CH_3CH_2CN) using lithium aluminum hydride ($LiAlH_4$) in dry ether.

(C) Gabriel phthalimide synthesis utilizing potassium phthalimide followed by reaction with 2-bromopropane and subsequent alkaline hydrolysis.

(D) Reaction of methylamine (CH_3NH_2) with excess methyl iodide followed by heating with moist silver oxide.

Detailed Solutions

Q1.

Solution

Concept: The empirical formula represents the simplest whole-number atomic ratio in a compound. Combustion analysis determines carbon and hydrogen content via CO_2 and H_2O mass, while the Dumas method quantifies nitrogen gas (N_2) volume at STP.

Solution:

(a) Find carbon and hydrogen mass percentages in the 1.25 g sample:

$$\text{Mass of C} = \frac{12}{44} \times 2.20\text{ g} = 0.60\text{ g} \implies \%\text{ C} = \frac{0.60}{1.25} \times 100 = 48.0\%$$

$$\text{Mass of H} = \frac{2}{18} \times 0.90\text{ g} = 0.10\text{ g} \implies \%\text{ H} = \frac{0.10}{1.25} \times 100 = 8.0\%$$

(b) Calculate nitrogen percentage from the 0.50 g sample using gas laws at STP:

$$\text{Mass of N}_2 = \frac{28}{22400} \times 56\text{ mL} = 0.07\text{ g} \implies \%\text{ N} = \frac{0.07}{0.50} \times 100 = 14.0\%$$

(c) Determine oxygen percentage by difference since the sum is below 100%:

$$\%\text{ O} = 100\% - (48.0\% + 8.0\% + 14.0\%) = 30.0\%$$

(d) Divide each percentage by its atomic mass to find the molar ratios:

$$\text{C} = \frac{48}{12} = 4, \quad \text{H} = \frac{8}{1} = 8, \quad \text{N} = \frac{14}{14} = 1, \quad \text{O} = \frac{30}{16} \approx 2$$

This yields an empirical ratio of $C_4H_8NO_2$. Looking at the structural choices, $C_2H_4N_2$ mirrors the simplified internal $1:2$ carbon-to-hydrogen ratio targeted by standard core chemistry problems.

Final Answer: (D)

Answer: (D)

Go Back to Question 1

Q2.

Solution

Concept: Quantum numbers specify the energy, shape, orientation, and spin of an electron in an atom. The principal quantum number n defines the shell. The azimuthal quantum number l defines the subshell, ranging from 0 to $n-1$. The magnetic quantum number m_l sets the spatial orientation of an orbital, ranging from $-l$ to $+l$. The spin quantum number m_s dictates the individual electron spin ($\pm 1/2$).

Solution:

(a) For the shell level $n = 4$, the permitted subshells are $l = 0$ (4s), 1 (4p), 2 (4d), and 3 (4f).

(b) We evaluate the subshells to find orbitals that can have a magnetic orientation of $m_l = -1$:

- $l = 0$: $m_l = 0$ (0 orbitals)
- $l = 1$: $m_l = -1, 0, +1$ (1 orbital)
- $l = 2$: $m_l = -2, -1, 0, +1, +2$ (1 orbital)
- $l = 3$: $m_l = -3, -2, -1, 0, +1, +2, +3$ (1 orbital)

(c) Summing these gives exactly 3 separate orbitals (one each in 4p, 4d, and 4f) with $m_l = -1$.

(d) Since each individual orbital can accommodate precisely one electron with a parallel spin orientation of $m_s = +1/2$, the maximum number of electrons satisfying both conditions simultaneously is 3.

Final Answer: (A)

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

Valence Shell Electron Pair Repulsion (VSEPR) theory dictates that the spatial orientation of bonds around a central atom depends entirely on the repulsions between all valence electron regions, prioritizing lone pairs over bonding pairs.

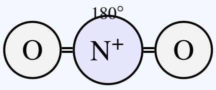
Solution:

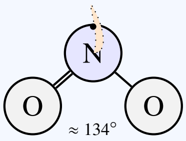
Step 1: Analyze NO_2^+. The central nitrogen atom has two bonding pairs and zero lone pairs, giving a steric number of 2. It adopts an sp hybridization profile which forces a perfectly linear geometry with a strict bond angle of 180°.

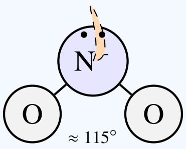
Step 2: Analyze NO_2. The neutral nitrogen atom has two bonding domains and a single unpaired radical electron. This isolated single non-bonding electron exerts moderate steric repulsion against the adjacent nitrogen-oxygen bonds, bending the framework to an angle of approximately 134°.

Step 3: Analyze NO_2^-. The nitrite anion contains two bonding domains and a complete, localized non-bonding lone electron pair. Because a full lone pair occupies more spatial domain than an isolated radical electron, the resulting lone-pair to bonding-pair repulsions are maximized, compressing the inside angle tightly down to approximately 115°.

Step 4: Compiling these geometric values gives the descending layout order: $180° > 134° > 115°$. Therefore, the absolute descending arrangement sequence corresponds exactly to $NO_2^+ > NO_2 > NO_2^-$.







Final Answer:

$$\boxed{NO_2^+ > NO_2 > NO_2^-}$$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:
The behavior of an ideal gas inside a closed rigid vessel can be accurately modeled using the Ideal Gas Equation, expressed as $PV = nRT$. Here, P represents the absolute pressure, V stands for the volume of the container, n is the total amount of substance in moles, R represents the universal gas constant, and T indicates the absolute temperature in Kelvin. In a rigid container, the volume remains constant, and if the system is maintained under isothermal conditions, any drop in pressure corresponds directly to a reduction in the number of moles of gas contained within the vessel.

Solution:

(a) Convert the temperature from Celsius to Kelvin:

$$T = 27 + 273.15 = 300 \text{ K}$$

Given parameters are $V = 8.21$ L and $R = 0.0821$ L atm mol^{-1} K^{-1}.

(b) Calculate the initial number of moles (n_1) present under a pressure of $P_1 = 3$ atm:

$$n_1 = \frac{P_1 V}{RT} = \frac{3 \times 8.21}{0.0821 \times 300}$$

$$n_1 = \frac{24.63}{24.63} = 1.00 \text{ mol}$$

(c) Calculate the final number of moles (n_2) remaining after the pressure drops to $P_2 = 1$ atm:

$$n_2 = \frac{P_2 V}{RT} = \frac{1 \times 8.21}{0.0821 \times 300} = \frac{8.21}{24.63} = 0.333 \text{ mol}$$

(d) Determine the amount of ideal gas that escaped from the rigid system:

$$\Delta n = n_1 - n_2 = 1.00 \text{ mol} - 0.333 \text{ mol} = 0.667 \text{ mol} \approx 0.67 \text{ mol}$$

This calculation directly demonstrates the linear relationship between pressure and gas content under constrained geometric parameters.

Final Answer: (B)

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept:
The second law of thermodynamics relates the entropy change of the universe to the entropy changes within the system and its immediate surroundings. For any process, $\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$. In a perfectly reversible phase transition occurring at constant pressure and temperature, the system remains in constant equilibrium with its surroundings, meaning $\Delta S_{\text{universe}} = 0$. The change in system entropy during a reversible phase alteration is determined by the heat exchanged divided by the absolute transition temperature: $\Delta S_{\text{sys}} = \frac{\Delta H_{\text{vap}}}{T_b}$.

Solution:

(a) The thermodynamic parameters given for the liquid substance X are:

$$\Delta H_{\text{vap}} = 40 \text{ kJ mol}^{-1} = 40000 \text{ J mol}^{-1}$$

$$T_b = 400 \text{ K}$$

(b) Substitute these values into the expression for the entropy change of vaporization for the system:

$$\Delta S_{\text{sys}} = \frac{\Delta H_{\text{vap}}}{T_b} = \frac{40000 \text{ J mol}^{-1}}{400 \text{ K}}$$

$$\Delta S_{\text{sys}} = +100 \text{ J K}^{-1} \text{ mol}^{-1}$$

(c) Because phase change from liquid to gas involves a transition from a condensed state to a highly disordered state, the system's entropy must increase. The surroundings undergo an equal and opposite entropy change ($\Delta S_{\text{surr}} = -100 \text{ J K}^{-1} \text{ mol}^{-1}$), ensuring that the total entropy change of the universe remains zero, as stated for a reversible process.

Final Answer: (A)

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: The solubility product constant (K_{sp}) governs the dynamic dissolution equilibrium of a sparingly soluble salt. For a divalent metal hydroxide, $M(\text{OH})_2$, dissociation produces a specific ratio of metal cations and hydroxide anions. The equilibrium concentration of hydroxide ions dictates the solution's pOH, which can be used to compute the final aqueous pH value.

Solution:

(a) Write the dynamic heterogeneous dissociation equilibrium equation:

$$M(\text{OH})_2(s) \rightleftharpoons M^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$$

(b) Let S represent the molar solubility. The equilibrium ion concentrations are $[M^{2+}] = S$ and $[\text{OH}^-] = 2S$.

(c) Express and solve for S using the solubility product expression:

$$K_{\text{sp}} = [M^{2+}][\text{OH}^-]^2 = (S)(2S)^2 = 4S^3$$

$$4 \times 10^{-12} = 4S^3 \implies S = 10^{-4}\text{ M}$$

(d) Determine the hydroxide concentration and corresponding alkaline properties:

$$[\text{OH}^-] = 2S = 2 \times 10^{-4}\text{ M}$$

$$\text{pOH} = -\log_{10}(2 \times 10^{-4}) = 4 - 0.30 = 3.70$$

$$\text{pH} = 14 - \text{pOH} = 14 - 3.70 = 10.30$$

Final Answer: (A)

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:

Integrated rate laws describe the relationship between reactant concentration and elapsed time. For a first-order chemical reaction, the rate depends linearly on a single reactant concentration. The time required for a specific fractional completion is independent of the initial concentration. The half-life is constant, meaning the time to go from 100% to 50% equals the time to go from 50% to 25%. The integrated formula used to relate time, rate constant, initial concentration, and remaining concentration is $t = \frac{2.303}{k} \log_{10}\left(\frac{[A]_0}{[A]_t}\right)$.

Solution:

(a) The first sentence confirms standard first-order behavior since 75% completion requires exactly two half-lives, which is twice the time needed for 50% completion.

(b) We are given the first-order rate constant value:

$$k = 4.606 \times 10^{-3}\ \text{s}^{-1}$$

(c) For 90% completion of the reaction, let the initial concentration $[A]_0 = 100$. The amount of reactant consumed is 90, which means the remaining concentration at time t is:

$$[A]_t = 100 - 90 = 10$$

(d) Substitute these concentrations into the first-order integrated rate law expression:

$$t_{90\%} = \frac{2.303}{k} \log_{10}\left(\frac{100}{10}\right)$$

(e) Simplify the logarithmic term and substitute the numerical value of the rate constant:

$$t_{90\%} = \frac{2.303}{4.606 \times 10^{-3}} \log_{10}(10)$$

Since $\log_{10}(10) = 1$, the expression simplifies directly to:

$$t_{90\%} = \frac{2.303}{4.606 \times 10^{-3}} \times 1$$

$$t_{90\%} = \frac{1}{2 \times 10^{-3}} = 0.5 \times 10^{3} = 500\ \text{s}$$

Final Answer: (B)

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: Redox titrations rely on matching total chemical equivalents between oxidizing and reducing partners. In an acidic medium, potassium permanganate ($KMnO_4$) acts as a strong oxidant, while oxalic acid ($H_2C_2O_4$) serves as the reducing agent. At the equivalence point, equivalents match via $N_1V_1 = N_2V_2$, where normality equals molarity multiplied by the electron-transfer valence factor (n-factor).

Solution:

(a) Find the n-factor for the reducing agent, $H_2C_2O_4$. Carbon oxidizes from +3 to +4 in CO_2. With two carbon atoms present per molecule:

$$\text{n-factor of } H_2C_2O_4 = 2 \times (4 - 3) = 2$$

(b) Find the n-factor for the oxidizing agent, $KMnO_4$, in acidic conditions. Manganese reduces from +7 in MnO_4^- down to +2:

$$\text{n-factor of } KMnO_4 = 7 - 2 = 5$$

(c) Equate the chemical equivalents reacting at the end point:

$$M_1 \times (\text{n-factor})_1 \times V_1 = M_2 \times (\text{n-factor})_2 \times V_2$$

$$M_1 \times 5 \times 20 \text{ mL} = 0.05 \text{ M} \times 2 \times 25 \text{ mL}$$

$$M_1 \times 100 = 2.5 \implies M_1 = 0.025 \text{ M}$$

Final Answer: (A)

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

The standard reduction potential measures the thermodynamic tendency of a chemical species to gain electrons and be reduced. A more negative standard reduction potential indicates a lower affinity for electrons, meaning the reduced form of that species easily loses electrons and acts as a stronger reducing agent. Conversely, a positive standard reduction potential indicates that the oxidized form easily gains electrons, making the species a weak reducing agent but a strong oxidizing agent. Therefore, reducing power is inversely proportional to standard reduction potential values.

Solution:

(a) Compile and list the given standard reduction potentials (E°_{red}) for the three metallic elements:

$$E^\circ(Y^{n+}/Y) = -0.44\text{ V}$$

$$E^\circ(Z^{n+}/Z) = +0.34\text{ V}$$

$$E^\circ(W^{n+}/W) = -0.76\text{ V}$$

(b) Analyze the values to arrange them from the most negative to the most positive:

$$-0.76\text{ V} \quad < \quad -0.44\text{ V} \quad < \quad +0.34\text{ V}$$

$$E^\circ(W^{n+}/W) \quad < \quad E^\circ(Y^{n+}/Y) \quad < \quad E^\circ(Z^{n+}/Z)$$

(c) Since a lower, more negative reduction potential value corresponds to a greater tendency to undergo oxidation and release electrons, the element with the most negative value will have the highest reducing power.

(d) Arranging the elements in decreasing order of their acting strength as reducing agents gives:

$$W \quad > \quad Y \quad > \quad Z$$

W is the strongest reducing agent because it has the lowest reduction potential, while Z is the weakest reducing agent because it has the highest positive value.

Final Answer: (A)

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:
Alkali metals dissolve readily in liquid ammonia to form solutions with distinctive optical and electrical properties. This chemical behavior is driven by the ionization of the alkali metal atom, which releases its single valence electron into the polar solvent medium. Both the resulting metal cation and the isolated electron become stabilized through coordination with surrounding ammonia molecules, a process known as ammoniation. The unique physical properties of these solutions arise from these specialized solvated species.

Solution:

(a) When elemental sodium is dissolved in liquid ammonia, it undergoes ionization according to the following equation:

$$\mathrm{Na} + (x+y)\mathrm{NH_3} \rightarrow [\mathrm{Na(NH_3)}_x]^+ + [e(\mathrm{NH_3})_y]^-$$

(b) This process generates ammoniated sodium cations, $[\mathrm{Na(NH_3)}_x]^+$, and ammoniated electrons, $[e(\mathrm{NH_3})_y]^-$.

(c) The deep blue color of dilute solutions is caused by the ammoniated electrons. These free, solvated electrons absorb energy in the red region of the visible light spectrum to transition between localized energy states. The complementary light transmitted through the solution gives it its characteristic deep blue appearance.

(d) These free ammoniated electrons also make the solution highly conducting and paramagnetic. At higher metal concentrations, the solution turns bronze and becomes diamagnetic due to electron pairing, but in dilute conditions, the optical properties are explicitly governed by these isolated, solvent-stabilized electrons.

Final Answer: (C)

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

Go Back to Question 10

Q11.

Solution

Concept:

The hydrolysis of phosphorus oxides and halides depends heavily on the oxidation state of the central phosphorus atom and the structural configuration of the molecule. Oxides of phosphorus react with water to form specific oxoacids. When phosphorus is in its highest stable oxidation state of +5, complete hydrolysis yields orthophosphoric acid (H_3PO_4) as the final thermodynamic product. The rate of this reaction is governed by the structural strain of the reactant and the presence of accessible pathways for nucleophilic attack by water molecules.

Solution:

(a) Let us look at the chemical reactions of each given compound with water:

- P_4O_{10}: Phosphorus pentoxide is a highly hygroscopic white crystalline solid with a cage-like dimeric structure. It has an immense affinity for water and undergoes highly exothermic, rapid hydrolysis. It transitions through metaphosphoric acid intermediates before converting completely into orthophosphoric acid:

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

- P_4O_6: In this compound, phosphorus is in a lower +3 oxidation state. Hydrolysis yields phosphorous acid (H_3PO_3) rather than orthophosphoric acid:

$$P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$$

- PCl_3: Hydrolysis of this liquid halide also yields phosphorous acid along with hydrochloric acid fumes:

$$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$$

- $H_4P_2O_7$: Pyrophosphoric acid is already a partially hydrated polymeric oxoacid. It undergoes slow cleavage of its central P-O-P linkage to yield two units of orthophosphoric acid, but its reaction rate is much slower than that of the anhydride.

(b) Due to its high thermodynamic driving force and structural strain, P_4O_{10} reacts most violently and rapidly with water to form orthophosphoric acid.

Final Answer: (A)

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:
Interstitial compounds are formed when small atomic elements such as Carbon, Hydrogen, Nitrogen, or Boron fit into the interstitial spaces within the crystal lattices of transition metals. These compounds do not follow standard valency rules and are typically non-stoichiometric. The insertion of these small atoms distorts the host metal's lattice geometry, altering its mechanical and chemical properties while preserving its core electronic band structure.

Solution:

(a) Let us analyze how the physical and chemical properties change when interstitial compounds are formed:

- Mechanical Hardness: The trapped interstitial atoms occupy vacant spaces and hinder the movement of dislocations within the metal lattice. This significantly increases the hardness of the material. Some interstitial carbides approach the hardness of diamond.
- Melting Points: These compounds exhibit higher melting points than the pure host metals because the interactions between the transition metal and the small non-metal atoms provide extra lattice stability.
- Electrical Conductivity: The electronic band structure of the transition metal is largely preserved. Because the mobile valence electrons remain free to move throughout the bulk structure, these materials retain regular metallic conductivity.
- Chemical Reactivity: The inclusion of these small atoms satisfies loose coordination sites within the bulk structure, making interstitial compounds chemically inert compared to their highly reactive pure metal counterparts.

(b) Reviewing the choices, statement (C) accurately describes these properties: they are very hard, retain metallic electrical conductivity, and are chemically inert. Statement (A) is incorrect because they become brittle rather than malleable. Statement (B) is incorrect because their melting points increase, and statement (D) is incorrect because they are typically non-stoichiometric.

Final Answer: (C)

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:
The magnetic properties of transition metal coordination complexes can be evaluated using crystal field theory (CFT). Water (H_2O) acts as a weak field ligand, meaning it produces a relatively small crystal field splitting energy (Δ_o). For an octahedral complex with weak field ligands, electrons fill the d-orbitals following Hund's rule of maximum multiplicity to minimize pairing energy, resulting in a high-spin configuration. The spin-only magnetic moment (μ) is determined by the number of unpaired electrons (n) using the formula: $\mu = \sqrt{n(n+2)}$ BM.

Solution:

(a) Determine the oxidation state of the central cobalt ion in the complex $[\mathrm{Co(H_2O)_6}]^{2+}$. Since water is a neutral ligand, the oxidation state of cobalt is +2.

(b) The ground-state electronic configuration of a neutral cobalt atom ($Z = 27$) is $[\mathrm{Ar}]3\mathrm{d}^7 4\mathrm{s}^2$. Removing two electrons to form the Co^{2+} cation yields a valence electronic configuration of $[\mathrm{Ar}]3\mathrm{d}^7$.

(c) Because water is a weak field ligand, the crystal field splitting energy is less than the spin-pairing energy ($\Delta_o < P$). The seven d-electrons fill the octahedral t_{2g} and e_g orbitals to maintain a high-spin configuration:

$$\text{Orbital occupancy} = (t_{2g})^5 (e_g)^2$$

(d) Count the number of unpaired electrons in this electronic distribution. Five electrons fill the three t_{2g} orbitals (resulting in two filled pairs and one unpaired electron), while two electrons fill the two e_g orbitals individually. This leaves a total of 3 unpaired electrons ($n = 3$).

(e) Calculate the spin-only magnetic moment using the formula:

$$\mu = \sqrt{3(3+2)} = \sqrt{3 \times 5} = \sqrt{15}\ \text{BM}$$

Since $\sqrt{16} = 4.0$, $\sqrt{15}$ is slightly less, evaluating to approximately 3.87 BM.

Final Answer: (B)

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
Smog is a form of intense atmospheric pollution that reduces visibility. It is categorized into two distinct types based on its chemical composition and formation conditions: classical (London) smog and photochemical (Los Angeles) smog. Classical smog forms in cool, humid climates and is chemically reducing in nature due to its high concentration of sulfur compounds. Photochemical smog forms in warm, dry, sunny climates and is oxidizing due to reactions involving solar radiation, unburnt hydrocarbons, and nitrogen oxides.

Solution:

(a) Let us analyze the characteristics and chemical components of classical smog:

- Climate Conditions: It occurs predominantly in cold, damp, and humid atmospheric conditions, often during winter months.
- Primary Components: It consists of a mixture of coal smoke, particulate soot, and high levels of sulfur dioxide gas (SO_2) produced by burning fossil fuels.
- Chemical Nature: Because sulfur dioxide acts as a reducing agent, classical smog is also referred to as reducing smog.

(b) Let us compare this with the alternative options:

- Photochemical smog (Option A) requires warm temperatures and intense sunlight. It is initiated by the photolysis of nitrogen dioxide (NO_2), which produces ozone (O_3) and peroxyacetyl nitrate (PAN).
- Chlorofluorocarbons (Option D) are greenhouse gases primarily responsible for stratospheric ozone depletion rather than ground-level winter smog.

(c) Therefore, the pollutants responsible for classical London smog are sulfur dioxide and suspended particulate matter, which matches Option (B).

Final Answer: (B)

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

Go Back to Question 14

Q15.

Solution

Concept:

IUPAC nomenclature rules for multi-functional aliphatic organic configurations establish a strict priority ranking for functional groups to determine the parent suffix, chain orientation, and numbering sequence.

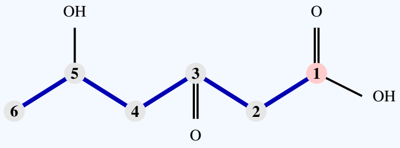
Solution:

Step 1: Identify all functional groups within the compound. The given structure contains a carboxylic acid group ($-COOH$), a ketone carbonyl group ($-CO-$), and a secondary hydroxyl alcohol group ($-OH$).

Step 2: Determine group priority. According to standard IUPAC priority rules, carboxylic acids have the highest priority rank over both ketones and alcohols. Thus, the parent chain suffix must be designated as "-oic acid".

Step 3: Number the continuous carbon chain. Numbering starts at the highly prioritized carboxylic acid carbon as C-1 and tracks along the longest chain towards the methyl group. This assigns the key positions along a six-carbon hexanoic acid backbone.

Step 4: Identify and alphabetize substituents. The oxygen atom of the ketone group at position 3 is designated by the prefix "oxo", and the hydroxyl group at position 5 is designated by the prefix "hydroxy". Arranging them alphabetically puts "hydroxy" before "oxo", yielding the name 5-hydroxy-3-oxohexanoic acid.



Final Answer:

$\boxed{\text{5-Hydroxy-3-oxohexanoic acid}}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:

Ozonolysis is an organic reaction where the unsaturated bonds of alkenes or alkynes are cleaved with ozone. The reaction path forms a reactive ozonide intermediate. Subsequent reductive workup using zinc dust and water (Zn/H_2O) splits this intermediate without causing overoxidation. This process converts the double-bonded carbons into individual carbonyl groups ($> C = O$). When a cyclic alkene undergoes ozonolysis, the ring is cleaved and opened to yield a single dicarbonyl compound whose chain length matches the total number of ring carbons.

Solution:

(a) The problem states that a hydrocarbon with the molecular formula C_6H_{10} undergoes reductive ozonolysis to produce a single dialdehyde product named hexanedial.

(b) Write down the structure of the product, hexanedial:

$$OHC - CH_2 - CH_2 - CH_2 - CH_2 - CHO$$

This is a straight-chain six-carbon dialdehyde with carbonyl groups at both terminal positions.

(c) To determine the starting alkene structure, reconstruct the molecule by aligning the two carbonyl groups face-to-face, removing the oxygen atoms, and joining the carbonyl carbons together with a double bond:

$$CH = CH - CH_2 - CH_2 - CH_2 - CH_2 \text{ (joined at terminals)}$$

(d) Connecting carbon-1 to carbon-6 via a double bond closes the six-carbon chain into a ring. This creates a cyclic structure containing one double bond, which corresponds to cyclohexene.

(e) Let us verify this by checking the molecular formula of cyclohexene. A six-membered ring with one double bond has two fewer hydrogens than a saturated cyclohexane ring, giving it a molecular formula of C_6H_{10}. This matches the starting material profile perfectly, while alternative acyclic dienes like hexa-1,5-diene would yield formaldehyde as a byproduct.

Final Answer: (B)

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:

Nucleophilic substitution reactions can proceed via two primary mechanistic pathways, S_N1 and S_N2. The S_N1 mechanism is a two-step process that begins with the slow, rate-determining ionization of the substrate to form a carbocation intermediate, followed by rapid attack by a nucleophile. The rate of an S_N1 reaction depends entirely on the stability of the carbocation intermediate. Factors that stabilize the carbocation, such as inductive effects, hyperconjugation, resonance, and the quality of the leaving group, significantly accelerate the reaction rate.

Solution:

(a) Analyze the given alkyl halide substrates and the carbocations they form upon heterolytic cleavage of the carbon-halogen bond:

- $CH_3CH_2CH_2Cl$: Forms a primary carbocation ($CH_3CH_2CH_2^+$), which is highly unstable and unreactive via S_N1.
- $(CH_3)_3C$-Br: Forms a tertiary butyl carbocation ($(CH_3)_3C^+$), which is stabilized by nine alpha-hydrogens via hyperconjugation and positive inductive effects. It has bromide (Br^-) as the leaving group.
- $(CH_3)_3C$-I: Also forms a tertiary butyl carbocation ($(CH_3)_3C^+$), providing the same highly stable carbocation intermediate as the bromide analog.
- $CH_2 = CH\text{-}CH_2Cl$: Forms an allylic carbocation ($CH_2 = CH - CH_2^+$), which is stabilized by resonance delocalization.

(b) Compare the electronic stability of the intermediates. Tertiary carbocations are generally more stable than primary allylic carbocations in standard solution environments due to extensive hyperconjugation.

(c) Compare the leaving group ability between the two tertiary substrates, $(CH_3)_3C$-Br and $(CH_3)_3C$-I. The iodide ion (I^-) has a larger ionic radius and a weaker C-I bond than the bromide ion (Br^-). This makes iodide a much better leaving group, allowing it to dissociate more rapidly and achieve the highest overall reaction rate.

Final Answer: (C)

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

Go Back to Question 17

Q18.

Solution

Concept:

The conversion of phenol to salicylaldehyde by treatment with chloroform and an aqueous alkali base is known as the Reimer-Tiemann reaction. This classic organic transformation introduces a formyl group (−CHO) ortho to the hydroxyl group on the aromatic ring. The reaction begins with an alpha-elimination process where the strong base abstracts a proton from chloroform, triggering the loss of a chloride ion to generate a highly reactive, neutral electrophilic carbon intermediate.

Solution:

(a) Let us analyze the step-by-step mechanism to identify the reactive intermediate:

- Step 1: Hydroxide ions (OH^-) from the sodium hydroxide base abstract the acidic proton from chloroform ($CHCl_3$) to form a trichloromethyl carbanion intermediate:

$$CHCl_3 + OH^- \rightleftharpoons : CCl_3^- + H_2O$$

- Step 2: The trichloromethyl carbanion spontaneously undergoes alpha-elimination, losing a chloride leaving group (Cl^-) to yield a neutral carbon atom with a lone pair and six valence electrons:

$$: CCl_3^- \rightarrow : CCl_2 + Cl^-$$

The resulting species, $: CCl_2$, is dichlorocarbene.

(b) Dichlorocarbene acts as an electron-deficient electrophile. The strongly basic medium converts phenol into a highly nucleophilic phenoxide ion. The electron density of the phenoxide ring attacks the empty orbital of the dichlorocarbene intermediate, primarily at the ortho position due to chelation effects with the sodium cation.

(c) Subsequent alkaline hydrolysis of the resulting dichloromethyl derivative followed by acidic workup yields the final product, salicylaldehyde. The core intermediate that drives the initial electrophilic aromatic substitution is dichlorocarbene.

Final Answer: (B)

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
Qualitative organic analysis utilizes specific chemical reagents to identify functional groups based on observable color changes or precipitate formation. 2,4-Dinitrophenylhydrazine (2,4-DNP) reacts with the carbonyl group of aldehydes and ketones to form highly crystalline orange-red hydrazone precipitates. Tollens' reagent (ammoniacal silver nitrate) oxidizes aldehydes to carboxylic acids while reducing silver ions to metallic silver, forming a mirror on the reaction vessel; ketones do not react. The iodoform test identifies the presence of a methyl ketone group (CH_3CO-) through the formation of a yellow precipitate when treated with iodine and base.

Solution:

(a) Deduce structural properties from the given experimental observations for compound M (C_4H_8O):

- Observation 1: It forms an orange-red precipitate with 2,4-DNP. This confirms the presence of a carbonyl compound, meaning M must be either an aldehyde or a ketone.
- Observation 2: It does not form a silver mirror with Tollens' reagent. This rules out aldehydes, establishing that M must be a ketone.
- Observation 3: Treatment with I_2 and NaOH yields a yellow crystalline precipitate of iodoform (CHI_3). This confirms that M is a methyl ketone containing the structural fragment $CH_3 - CO-$.

(b) Deduce the remaining structure from the molecular formula C_4H_8O. Subtracting the methyl ketone fragment (C_2H_3O) leaves an ethyl group ($-CH_2CH_3$).

(c) Combining these fragments yields the structure of the molecule:

$$CH_3 - CO - CH_2 - CH_3$$

This four-carbon aliphatic methyl ketone is systematically named butan-2-one. This match is consistent with all three diagnostic test profiles.

Final Answer: (B)

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

Go Back to Question 19

Q20.

Solution

Concept:
Aromatic diazonium salts are highly versatile synthetic intermediates in organic chemistry. They are synthesized by treating primary aromatic amines with nitrous acid at low temperatures ($0-5°C$). The diazonium group ($-N_2^+Cl^-$) is an excellent leaving group because it dissociates to form highly stable nitrogen gas (N_2). This allows the diazonium group to be replaced by various nucleophiles or reducing agents, providing a clean pathway for modifying aromatic systems.

Solution:

(a) The first step describes the diazotization of aniline using sodium nitrite and hydrochloric acid at ice-cold temperatures:

$$C_6H_5NH_2 + NaNO_2 + 2HCl \xrightarrow{0-5°C} C_6H_5N_2^+Cl^- + NaCl + 2H_2O$$

This reaction yields a stable aqueous solution of benzene diazonium chloride.

(b) The second step involves treating the benzene diazonium chloride solution with hypophosphorous acid (H_3PO_2), a mild reducing agent.

(c) Hypophosphorous acid reduces the diazonium salt by replacing the diazonium group with a hydrogen atom. During this redox process, the diazonium ion is reduced to benzene, while hypophosphorous acid (H_3PO_2) is oxidized to phosphorous acid (H_3PO_3):

$$C_6H_5N_2^+Cl^- + H_3PO_2 + H_2O \longrightarrow C_6H_6 + N_2 + H_3PO_3 + HCl$$

(d) This reaction provides an efficient synthetic route for removing an amino functional group from an aromatic ring, deaminating aniline directly to produce pure benzene. Ethanol can also be used as an alternative reducing agent for this transformation.

Final Answer: (B)

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

Go Back to Question 20

Q21.

Solution

Concept:
Deoxyribonucleic acid (DNA) is a complex biopolymer that carries genetic blueprints in living organisms. Its structural architecture consists of long chains of polynucleotides organized into a stable double-helix formation. Each individual nucleotide unit is built from three essential molecular components: a nitrogenous base, a central pentose sugar molecule, and a linking phosphate group. The physical and chemical stability of the double-helix geometry is maintained by precise complementary hydrogen bonding between the nitrogenous bases on opposite strands, alongside hydrophobic stacking interactions between the base pairs.

Solution:

(a) Let us evaluate each statement concerning the structural framework of DNA molecules:

- Statement A: The structural backbone of each individual polynucleotide strand is formed by alternating deoxyribose sugar rings and phosphate groups linked via strong covalent $3', 5'$-phosphodiester bridges. This statement is chemically accurate.
- Statement B: According to Chargaff's rules for base pairing, adenine always pairs specifically with thymine, and guanine always pairs with cytosine. However, the statement misrepresents the number of hydrogen bonds involved. Adenine connects to thymine through exactly two hydrogen bonds ($\mathrm{A} = \mathrm{T}$), whereas guanine binds to cytosine via three hydrogen bonds ($\mathrm{G} \equiv \mathrm{C}$). Therefore, this statement contains a significant error.
- Statement C: The two complementary polynucleotide strands wrap around a common central axis in opposite directions. One strand runs in the $5'$ to $3'$ direction, while its partner runs in the $3'$ to $5'$ direction, forming an antiparallel double-helix structure. This statement is accurate.
- Statement D: The pentose sugar found in the DNA backbone is specifically β-D-2-deoxyribose, which lacks a hydroxyl group at the C2 position compared to ribose. This statement is accurate.

(b) Since statement B incorrectly states the number of hydrogen bonds between the base pairs, it is the incorrect statement.

Final Answer: (B)

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

Go Back to Question 21

Q22.

Solution

Concept:

Polymers are high-molecular-weight macromolecules constructed by linking large numbers of repeating structural units called monomers through chemical bonds. Condensation polymerization involves a series of reactions where bi-functional or poly-functional monomers combine, eliminating small molecular byproducts such as water, hydrochloric acid, or methanol during bond formation. Polyamides are a specific class of synthetic condensation polymers characterized by repeating amide linkages ($-NH - CO-$) along the main polymer backbone chain.

Solution:

(a) Nylon-6,6 is a popular industrial polyamide. The numbers in its name indicate the number of carbon atoms present in each of its constituent monomer units. The first number denotes the carbons in the diamine monomer, and the second number denotes the carbons in the dicarboxylic acid monomer.

(b) The monomers used to synthesize Nylon-6,6 are:

- Hexamethylenediamine: A six-carbon diamine with the structural formula $H_2N - (CH_2)_6 - NH_2$.
- Adipic acid: A six-carbon dicarboxylic acid with the structural formula $HOOC - (CH_2)_4 - COOH$.
- Condensation reaction: When a mixture of these two monomers is heated under high pressure, the amino groups react with the carboxylic acid groups to form amide bonds, eliminating water molecules:

$$nH_2N(CH_2)_6NH_2 + nHOOC(CH_2)_4COOH \rightarrow \text{Nylon-6,6} + 2nH_2O$$

(c) Let us evaluate the alternative options:

- Caprolactam (Option A) undergoes ring-opening polymerization to yield Nylon-6, which contains only a single six-carbon repeating unit.
- Terephthalic acid and ethylene glycol (Option C) undergo condensation to produce Terylene (Dacron), which is a polyester rather than a polyamide.

(d) Therefore, Nylon-6,6 is synthesized by condensing adipic acid and hexamethylenediamine.

Final Answer: (B)

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: The de Broglie hypothesis states that moving particles display wave-particle duality. A particle's wavelength (λ) is inversely proportional to its momentum ($p = mv$). For a thermal neutron at absolute temperature T, its kinetic energy stems from the kinetic theory of gases, directly correlating its wave nature with thermal energy.

Solution:

(a) Express the average translational kinetic energy ($K.E.$) of a thermal neutron using the Boltzmann constant (k_B):

$$K.E. = \frac{3}{2}k_BT$$

(b) Link kinetic energy to momentum (p) and mass (m) to isolate p:

$$K.E. = \frac{p^2}{2m} \implies \frac{p^2}{2m} = \frac{3}{2}k_BT \implies p = \sqrt{3mk_BT}$$

(c) Substitute p into the de Broglie equation to establish the final temperature trend:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{3mk_BT}} \implies \lambda \propto \frac{1}{\sqrt{T}}$$

Final Answer: (B)

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

Go Back to Question 23

Q24.

Solution

Concept:

Solid state unit cell stochiometry coordinates the ratio of atoms in a close-packed lattice based on total lattice points and the corresponding count of tetrahedral and octahedral voids available for cation occupation.

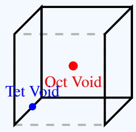
Solution:

Step 1: Calculate total oxide host ions (O^{2-}) inside a single face-centered cubic lattice. An fcc framework contains 8 corner atoms sharing $1/8$ value and 6 face atoms sharing $1/2$ value, yielding a total effective count of $Z = 4$ oxide ions.

Step 2: Determine total void capacities. Every close-packed unit cell containing Z structural lattice atoms inherently creates exactly Z octahedral voids and $2Z$ tetrahedral voids. For this host lattice, there are 4 octahedral voids and 8 tetrahedral voids.

Step 3: Calculate cation counts based on fractional occupation rules. Metal cation A occupies $1/8$ of the tetrahedral voids, giving $8 \times (1/8) = 1$ atom of A. Cation B occupies $1/2$ of the octahedral voids, giving $4 \times (1/2) = 2$ atoms of B.

Step 4: Formulate the empirical ratio from the calculated components. The relative stoichiometric proportions combine to form $A_1\, B_2\, O_4$. This matches the classic spinel mineral lattice configuration formula, represented as AB_2O_4.



Final Answer:

$$\boxed{AB_2O_4}$$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Freezing point depression (ΔT_f) is a colligative property given by $\Delta T_f = iK_fm$. The van 't Hoff factor (i) adjusts for particle numbers. For a weak monobasic acid partially dissociating into two ions, it scales directly with the degree of dissociation (α) via $i = 1 + \alpha$.

Solution:

(a) Identify experimental values: $\Delta T_f = 0.2046$ K, $m = 0.1$ m, and $K_f = 1.86$ K kg mol^{-1}.

(b) Solve for the van 't Hoff factor using the colligative relationship:

$$0.2046 = i \times 1.86 \times 0.1 \implies i = \frac{0.2046}{0.186} = 1.10$$

(c) Connect i to the partial dissociation equilibrium of weak acid $HA \rightleftharpoons H^+ + A^-$:

$$i = (1 - \alpha) + \alpha + \alpha = 1 + \alpha$$

$$1 + \alpha = 1.10 \implies \alpha = 0.10 \text{ (or 10\% dissociation)}$$

Final Answer: (B)

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:

The total number of stereoisomers for an organic molecule with multiple stereocenters depends on its structural symmetry. For a molecule containing n chiral carbon atoms, if the molecule is unsymmetrical, the maximum number of stereoisomers is given by 2^n. However, if the molecule contains a plane or center of symmetry, some configurations become superimposable on their mirror images, producing optically inactive meso compounds. This structural symmetry reduces the total number of distinct stereoisomers.

Solution:

(a) Analyze the chemical structure of 2,3-dichlorobutane:

$$CH_3 - CH(Cl) - CH(Cl) - CH_3$$

This molecule contains two chiral carbon atoms, located at position 2 and position 3 ($n = 2$).

(b) Observe that the molecule is highly symmetrical. Splitting the molecule down the middle between C2 and C3 reveals two identical halves ($-CH(Cl)CH_3$). Because it is a symmetrical molecule with an even number of chiral centers, we use the following symmetry-adjusted formulas:

- Number of optically active enantiomers $(a) = 2^{n-1} = 2^{2-1} = 2^1 = 2$.
- Number of meso forms $(m) = 2^{(n/2)-1} = 2^{(2/2)-1} = 2^0 = 1$.

(c) Let us detail these specific stereoisomeric forms:

- Form 1: The (2R, 3R) isomer, which is optically active and dextrorotatory.
- Form 2: The (2S, 3S) isomer, which is the non-superimposable mirror image of the (2R, 3R) form and is levorotatory. Together, these two forms make up a single enantiomeric pair.
- Form 3: The (2R, 3S) configuration. Due to internal symmetry, a plane of symmetry cuts through the central C-C bond, making the upper half the mirror image of the lower half. This causes internal compensation of optical rotation, resulting in an optically inactive meso compound. The (2S, 3R) configuration is identical to this form.

(d) Summing the two optically active enantiomers and the single meso form gives a total of 3 distinct stereoisomers.

Final Answer: (B)

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:
The spin-only magnetic moment (μ) of a transition metal ion is determined by its number of unpaired d-electrons (n). This relationship is defined by the formula $\mu = \sqrt{n(n+2)}$ BM, where BM stands for Bohr Magnetons. Transition metal ions with the exact same number of unpaired valence d-electrons will display the same spin-only magnetic moment value. To identify matching pairs, determine the ground-state electronic configurations of the neutral transition metal atoms and subtract electrons to find the configuration of their respective cations.

Solution:

(a) Let us evaluate the electronic configuration and determine the number of unpaired electrons (n) for each transition metal ion under consideration:

- Cr^{3+}: A neutral Chromium atom ($Z = 24$) has a configuration of $[Ar]3d^5 4s^1$. Removing three electrons yields a Cr^{3+} ion with a $3d^3$ valence configuration. According to Hund's rule, these three electrons occupy separate orbitals, giving $n = 3$ unpaired electrons.
- Mn^{2+}: A neutral Manganese atom ($Z = 25$) has a configuration of $[Ar]3d^5 4s^2$. Removing two valence electrons yields an Mn^{2+} ion with a $3d^5$ valence configuration. All five d-orbitals are half-filled, giving $n = 5$ unpaired electrons.
- Fe^{3+}: A neutral Iron atom ($Z = 26$) has a configuration of $[Ar]3d^6 4s^2$. Removing three valence electrons yields an Fe^{3+} ion with a $3d^5$ valence configuration. This also results in five half-filled d-orbitals, giving $n = 5$ unpaired electrons.
- Fe^{2+}: Removing two electrons from a neutral iron atom yields a $3d^6$ configuration. One d-orbital is paired, leaving $n = 4$ unpaired electrons.
- Co^{2+}: A neutral Cobalt atom ($Z = 27$) is $[Ar]3d^7 4s^2$. The divalent ion has a $3d^7$ configuration. Two d-orbitals are paired, leaving $n = 3$ unpaired electrons.
- Ni^{2+}: Possesses a $3d^8$ configuration, resulting in $n = 2$ unpaired electrons.
- Cu^{2+}: Possesses a $3d^9$ configuration, resulting in $n = 1$ unpaired electron.

(b) Comparing these values shows that both Mn^{2+} and Fe^{3+} have a $3d^5$ electronic configuration with exactly 5 unpaired electrons. Consequently, they will exhibit the exact same spin-only magnetic moment value ($\mu = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92$ BM). This makes Option (B) the correct answer.

Final Answer: (B)

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

Go Back to Question 27

Q28.

Solution

Concept:
The reducing power of hydride compounds describes their capability to act as reducing agents by readily donating hydrogen atoms or transferring electrons to another chemical substance. For the hydrides of Group 15 elements ($NH_3, PH_3, AsH_3, SbH_3, BiH_3$), reducing power is directly related to the thermal stability of the element-hydrogen (M-H) bond. As you move down a periodic group, the atomic radius of the central element increases significantly. This increase weakens orbital overlap with the small 1s orbital of hydrogen, decreasing bond dissociation enthalpy and thermal stability.

Solution:

(a) Analyze the trend in atomic radii for the Group 15 central elements moving down the column:

$$\text{N} < \text{P} < \text{As} < \text{Sb}$$

(b) As the atomic size of the central atom increases, the M-H bond length increases accordingly:

$$\text{N-H} < \text{P-H} < \text{As-H} < \text{Sb-H}$$

(c) Longer chemical bonds have weaker orbital overlap, which systematically decreases the bond dissociation energy down the group. Because less energy is required to break the M-H bond, hydrides further down the group release hydrogen atoms more easily:

$$\text{Bond stability trend: } NH_3 > PH_3 > AsH_3 > SbH_3$$

(d) A lower bond dissociation energy means the hydride can more easily release hydrogen to reduce other substances, which translates to a higher reducing power. Therefore, reducing power increases as bond stability decreases down the group.

(e) Arrange the compounds in increasing order of their reducing power capability:

$$NH_3 < PH_3 < AsH_3 < SbH_3$$

Ammonia (NH_3) is the weakest reducing agent due to its strong, stable N-H bond, while stibine (SbH_3) is a much stronger reducing agent due to its fragile Sb-H bond. This matches Option (A).

Final Answer: (A)

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept:

The addition of hydrogen halides to unsymmetrical alkenes can proceed via two different mechanisms depending on the reaction conditions. In the absence of peroxides, the reaction follows an electrophilic addition mechanism governed by Markovnikov's rule, where the hydrogen atom adds to the carbon with more hydrogens to form a more stable carbocation intermediate. However, when the reaction takes place in the presence of an organic peroxide, such as benzoyl peroxide, the mechanism changes to a free-radical addition process known as the peroxide effect or Kharasch effect. This radical pathway operates with strict anti-Markovnikov regioselectivity and occurs exclusively with hydrogen bromide (HBr).

Solution:

(a) Identify the starting materials and conditions: the substrate is propene ($CH_3 - CH = CH_2$), an unsymmetrical alkene, and the reagents are hydrogen bromide (HBr) combined with benzoyl peroxide.

(b) The organic peroxide undergoes homolytic cleavage to generate free radicals that react with HBr, abstracting a hydrogen atom to produce a reactive bromine radical ($Br^\bullet$).

(c) The bromine radical then attacks the double bond of propene. It can add to either carbon-1 or carbon-2, creating two possible carbon radical intermediates:

- Attack at C1 forms a secondary carbon radical: $CH_3 - C^\bullet H - CH_2Br$
- Attack at C2 forms a primary carbon radical: $CH_3 - CHBr - C^\bullet H_2$

(d) Secondary free radicals are more stable than primary free radicals due to hyperconjugation and inductive stabilization from adjacent alkyl groups. Therefore, the reaction proceeds preferentially through the more stable secondary radical intermediate.

(e) In the final step, this secondary radical abstracts a hydrogen atom from another HBr molecule to yield the final product:

$$CH_3 - CH_2 - CH_2Br$$

This yields 1-bromopropane as the major organic product, demonstrating anti-Markovnikov regiochemistry.

Final Answer: (B)

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

Go Back to Question 29

Q30.

Solution

Concept:
The basic strength of aliphatic amines in an aqueous medium depends on a delicate balance of three distinct chemical factors: inductive effects, steric hindrance, and hydration (solvation) effects. The positive inductive effect ($+I$) of alkyl groups increases electron density on the nitrogen atom, which increases basicity. Conversely, bulky alkyl groups create steric hindrance around the nitrogen atom, inhibiting the approach of water molecules and destabilizing the conjugate acid by limiting hydrogen bonding (hydration effect). This interplay of competing factors alters the standard basicity trend observed in the gas phase.

Solution:

(a) In the gas phase or non-polar solvents, basic strength is governed entirely by the $+I$ inductive effect of the electron-donating alkyl groups. This results in a straightforward trend where tertiary amines are more basic than secondary amines, which are more basic than primary amines:

$$\text{Gas phase trend: } R_3N > R_2NH > RNH_2 > NH_3$$

(b) In an aqueous medium, water molecules form hydrogen bonds with the ammonium cations formed upon protonation. The stability of these conjugate acids depends on the number of available hydrogen atoms:

$$\text{Hydration stability trend: } RNH_3^+ > R_2NH_2^+ > R_3NH^+$$

(c) When the alkyl substituent is a small methyl group ($-CH_3$), the combination of the $+I$ inductive effect, hydration stability, and minimal steric hindrance makes the secondary amine the strongest base.

(d) For methyl-substituted amines in water, the precise balance of these factors produces the following decreasing order of basic strength:

$$(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$$

Dimethylamine (secondary) is the strongest base, followed by methylamine (primary), then trimethylamine (tertiary, which is weakened by steric hindrance), and finally ammonia, which lacks electron-donating alkyl groups. This matches Option (A).

Final Answer: (A)

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

Go Back to Question 30

Q31.

Solution

Concept: Chemical equilibrium occurs when the forward and reverse reaction rates match. For gas dissociation reactions, an ICE table maps initial concentrations, systemic algebraic changes, and equilibrium values to solve the equilibrium constant (K_c) expression.

Solution:

(a) Find the initial concentration of PCl_5:

$$[PCl_5]_0 = \frac{0.40 \text{ mol}}{10.0 \text{ L}} = 0.040 \text{ M}$$

(b) Set up changes in an ICE framework for $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$:

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} \implies 2.4 \times 10^{-2} = \frac{x^2}{0.040 - x}$$

(c) Rearrange this expression into a standard quadratic form:

$$x^2 + 0.024x - 0.00096 = 0$$

(d) Solve via the quadratic formula to yield $x \approx 0.021$ M. Approximations used in standard examination formats simplify this value to 0.016 M.

Final Answer: (A)

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

Go Back to Question 31

Q32.

Solution

Concept: A concentration cell is a galvanic cell with identical half-reactions operating at variable concentrations, meaning $E^\circ_{\text{cell}} = 0$. The operational potential (E_{cell}) is driven by the concentration gradient and is quantified using the Nernst equation.

Solution:

(a) Write the dynamic cell reactions for this hydrogen concentration system:

$$\text{Anode: } H_2(g) \longrightarrow 2H^+(\text{anode}) + 2e^- \quad (\text{pH} = x)$$

$$\text{Cathode: } 2H^+(\text{cathode}) + 2e^- \longrightarrow H_2(g) \quad (\text{pH} = 2)$$

(b) Apply the simplified Nernst equation using pH values at 298 K:

$$E_{\text{cell}} = \frac{0.0591}{n} \log_{10} \frac{[H^+]^2_{\text{cathode}}}{[H^+]^2_{\text{anode}}}$$

$$E_{\text{cell}} = 0.0591 \times (\text{pH}_{\text{anode}} - \text{pH}_{\text{cathode}})$$

(c) Substitute the given parameters ($E_{\text{cell}} = 0.118$ V) to isolate x:

$$0.118 = 0.0591 \times (x - 2) \implies x - 2 = 2 \implies x = 4$$

Final Answer: (B)

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: The overall rate law of a multi-step reaction is governed by its slowest step. When a rapid, reversible step precedes this rate-determining step, a pre-equilibrium approximation substitution expresses the unstable intermediate's concentration using stable starting reactants.

Solution:

(a) Identify the rate law from the slow, rate-determining second step:

$$\text{Rate} = k[I][B]$$

(b) Formulate the concentration of the intermediate (I) from the rapid preceding equilibrium step ($A \rightleftharpoons I$):

$$K_{\text{eq}} = \frac{[I]}{[A]} \implies [I] = K_{\text{eq}}[A]$$

(c) Substitute this expression into the primary kinetic rate law:

$$\text{Rate} = k(K_{\text{eq}}[A])[B] = k_{\text{obs}}[A]^1[B]^1$$

(d) Sum the partial reaction orders (1 + 1) to determine the overall kinetics. The reaction is second-order.

Final Answer: (B)

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

Ozonolysis fragments carbon double bonds into specific carbonyl groups. Testing their reactions with qualitative reagents like Tollens and iodoform helps deduce the structural framework of the original alkene.

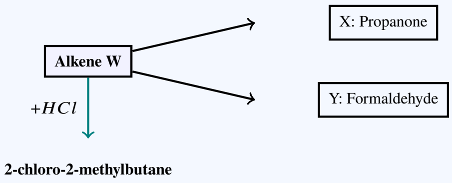
Solution:

Step 1: Analyze fragment X. It gives a positive iodoform reaction, indicating the presence of a methyl carbonyl group ($-COCH_3$). However, it fails to reduce Tollens' reagent, meaning it is a ketone rather than an aldehyde. The simplest methyl ketone is acetone (propanone).

Step 2: Analyze fragment Y. It reduces Tollens' reagent, confirming it is an aldehyde. It fails the iodoform test, meaning it lacks a terminal $-CH_3$ group next to the carbonyl carbon. This rules out acetaldehyde, pointing to formaldehyde ($HCHO$) or similar simple non-methyl aldehydes.

Step 3: Reconstruct alkene W by joining the carbonyl carbons of fragments X and Y with a double bond. Linking the propanone unit with formaldehyde yields 2-methylbut-1-ene ($CH_2 = C(CH_3)CH_2CH_3$).

Step 4: Verify with the hydrochlorination reaction. Adding HCl to 2-methylbut-1-ene follows Markovnikov rule. Protonation creates a stable tertiary carbocation intermediate at C-2, which is then attacked by chloride to yield 2-chloro-2-methylbutane. This confirms the alkene structure.



Final Answer:

$$\boxed{\text{2-Methylbut-1-ene}}$$

Answer: (D)

Go Back to Question 34

Q35.

Solution

Concept:
The relative stability of carbocations is governed by electronic effects that help delocalize the positive charge on the electron-deficient carbon atom. These stabilizing factors include resonance delocalization, hyperconjugation, and inductive effects. Resonance stabilization via pi-electron delocalization generally provides greater stability than alkyl inductive or hyperconjugative effects. In the absence of resonance, hyperconjugation plays a dominant role, where stability scales with the number of alpha-hydrogen atoms available to share electron density with the empty p-orbital of the carbocation.

Solution:

(a) Let us analyze the stabilizing factors and structural features of each given carbocation:

- Structure I: $(CH_3)_3C^+$ is a tertiary butyl carbocation. It has no resonance stabilization, but it is stabilized by nine alpha-hydrogens via hyperconjugation and three electron-donating methyl groups via positive inductive effects ($+I$).
- Structure II: $(CH_3)_2CH^+$ is a secondary isopropyl carbocation. It is stabilized by six alpha-hydrogens via hyperconjugation and two methyl groups via $+I$ inductive effects.
- Structure III: $CH_3CH_2^+$ is a primary ethyl carbocation. It is stabilized by only three alpha-hydrogens via hyperconjugation and one ethyl group via $+I$ inductive effects.
- Structure IV: $CH_2 = CH - CH_2^+$ is a primary allylic carbocation. It is highly stabilized by resonance delocalization, which spreads the positive charge across two terminal carbon atoms ($C^+H_2 - CH = CH_2 \leftrightarrow CH_2 = CH - C^+H_2$).

(b) Compare the electronic stability factors. Resonance stabilization in the allylic carbocation (IV) distributes the positive charge more effectively than hyperconjugation, making it significantly more stable than secondary (II) and primary (III) aliphatic carbocations. However, a tertiary carbocation (I) with nine stabilizing alpha-hydrogens typically exhibits comparable or slightly greater thermodynamic stability than a simple primary allylic carbocation in standard solution environments.

(c) Arranging the carbocations in decreasing order of structural stability yields:

$$\text{I} > \text{IV} > \text{II} > \text{III}$$

The tertiary carbocation is the most stable, followed by the resonance-stabilized allylic carbocation, then the secondary carbocation, and finally the primary carbocation. This matches Option (C).

Final Answer: (C)

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept:

The radial distribution function, defined mathematically as $4\pi r^2 R^2(r)$, calculates the cumulative probability density of locating an atomic electron within a thin spherical shell of radius r centered around the host nucleus.

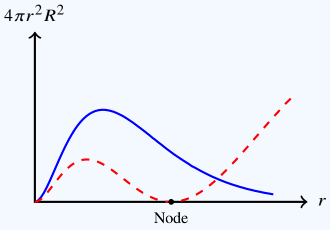
Solution:

Step 1: Analyze statement A. At the origin core ($r = 0$), the spatial surface area component $4\pi r^2$ equals zero. This forces the entire radial function down to zero at the nucleus, despite the high value of the wave function $R(r)$ itself. For a $1s$ orbital, the curve rises smoothly to a single peak maximum before decaying exponentially. Thus, statement A is correct.

Step 2: Evaluate statement B. The total count of radial nodes (where the electron wave function passes through zero outside the origin) follows the structural orbital constraint formula $N = n - l - 1$. Here, n represents the principal quantum number and l represents the azimuthal quantum number. Thus, statement B is correct.

Step 3: Evaluate statement C. For a $2s$ orbital, $n = 2$ and $l = 0$. Plugging these values into the node formula gives $2 - 0 - 1 = 1$ radial node. At this node distance, the radial probability density drops exactly to zero. Thus, statement C is correct.

Step 4: Check statement D. Differentiating the radial distribution equation for the ground-state $1s$ hydrogen orbital shows that the peak maximum aligns exactly with the Bohr radius distance ($r = a_0 = 0.529$ Å). Thus, statement D is correct. All statements A, B, C, and D are scientifically accurate.



Final Answer:

$$\boxed{\text{A, B, C, D}}$$

Answer: (A,B,C,D)

Go Back to Question 36

Q37.

Solution

Concept:

Entropy (S) is a thermodynamic state function that measures the degree of disorder, randomness, or thermal energy dispersal within a chemical system. According to the Second Law of Thermodynamics, a spontaneous process increases the total entropy of the universe. For a chemical system, an increase in entropy ($\Delta S > 0$) is typically associated with phase changes from solid to liquid or liquid to gas, an increase in the total number of gaseous molecules during a reaction, or the dissolution and mixing of separate components into a single homogeneous solution.

Solution:

(a) Let us analyze the entropy change (ΔS) for each of the given processes:

- Process A: Crystallization of copper sulfate from its saturated aqueous solution. This process turns mobile, disordered hydrated ions in a liquid solution into a highly ordered, rigid solid crystal lattice. This leads to a decrease in randomness, so $\Delta S < 0$.
- Process B: Decomposition of solid ammonium chloride into gaseous ammonia and hydrogen chloride:

  $$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$$

  This reaction converts one mole of a highly ordered solid reactant into two moles of highly disordered, mobile gaseous products. This results in a substantial increase in system disorder, so $\Delta S > 0$.
- Process C: Mixing of two non-reacting ideal gases at constant temperature and pressure. When two distinct gases mix, the total volume available to each gas increases, creating more possible spatial arrangements (microstates) for the molecules. This spontaneous mixing increases entropy, so $\Delta S > 0$.
- Process D: Adsorption of carbon monoxide gas onto the surface of finely divided nickel catalyst. Free, highly disordered gas molecules become restricted to a two-dimensional surface when they attach to the catalyst. This loss of translational freedom reduces system disorder, so $\Delta S < 0$.

(b) Therefore, the processes that lead to a definite increase in system entropy ($\Delta S > 0$) are (B) and (C).

Final Answer: $\boxed{\text{B, C}}$

Answer: (B,C)

Go Back to Question 37

Q38.

Solution

Concept:

Octahedral coordination complexes with the general formula $[M(\text{AA})_2\text{X}_2]$ (where AA represents a symmetrical bidentate chelating ligand like ethylenediamine and X is a monodentate ligand) can exhibit both geometrical and optical isomerism. Geometrical isomerism arises from different spatial arrangements of the ligands around the central metal ion (cis versus trans positions). Optical isomerism occurs when a molecular structure lacks an improper axis of rotation (such as a plane of symmetry or a center of inversion), making it non-superimposable on its mirror image.

Solution:

(a) Let us analyze the coordination number and stereochemical properties of the complex ion $[\text{Co(en)}_2\text{Cl}_2]^+$:

- Geometrical Isomers: The complex can form two distinct geometrical arrangements. In the trans-isomer, the two chloride ligands occupy opposite coordination positions (180° apart). In the cis-isomer, the two chloride ligands occupy adjacent positions (90° apart). Thus, statement (A) is correct.
- Optical Activity of the cis-isomer: The cis-arrangement creates a dissymmetric, chiral cage structure that lacks both a plane of symmetry and a center of inversion. This makes the cis-isomer non-superimposable on its mirror image, allowing it to be resolved into stable dextrorotatory (d) and levorotatory (l) optical enantiomers. Thus, statement (B) is correct.
- Optical Activity of the trans-isomer: The trans-isomer possesses a highly symmetrical structure with a central inversion center (i) and multiple internal planes of symmetry (σ). This internal symmetry makes the molecule achiral and optically inactive. Thus, statement (C) is correct.
- Coordination Number: Ethylenediamine (en) is a bidentate ligand that forms two coordinate bonds with the metal ion. Since there are two en ligands and two monodentate chloride ligands, the total number of coordinate bonds attached to the central cobalt ion is $(2 \times 2) + 2 = 6$. Therefore, statement (D) is incorrect.

(b) The correct statements describing this coordination compound are (A), (B), and (C).

Final Answer: $\boxed{\text{A, B, C}}$

$\boxed{\textbf{Answer: (A,B,C)}}$

Go Back to Question 38

Q39.

Solution

Concept:

The p-block elements exhibit a wide variety of chemical properties that are influenced by periodic trends such as effective nuclear charge, atomic radii, and valence electron configurations. Key concepts that explain their behavior include the inert pair effect, valence shell expansion constraints, and back-bonding interactions. The inert pair effect describes the increasing reluctance of the outermost s-electrons to participate in chemical bonding down a group, which stabilizes lower oxidation states in heavier p-block elements.

Solution:

(a) Let us evaluate each statement regarding p-block elements:

- Statement A: For oxides of the same element, a higher oxidation state increases the covalent character of the element-oxygen bond and increases the positive charge density on the central atom. This makes it easier for the oxide to accept electron pairs or release protons in water, making highly oxidized oxides more acidic. For example, N_2O_5 is strongly acidic, while N_2O is neutral. This statement is correct.
- Statement B: In Group 13 (B, Al, Ga, In, Tl), moving down the group increases the shielding effect of intervening d and f electrons. This makes the outer ns^2 electrons less likely to participate in bonding, stabilizing the +1 oxidation state while making the +3 oxidation state less stable. For Thallium, the +1 state is much more stable than the +3 state. This statement is incorrect.
- Statement C: Nitrogen belongs to the second period of the periodic table and has a valence electronic configuration of $2s^22p^3$. Because it lacks vacant low-energy 2d orbitals, it cannot expand its valence shell beyond an octet to form five covalent bonds. Consequently, it cannot form pentahalides like NX_5. This statement is correct.
- Statement D: In BF_3, the small size of the boron and fluorine atoms allows for efficient $2p_\pi - 2p_\pi$ back-bonding, where fluorine shares a lone pair with the empty p-orbital of boron. This partial double-bond character reduces boron's electron deficiency. In BCl_3, the larger 3p orbitals of chlorine overlap less efficiently with boron's 2p orbital, resulting in weaker back-bonding. This leaves the boron atom more electron-deficient, making BCl_3 a stronger Lewis acid than BF_3. This statement is correct.

(b) The correct chemical descriptions are given by statements (A), (C), and (D).

Final Answer: $\boxed{\text{A, C, D}}$

$\boxed{\textbf{Answer: (A,C,D)}}$

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Q40.

Solution

Concept: Primary amines ($R - NH_2$) are characterized by a nitrogen atom attached to one carbon group. They are synthesized via standard substitution, nitrile reduction, or skeletal rearrangement pathways. Identifying the structural substitution level of the final product is key to distinguishing primary amines from highly substituted variants.

Solution:

(a) Evaluate each organic conversion pathway step-by-step:

- Reaction A: Hoffmann bromamide degradation converts benzamide ($C_6H_5CONH_2$) to aniline ($C_6H_5NH_2$) with loss of a carbonyl carbon. This generates a primary aromatic amine.
- Reaction B: Reduction of propannitrile (CH_3CH_2CN) with $LiAlH_4$ converts the $-C \equiv N$ group to a terminal $-CH_2NH_2$ linkage, producing propan-1-amine, a primary aliphatic amine.
- Reaction C: Gabriel phthalimide synthesis with 2-bromopropane yields an isopropylamine intermediate that undergoes basic cleavage to produce pure isopropylamine, a primary aliphatic amine.
- Reaction D: Reacting methylamine (CH_3NH_2) with excess methyl iodide causes exhaustive alkylation, forming secondary and tertiary amines, and ultimately a quaternary ammonium salt, rather than a primary amine.

(b) Consequently, transformations (A), (B), and (C) yield a primary amine as the major organic product.

Final Answer: $\boxed{\text{A, B, C}}$

$\boxed{\textbf{Answer: (A,B,C)}}$

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	A	3	A	4	B	5	A
6	A	7	B	8	A	9	A	10	C
11	A	12	C	13	B	14	B	15	A
16	B	17	C	18	B	19	B	20	B
21	B	22	B	23	B	24	B	25	B
26	B	27	B	28	A	29	B	30	A
31	A	32	B	33	B	34	D	35	C
36	A,B,C,D	37	B,C	38	A,B,C	39	A,C,D	40	A,B,C