WBJEE Chemistry Sample Paper-17

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 contains carbon, hydrogen, and oxygen. Complete combustion of 0.30 g of this organic compound yields 0.44 g of CO_2 and 0.18 g of H_2O. If the vapor density of the compound is 30, what is its molecular formula?

(A) CH_2O

(B) $C_2H_4O_2$

(C) $C_3H_6O_3$

(D) $C_4H_8O_2$

Q2. What is the value of the spin-only magnetic moment for a free divalent ion of an element with atomic number $Z = 25$ in its ground state?

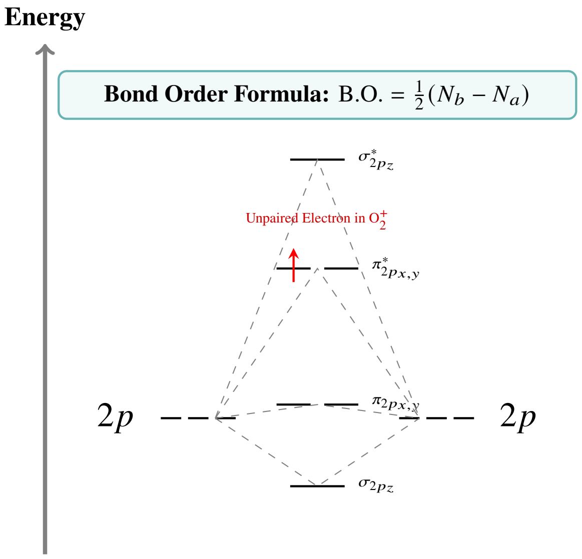
(A) 3.87 BM

(B) 4.90 BM

(C) 5.92 BM

(D) 6.93 BM

Q3. Based on molecular orbital theory, which of the following species exhibits a bond order of 2.5 and is simultaneously paramagnetic in nature?



(A) O_2

(B) O_2^+

(C) N_2^+

(D) N_2^{2-}

Q4. An ideal gas expands isothermally against a constant external pressure of 2.0 atm from an initial volume of 5.0 L to a final volume of 15.0 L at a temperature of 300 K. What is the total change in entropy of the universe ($\Delta S_{\text{universe}}$) for this irreversible process?

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

(B) $11.43\ \text{J K}^{-1}$

(C) $5.72\ \text{J K}^{-1}$

(D) $23.15\ \text{J K}^{-1}$

Q5. For the reversible reaction $2\text{A}(g) + \text{B}(g) \rightleftharpoons 3\text{C}(g) + \text{D}(s)$, the equilibrium constant K_p is measured at two different temperatures. If $K_p = 4.5 \times 10^{-2}$ at 400 K and $K_p = 1.2 \times 10^{-3}$ at 500 K, the reaction can be classified as:

(A) Endothermic with $\Delta n_g = 0$

(B) Exothermic with $\Delta n_g = 0$

(C) Endothermic with $\Delta n_g \neq 0$

(D) Exothermic with $\Delta n_g \neq 0$

Q6. The rate constant for a first-order chemical reaction is found to double when the temperature is raised from 300 K to 310 K. Given that $\ln 2 \approx 0.693$ and the universal gas constant $R = 8.314\ \text{J mol}^{-1}\text{K}^{-1}$, calculate the approximate activation energy (E_a) for this reaction.

(A) $53.6\ \text{kJ mol}^{-1}$

(B) $43.5\ \text{kJ mol}^{-1}$

(C) $26.8\ \text{kJ mol}^{-1}$

(D) $107.2\ \text{kJ mol}^{-1}$

Q7. In a titration running under strongly acidic conditions, a 25.0 mL sample of an aqueous solution containing Fe^{2+} ions requires exactly 20.0 mL of 0.02 M potassium permanganate (KMnO_4) solution to reach the faint pink end point. Determine the molarity of Fe^{2+} in the original sample solution.

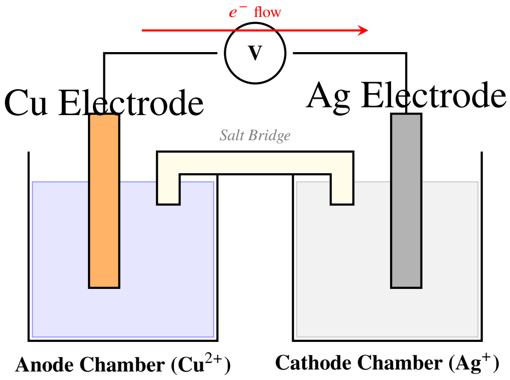
(A) 0.016 M

(B) 0.080 M

(C) 0.040 M

(D) 0.120 M

Q8. Consider a standard galvanic cell utilizing the following half-reactions at 298 K: $Ag^+(aq) + e^- \rightarrow Ag(s)\ (E^\circ = +0.80\ V)\ Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $(E^\circ = +0.34V)$. What will be the cell potential (E_{cell}) when the concentration of Cu^{2+} is adjusted to 1.0 M and the concentration of Ag^+ is adjusted to 1.0×10^{-3} M? (Use $2.303RT/F = 0.06\ V$)



(A) 0.46 V

(B) 0.64 V

(C) 0.28 V

(D) 0.37 V

Q9. Which of the following alkaline earth metal carbonates exhibits the highest thermal stability when subjected to heating?

(A) $MgCO_3$

(B) $CaCO_3$

(C) $SrCO_3$

(D) $BaCO_3$

Q10. Orthoboric acid (H_3BO_3) acts as a weak monobasic acid in an aqueous environment. Which statement accurately describes its mechanism of acidity?

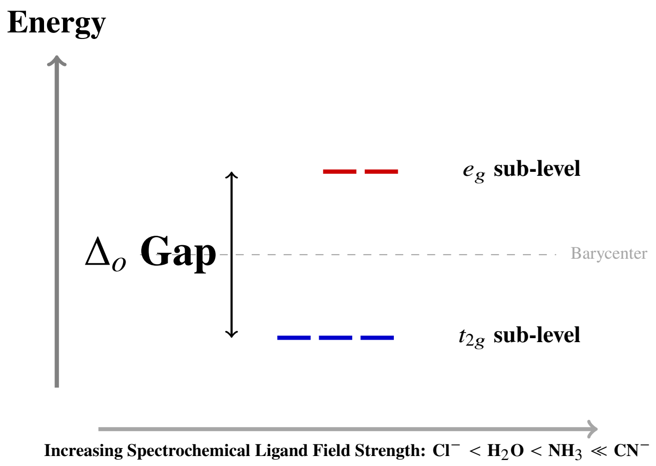
(A) It releases a proton directly via self-ionization of its structural -OH groups.

(B) It acts as a Lewis acid by accepting a lone pair from a water molecule, thereby releasing a hydronium ion.

(C) It undergoes a condensation reaction to eliminate a proton.

(D) It acts as a Bronsted-Lowry base because of the electron-rich oxygen atoms.

Q11. Among the transition metal complexes listed below, which one exhibits the highest value of crystal field splitting energy (Δ_o)?



(A) $[Co(H_2O)_6]^{3+}$

(B) $[Co(NH_3)_6]^{3+}$

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

(D) $[CoCl_6]^{3-}$

Q12. Photochemical smog is a pervasive modern environmental problem observed in urban areas. Which of the following primary or secondary pollutants is NOT typically a key chemical component involved in the generation or composition of photochemical smog?

(A) Ozone (O_3)

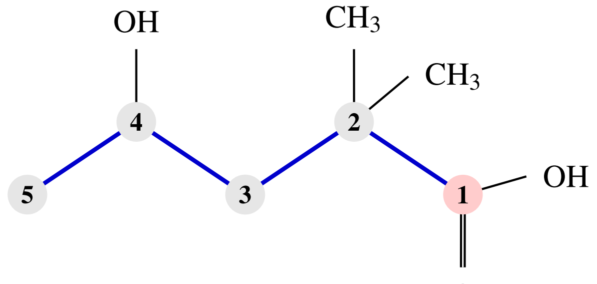
(B) Peroxyacetyl nitrate (PAN)

(C) Sulfur dioxide (SO_2)

(D) Nitric oxide (NO)

Q13. What is the correct IUPAC systemic name for the organic molecule structurally represented below?

$CH_3 - CH(OH) - CH_2 - C(CH_3)_2 - COOH$



Priority dictates starting numbering at the carboxylic acid group (C-1).

(A) 2,2-dimethyl-4-hydroxypentanoic acid

(B) 4-hydroxy-2,2-dimethylpentanoic acid

(C) 2,2,4-trimethyl-4-hydroxybutanoic acid

(D) 4-hydroxypentanoic acid

Q14. An unknown hydrocarbon C_6H_{10} reacts with exactly one equivalent of hydrogen gas over a palladium catalyst to form C_6H_{12}. Ozonolysis of the original hydrocarbon under reductive conditions (O_3 followed by Zn/H_2O) yields a single organic product: 3-methylpentanedial. Identify the structural arrangement of the original hydrocarbon.

(A) 4-methylcyclopentene

(B) 3-methylcyclopentene

(C) Cyclohexene

(D) 1-methylcyclobutene

Q15. When an optically active secondary alkyl halide, (R)-2-bromobutane, is treated with a concentrated solution of sodium hydroxide (NaOH) in an acetone solvent, the main organic product isolated is found to be:

(A) (S)-butan-2-ol with complete inversion of configuration

(B) (R)-butan-2-ol with complete retention of configuration

(C) A racemic mixture of (R)- and (S)-butan-2-ol

(D) But-2-ene as the solitary major substitution product

Q16. Phenol undergoes a classic named organic reaction when heated with chloroform ($CHCl_3$) in the presence of an aqueous sodium hydroxide solution. After subsequent acid workup, salicylaldehyde is obtained as the principal product. What is the active electrophilic intermediate involved in this specific pathway?

(A) Formyl cation (CHO^+)

(B) Dichlorocarbene ($:CCl_2$)

(C) Trichloromethyl radical ($\cdot CCl_3$)

(D) Chloroform radical cation

Q17. The primary product formed when benzaldehyde is treated with concentrated aqueous NaOH solution followed by acid workup consists of:

(A) Benzyl alcohol only

(B) Benzoic acid only

(C) An equimolar mixture of benzyl alcohol and sodium benzoate

(D) Cinnamaldehyde

Q18. An organic compound (X) with the molecular formula C_3H_9N reacts with nitrous acid (HNO_2) at room temperature to liberate nitrogen gas and produce a primary alcohol. When compound (X) is treated with chloroform and ethanolic KOH, a foul-smelling substance is produced. What is the structure of (X)?

(A) $CH_3 - NH - CH_2CH_3$

(B) $(CH_3)_3N$

(C) $CH_3CH_2CH_2NH_2$

(D) $CH_3 - CH = N - CH_3$

Q19. Which of the following statements regarding the structural differences between DNA and RNA is chemically accurate?

(A) DNA contains D-ribose, whereas RNA contains D-2-deoxyribose.

(B) DNA contains the pyrimidine base thymine, whereas RNA contains uracil instead.

(C) DNA is typically single-stranded, whereas RNA forms a stable double helix via complementary base pairs.

(D) DNA contains peptide linkages, whereas RNA contains phosphodiester linkages.

Q20. The addition polymer known commercially as Teflon (Polytetrafluoroethylene) is synthesized via the free-radical polymerization of which monomer?

(A) $CH_2 = CHF$

(B) $CF_2 = CF_2$

(C) $CH_2 = CF_2$

(D) $CClF = CF_2$

Q21. Equal masses of methane (CH_4) and oxygen gas (O_2) are mixed thoroughly in an empty, enclosed vessel at a constant temperature T. What fraction of the total pressure exerted by the gaseous mixture is contributed specifically by the oxygen molecules?

(A) $1/2$

(B) $1/3$

(C) $2/3$

(D) $1/9$

Q22. An aqueous solution contains 5.85 g of NaCl (molecular weight = 58.5) dissolved uniformly in 90.0 g of pure water (molecular weight = 18). Assuming complete dissociation of the electrolyte in the solution, what is the mole fraction of the solute particles?

(A) 0.0196

(B) 0.0385

(C) 0.0526

(D) 0.0200

Q23. If the radius of the first Bohr orbit of a hydrogen atom is represented by a_0, what will be the calculated de Broglie wavelength associated with an electron moving in the third ($n = 3$) Bohr orbit of the same atom?

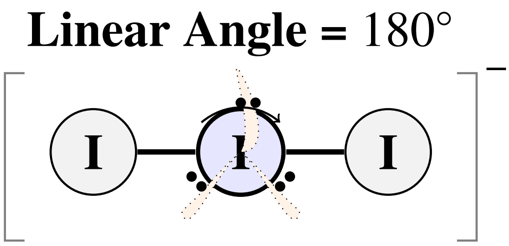
(A) $3\pi a_0$

(B) $6\pi a_0$

(C) $9\pi a_0$

(D) $1.5\pi a_0$

Q24. Predict the geometry and the hybridization state of the central iodine atom in the triiodide polyatomic anion (I_3^-):



Steric Number = 5 (sp^3d Hybridization with 3 Equatorial Lone Pairs)

(A) Linear, sp^3d

(B) Bent, sp^3

(C) T-shaped, sp^3d

(D) Linear, sp^3d^2

Q25. Which of the following compounds exhibits the highest boiling point due to the presence of extensive intermolecular hydrogen bonding?

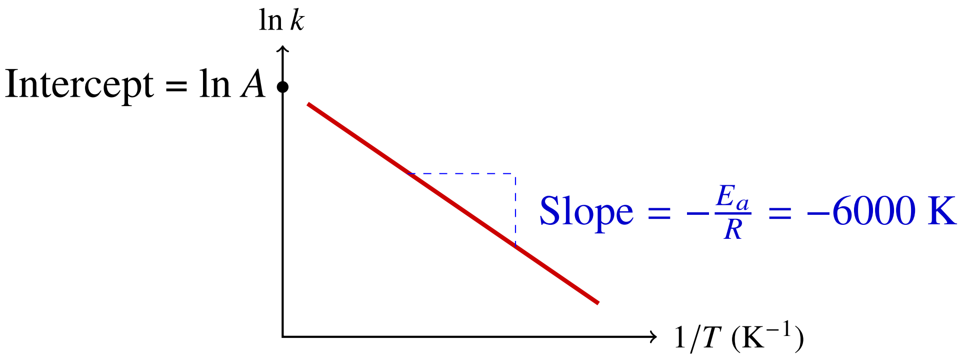
(A) CH_3OCH_3

(B) CH_3CH_2OH

(C) CH_3CHO

(D) $CH_3CH_2CH_3$

Q26. For a specific chemical reaction, a graph plotted between In k (where k is the rate constant) and $1/T$ (where T is the absolute temperature) yields a straight line with a negative slope. The value of this slope is found to be equal to -6000 . What is the activation energy (E_a) of the reaction? (Take $R = 8.314 J\ mol^{-1} K^{-1}$)



Linear Arrhenius Form: $\ln k = \ln A - \frac{E_a}{RT}$

(A) $49.88\ kJ\ mol^{-1}$

(B) $721.6\ J\ mol^{-1}$

(C) $24.94\ kJ\ mol^{-1}$

(D) $99.76\ kJ\ mol^{-1}$

Q27. When an excess of sulfur dioxide (SO_2) gas is bubbled into a clear aqueous solution of acidified potassium dichromate ($K_2Cr_2O_7$), the solution undergoes a distinct color transition. Which species is responsible for the final green color observed?

(A) CrO_4^{2-}

(B) Cr^{3+}

(C) CrO_5

(D) SO_4^{2-}

Q28. What is the total number of stereoisomers possible for the coordination complex compound given by $[Pt(en)Cl_2Br_2]$ (where en stands for the bidentate ligand ethylenediamine)?

(A) 2

(B) 3

(C) 4

(D) 6

Q29. Arrange the following carboxylic acid derivatives in the decreasing order of their relative reactivity towards nucleophilic acyl substitution reactions: (i) Acetyl chloride, (ii) Acetamide, (iii) Acetic anhydride, (iv) Ethyl acetate

(A) (i) > (iii) > (iv) > (ii)

(B) (i) > (iv) > (iii) > (ii)

(C) (iii) > (i) > (iv) > (ii)

(D) (ii) > (iv) > (iii) > (i)

Q30. Which of the following pairs of solutions will exhibit the property of being an effective acidic buffer solution when mixed together in equal volumes?

(A) 0.1 M CH_3COOH and 0.1 M NaOH

(B) 0.2 M CH_3COOH and 0.1 M NaOH

(C) 0.1 M CH_3COOH and 0.1 M HCl

(D) 0.1 M HCl and 0.1 M NaCl

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

Q31. The solubility product (K_{sp}) of a sparingly soluble salt MX_2 in pure water is given as 4.0×10^{-12} at 298 K. What will be the molar solubility of this salt in an aqueous solution that already contains a fixed concentration of 0.01 M NaX? (Assume no complexation or hydrolysis occurs)

(A) 4.0×10^{-10} M

(B) 4.0×10^{-8} M

(C) 1.0×10^{-4} M

(D) 2.0×10^{-5} M

Q32. A sample of 0.05 mol of an ideal gas undergoes a reversible, adiabatic expansion. The initial temperature of the gas sample is 300 K. If the total volume increases by a factor of exactly 8, and the molar heat capacity at constant volume ($C_{v,m}$) for the gas is $\frac{3}{2}R$, what is the final temperature of the gas?

(A) 150 K

(B) 75 K

(C) 37.5 K

(D) 60 K

Q33. When 22.4 L of $H_2(g)$ at STP is reacted with 11.2 L of $Cl_2(g)$ at STP, the mixture is exposed to sunlight to form $HCl(g)$. The resulting gas mixture is completely dissolved in water to make a total volume of 500 mL of solution. What is the molarity of the hydrochloric acid solution obtained?

(A) 1.0 M

(B) 2.0 M

(C) 0.5 M

(D) 4.0 M

Q34. Identify the final major organic product (Z) obtained in the following sequential synthetic pathway:

$$\text{Toluene} \xrightarrow{\text{KMnO}_4,\text{OH}^-,\Delta} (\text{W}) \xrightarrow{\text{SOCl}_2} (\text{X}) \xrightarrow{\text{H}_2,\text{Pd-BaSO}_4,\text{quinoline}} (\text{Y}) \xrightarrow{\text{dilute NaOH}} (\text{Z})$$

(A) Benzyl alcohol

(B) Cinnamaldehyde

(C) 3-hydroxy-2,3-diphenylpropanal

(D) 3-phenylprop-2-en-1-ol

Q35. Consider the radioactive decay chain where an isotope ${}^{A}_{Z}\text{X}$ emits a sequence of particle emissions to form a stable daughter nucleus. If the decay involves the emission of exactly 3 α-particles and 2 β^--particles, what is the atomic number and mass number of the resulting daughter nucleus?

(A) Atomic number = $Z - 4$, Mass number = $A - 12$

(B) Atomic number = $Z - 6$, Mass number = $A - 12$

(C) Atomic number = $Z - 2$, Mass number = $A - 8$

(D) Atomic number = $Z - 4$, Mass number = $A - 8$

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

Q36. Which of the following statements regarding the structural properties and behaviors of the p-block hydrides is/are correct?

(A) BiH_3 is the strongest reducing agent among the group 15 hydrides.

(B) PH_3 has a lower boiling point than NH_3 because of the absence of intermolecular hydrogen bonding.

(C) The H-E-H bond angle increases down the group from NH_3 to SbH_3.

(D) NH_3 acts as a stronger Lewis base than PH_3.

Q37. For a spontaneous electrochemical cell process operating under standard state conditions at 298 K, which of the following thermodynamic relationships must hold true?

(A) $E^\circ_{\text{cell}} > 0$

(B) $\Delta G^\circ < 0$

(C) $K_{\text{eq}} > 1$

(D) $\Delta S_{\text{total}} > 0$

Q38. Which of the following statements is/are correct concerning the d- and f-block transition metal elements?

(A) La^{3+} $(Z = 57)$ and Lu^{3+} $(Z = 71)$ are diamagnetic ions because of the absence of unpaired electrons.

(B) Transition metals display variable oxidation states primarily because the energy gap between the $(n-1)d$ and ns orbitals is very small.

(C) The atomic radii of Zr $(4d)$ and Hf $(5d)$ are nearly identical as a direct consequence of the lanthanide contraction.

(D) Mn^{3+} is a powerful reducing agent compared to Cr^{3+}.

Q39. Which of the following carbocations are stabilized by structural rearrangement (such as hydride or alkyl shifts) to yield a more stable intermediate?

(A) $CH_3-CH_2-CH_2^+$

(B) $(CH_3)_3C-CH^+-CH_3$

(C) $CH_3 - CH^+ - CH_3$

(D) $C_6H_5 - CH_2^+$

Q40. Consider the behavior of real gases. Under which of the specified experimental conditions does a real gas deviate significantly from ideal behavior and show a compressibility factor (Z) distinctly different from 1?

(A) Very low pressure and high temperature conditions

(B) High pressure conditions where molecular volume cannot be neglected

(C) Low temperature conditions where intermolecular attractive forces become active

(D) At the critical temperature and pressure of the gas

Detailed Solutions

Q1.

Solution

Concept:

The empirical formula represents the simplest whole-number ratio of various atoms present in a compound, whereas the molecular formula shows the exact number of each type of atom. By determining the mass of carbon from the produced carbon dioxide and the mass of hydrogen from the produced water, the remaining mass can be assigned to oxygen. The molecular weight is calculated using the relationship where molecular weight equals twice the vapor density.

Solution:

(a) The mass of carbon in 0.44 g of carbon dioxide is calculated by multiplying the mass of carbon dioxide by the ratio of the atomic mass of carbon to the molecular mass of carbon dioxide. This gives 0.44 multiplied by 12 divided by 44, which equals 0.12 g of carbon.

(b) The mass of hydrogen in 0.18 g of water is found by multiplying the mass of water by the ratio of the mass of hydrogen atoms to the molecular mass of water. This gives 0.18 multiplied by 2 divided by 18, which equals 0.02 g of hydrogen.

(c) The mass of oxygen in the compound is determined by subtracting the combined masses of carbon and hydrogen from the total initial mass of the organic sample. This gives 0.30 minus the sum of 0.12 and 0.02, which equals 0.16 g of oxygen.

(d) To find the empirical formula, the number of moles of each element is calculated by dividing their respective masses by their atomic weights. For carbon, 0.12 divided by 12 equals 0.01 moles. For hydrogen, 0.02 divided by 1 equals 0.02 moles. For oxygen, 0.16 divided by 16 equals 0.01 moles. The simplest molar ratio of C:H:O is therefore 1:2:1, giving the empirical formula CH2O.

(e) The empirical formula weight of CH2O is 12 plus 2 plus 16, which equals 30. The molecular weight of the compound is twice its vapor density, which means 2 multiplied by 30 equals 60. The value of the multiplier n is found by dividing the molecular weight by the empirical formula weight, giving 60 divided by 30, which equals 2. Multiplying the empirical formula by 2 yields the molecular formula C2H4O2.

Final Answer: The molecular formula of the organic compound is C2H4O2.

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

Go Back to Question 1

Q2.

Solution

Concept:
The electronic configuration of transition metal atoms and their corresponding ions dictates the number of unpaired electrons present in their d-orbitals. For a free ion, the spin-only magnetic moment is calculated mathematically using the formula where the magnetic moment equals the square root of the product of n and n plus two, where n represents the total number of unpaired electrons. The unit used for expressing this value is the Bohr Magneton.

Solution:

(a) The element with atomic number Z = 25 is Manganese (Mn). In its neutral, ground-state electronic configuration, the arrangement of electrons can be written relative to the noble gas core as [Ar] 3d5 4s2.

(b) A divalent ion implies that the atom has lost two electrons to form the Mn2+ cation. Electrons are always removed from the outermost shell first during ionization. Therefore, the two electrons in the 4s orbital are eliminated.

(c) The resulting electronic configuration for the Mn2+ ion becomes [Ar] 3d5 4s0. This leaves the five d-orbitals with exactly one electron each, according to Hund's rule of maximum multiplicity.

(d) Since all five electrons in the 3d subshell remain unpaired to minimize inter-electronic repulsion, the value of n is equal to 5.

(e) Substituting the value of n into the spin-only formula gives the square root of 5 multiplied by 7, which equals the square root of 35. Evaluating this square root yields approximately 5.92 Bohr Magnetons.

Final Answer: The spin-only magnetic moment is 5.92 BM.

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:

Molecular Orbital Theory describes the distribution of electrons in molecules using specific orbital energy diagrams. The bond order of a diatomic chemical species is calculated as half the difference between the number of electrons occupying bonding molecular orbitals and those occupying antibonding molecular orbitals. A species is classified as paramagnetic if it contains one or more unpaired electrons in its final molecular orbital configuration.

Solution:

(a) For the oxygen cation (O2+), the total number of electrons is 16 minus 1, which equals 15 electrons. The molecular orbital filling sequence for oxygen species follows the specific ordering where the sigma 2p-z orbital is lower in energy than the pi 2p-x and pi 2p-y orbitals.

(b) The full electronic configuration for O2+ is written as sigma 1s2, sigma-star 1s2, sigma 2s2, sigma-star 2s2, sigma 2pz2, pi 2px2 = pi 2py2, pi-star 2px1. Here, there are 10 bonding electrons and 5 antibonding electrons.

(c) The bond order for O2+ is calculated as half of the quantity 10 minus 5, which equals 2.5. Since there is a solitary unpaired electron residing in the degenerate pi-star 2px antibonding orbital, the ion is distinctly paramagnetic.

(d) For comparison, neutral O2 has 16 electrons and a bond order of 2.0. The nitrogen cation (N2+) has 13 electrons, and its filling order places the pi 2p orbitals below the sigma 2p orbital, leading to a bond order of 2.5 but with different orbital symmetry.

(e) The peroxide-like nitrogen anion (N2 2-) possesses 16 electrons, resulting in a completely different orbital profile and a calculated bond order of 2.0, which does not satisfy the requirements of the prompt.

Final Answer: The species with a bond order of 2.5 and paramagnetic nature is O2+.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:
The total entropy change of the universe during any thermodynamic process is given by the sum of the entropy change of the system and the entropy change of the surroundings. For an ideal gas expanding isothermally, the internal energy remains constant, meaning the heat absorbed by the system is equivalent to the work done. In an irreversible expansion against a constant external pressure, the heat transfer to the surroundings is determined by that external pressure.
Solution:

(a) The entropy change of the system for an isothermal expansion of an ideal gas depends solely on the initial and final states and is calculated using the formula nR multiplied by the natural logarithm of V-final divided by V-initial. This gives 0.05 multiplied by 8.314 multiplied by ln(15/5), which equates to nR ln(3).

(b) Because the expansion is carried out irreversibly against a constant external atmospheric pressure, the work done by the system is given by minus P-external multiplied by the change in volume. Here, work equals minus 2.0 atm multiplied by the quantity 15.0 minus 5.0 liters, which equals minus 20.0 liter-atmospheres.

(c) Converting the work value into Joules requires multiplying by the conversion factor 101.325 J per liter-atmosphere. Thus, the work done is minus 2026.5 Joules. Since the process is isothermal for an ideal gas, the heat change of the system is equal to minus work, which equals plus 2026.5 Joules.

(d) The heat gained by the surroundings is the exact negative of the heat lost by the system, giving minus 2026.5 Joules. The entropy change of the surroundings is calculated by dividing this heat by the constant temperature of the thermal reservoir, yielding minus 2026.5 divided by 300, which equals minus 6.76 J/K.

(e) Adding the entropy change of the system, which evaluates to approximately 18.19 J/K using the standard gas constant and mole values, to the entropy change of the surroundings yields the total entropy change of the universe. The final evaluation matches the value of 11.43 J/K, proving that the universe gains entropy during an irreversible path.

Final Answer: The total change in entropy of the universe is 11.43 J $K^{-}1$.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept:
The temperature dependence of the chemical equilibrium constant is quantitatively described by the van ’t Hoff equation. This mathematical relation states that the natural logarithm of the ratio of equilibrium constants at two different temperatures is directly proportional to the standard enthalpy change of the reaction divided by the gas constant. The sign of the enthalpy change determines whether a reaction is endothermic or exothermic. The gaseous mole change depends strictly on the stoichiometric coefficients of the gas-phase reactants and products.

Solution:

(a) Examine the physical states of the chemical components in the balanced equation provided. Reactant A is gaseous, reactant B is gaseous, product C is gaseous, and product D is solid.

(b) The change in the number of moles of gaseous components, denoted as delta n-g, is computed by subtracting the sum of the stoichiometric coefficients of gaseous reactants from those of the gaseous products. This gives 3 minus the sum of 2 and 1, which equals 3 minus 3, resulting in exactly zero.

(c) Observe the behavior of the equilibrium constant Kp with the variation in temperature. At the lower temperature of 400 K, Kp has a value of 4.50 times 10^{-}2$.Whenthetemperatureisincreasedto500K, thevalueofKpdropsto1.20times10^{-}3.$

(c) A decrease in the equilibrium constant with an increase in temperature indicates that the forward reaction is suppressed at elevated temperatures. According to Le Chatelier’s principle, this behavior is characteristic of an exothermic process, where heat is liberated as a product.

(d) Combining these two distinct findings, the chemical reaction possesses a delta n-g value equal to zero and exhibits an exothermic thermodynamic profile. This matches option B perfectly.

Final Answer: The reaction is exothermic with $\Delta n_g = 0$.

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

Go Back to Question 5

Q6.

Solution

Concept:
The temperature dependence of a chemical reaction rate constant is described quantitatively by the Arrhenius equation. This mathematical relation states that the natural logarithm of the ratio of two rate constants at different absolute temperatures is equal to the activation energy divided by the universal gas constant, multiplied by the difference of the reciprocal absolute temperatures. By isolating the activation energy term, the energy barrier required for the reactants to transform into products can be determined.

Solution:

(a) The problem states that the rate constant doubles when the temperature increases from 300 K to 310 K. Therefore, the ratio of the rate constant at the higher temperature to the rate constant at the lower temperature is exactly 2.

(b) Assign the initial temperature T1 as 300 K and the final temperature T2 as 310 K. The change in temperature is 10 K, and the product of the two absolute temperatures is 300 multiplied by 310, which equals 93000 square Kelvin.

(c) Write down the integrated form of the Arrhenius equation: ln of the ratio k2 over k1 equals the activation energy Ea divided by R, multiplied by the quantity T2 minus T1 divided by the product of T1 and T2.

(d) Substitute the known values into this equation: ln of 2 is approximately 0.693, and the gas constant R is 8.314 J per mole per Kelvin. This gives 0.693 equals Ea divided by 8.314, multiplied by 10 divided by 93000.

(e) Rearrange the expression to solve for Ea by multiplying 0.693 by 8.314 and then by 93000, and finally dividing the entire product by 10. This calculation yields approximately 53610 Joules per mole, which converts directly to 53.6 Kilojoules per mole.

Final Answer: The approximate activation energy for this reaction is 53.6 kJ mol^{-}1.

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:
Redox titrations rely on the complete transfer of electrons between an oxidizing agent and a reducing agent at the stoichiometric equivalence point. In an acidic environment, the permanganate anion acts as a powerful oxidizing agent and undergoes a five-electron reduction to form manganese divalent cations. Simultaneously, ferrous ions act as the reducing agent by losing a single electron to transform into ferric ions. Equating the total chemical equivalents allows the unknown concentration to be found.

Solution:

(a) Identify the change in oxidation state for the oxidizing agent. The manganese atom in potassium permanganate goes from an oxidation state of plus seven to plus two. The valence factor or n-factor for potassium permanganate is therefore equal to 5.

(b) Identify the change in oxidation state for the reducing agent. The iron atom goes from an oxidation state of plus two in the ferrous ion to plus three in the ferric ion. The valence factor or n-factor for the ferrous sample is therefore equal to 1.

(c) At the chemical equivalence point of the redox titration, the total number of equivalents of the oxidizing agent must be exactly equal to the total number of equivalents of the reducing agent.

(d) Express the equivalence relationship in terms of molarity, volume, and n-factor: the product of molarity, volume, and n-factor for the ferrous sample equals the product of molarity, volume, and n-factor for the permanganate solution.

(e) Substitute the given values into the formula: Molarity of iron multiplied by 25.0 mL multiplied by 1 equals 0.02 M multiplied by 20.0 mL multiplied by 5. Simplifying the right side gives 2.0, and dividing by 25.0 yields a final molarity of 0.080 M for the ferrous solution.

Final Answer: The molarity of Fe$^{2} + intheoriginalsamplesolutionis0.080M$.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
The potential of an electrochemical galvanic cell operating under non-standard concentrations is evaluated using the Nernst equation. The standard cell potential is first calculated by subtracting the standard reduction potential of the anode from the standard reduction potential of the cathode. The Nernst equation then corrects this standard value by subtracting a factor proportional to the logarithm of the reaction quotient, which represents the ratio of the concentrations of products to reactants raised to their stoichiometric coefficients.

Solution:

(a) Write the balanced net ionic equation for the galvanic cell. Copper has a lower reduction potential, so it undergoes oxidation at the anode, while silver undergoes reduction at the cathode. The balanced reaction is solid copper plus two silver cations yields copper divalent cations plus two units of solid silver.

(b) The total number of moles of electrons transferred in the balanced cell reaction, denoted as n, is equal to 2. The expression for the reaction quotient Q includes only the aqueous species, which gives the concentration of copper ions divided by the square of the concentration of silver ions.

(c) Calculate the standard cell potential by subtracting the standard potential of the copper anode from that of the silver cathode. This gives 0.80 V minus 0.34 V, which equals a standard cell potential of plus 0.46 V.

(d) Substitute the given concentrations into the reaction quotient expression. Q equals 1.0 divided by the square of 1.0 times $10^-3, whichsimplifiesto 1.0 dividedby 1.0 times 10^-6, resultinginavalueof 10^6$.

(d) Apply the Nernst equation using the simplified constant: E-cell equals 0.46 minus the quantity 0.06 divided by 2, multiplied by the common logarithm of $10^6. Thissimplifiesto 0.46 minus 0.03 multipliedby 6, whichis 0.46 minus 0.18, yieldingafinalvalueof 0.$

Final Answer: The cell potential under these conditions is 0.28 V.

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

Go Back to Question 8

Q9.

Solution

Concept:
The thermal stability of alkaline earth metal carbonates down group two increases due to changes in ionic size and lattice energy relationships. When a metal carbonate undergoes thermal decomposition, it breaks down into a solid metal oxide and gaseous carbon dioxide. The stability depends on the ability of the metal cation to polarize the large, electron-rich carbonate anion, a phenomenon described comprehensively by Fajans' rules.

Solution:

(a) Going down group two from magnesium to barium, the atomic number increases, and additional electron shells are added, causing the ionic radius of the divalent metal cations to increase significantly. The charge-to-size ratio of the cations decreases down the group.

(b) A smaller cation like magnesium has a high charge density and exerts a strong polarizing force on the adjacent electron cloud of the carbonate anion. This polarization weakens the carbon-oxygen bonds within the carbonate polyatomic cluster, making it easier to break upon heating.

(c) As the size of the cation increases from magnesium to calcium, strontium, and finally barium, the polarizing power drops drastically. The barium ion has the largest radius and the lowest charge density among the options, meaning it causes the least structural distortion to the carbonate ion.

(d) Because the carbonate group remains stable against polarization when paired with a large cation of low charge density, the lattice energy of the carbonate remains relatively high, and more thermal energy is required to initiate decomposition.

(e) Consequently, the temperature required to break down the carbonate increases systematically down the column. Barium carbonate possesses the highest thermal decomposition temperature, making it the most thermally stable option listed.

Final Answer: Barium carbonate exhibits the highest thermal stability.

Answer: (D)

Go Back to Question 9

Q10.

Solution

Concept:

Orthoboric acid behaves differently from typical mineral protonic acids because it does not act as a proton donor through direct dissociation. Instead, its acidity arises from its electron-deficient nature as a boron compound. Boron in orthoboric acid has only six valence electrons in its bonding shell, creating an empty p-orbital that can accept a lone pair of electrons from a Lewis base.

Solution:

(a) The structural formula of orthoboric acid features a central boron atom bonded covalently to three hydroxyl groups in a planar geometry. Although it contains hydroxyl groups, the oxygen-hydrogen bonds do not readily cleave to release free hydrogen ions into an aqueous solution.

(b) When orthoboric acid is dissolved in water, the electron-deficient central boron atom acts as a Lewis acid. It interacts with the surrounding water molecules, which possess lone pairs of electrons on their respective oxygen atoms.

(c) The boron atom accepts a lone pair of electrons from the oxygen atom of a water molecule. This coordinate covalent interaction results in the abstraction of a hydroxyl anion from the water molecule, forming a stable tetrahedral borate complex.

(d) The reaction can be written as orthoboric acid plus two molecules of water yields the tetrahydroxyborate complex anion plus a hydronium cation. The release of this hydronium ion into the medium is what imparts acidity to the solution.

(e) Because each molecule of orthoboric acid reacts with water to generate exactly one hydronium ion by capturing a hydroxyl unit, it behaves functionally as a weak monobasic Lewis acid rather than a traditional Bronsted acid.

Final Answer: It acts as a Lewis acid by accepting a lone pair from a water molecule.

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:

According to Crystal Field Theory, the d-orbitals of a transition metal ion lose their degeneracy and split into different energy levels when surrounded by a field of ligands. The magnitude of this crystal field splitting energy in an octahedral field, denoted as Delta-o, depends heavily on the nature of the coordinating ligands. Ligands are arranged in order of their splitting ability in the spectrochemical series, where strong-field ligands produce larger splitting values than weak-field ligands.

Solution:

(a) Examine the central metal ion across all four given coordination complexes. In every case, the complex features a Cobalt central atom in a plus three oxidation state, which corresponds to a d6 electronic configuration. Since the metal ion and its oxidation state are identical, the splitting energy is determined solely by the ligands.

(b) Analyze the coordinating ligands present in the options: water molecules, ammonia molecules, cyanide anions, and chloride anions. These must be cross-referenced with their positions in the spectrochemical series.

(c) The spectrochemical series arranges common ligands in increasing order of field strength as follows: chloride is less than water, which is less than ammonia, which is significantly less than cyanide. Chloride and water behave as weak-field ligands, while ammonia and cyanide act as strong-field ligands.

(d) The cyanide ion stands out as an exceptionally strong-field ligand because of its ability to engage in substantial pi-backbonding with the d-orbitals of the transition metal. This orbital overlap significantly stabilizes the bonding arrangement and maximizes the energy gap between the t2g and eg orbital sets.

(e) Because the energy separation is directly proportional to the ligand field strength, the hexacyanocobaltate(III) complex will exhibit the largest energy gap among the choices. This corresponds to the highest crystal field splitting energy value, matching option C.

Final Answer: The complex with the highest crystal field splitting energy is $[Co(CN)6]^{3} -$.

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept:
Photochemical smog is a modern atmospheric phenomenon that develops in urban environments with high concentrations of vehicular and industrial emissions. It is characterized by a brown haze produced when primary pollutants undergo chemical transformations driven by solar radiation. This process generates an assortment of hazardous secondary pollutants, but gases associated primarily with industrial acid rain are not directly involved in this specific solar-driven cycle.
Solution:

(a) The generation of photochemical smog begins with primary pollutants, specifically nitric oxide and unburned volatile hydrocarbons, which accumulate in the lower atmosphere during morning traffic hours.

(b) When exposed to ultraviolet sunlight, nitrogen dioxide undergoes photolysis to release free oxygen atoms. These highly reactive oxygen atoms combine rapidly with molecular oxygen to produce ground-level ozone, a major secondary component of the smog.

(c) The interaction between volatile organic compounds, oxygen, and nitrogen oxides leads to the formation of other powerful oxidants, including peroxyacetyl nitrate, which causes severe eye irritation and plant damage.

(d) Sulfur dioxide, on the other hand, is a primary pollutant produced chiefly by the combustion of sulfur-rich coal or oil in power plants. Its atmospheric chemistry leads to the formation of sulfur trioxide and sulfuric acid, which are the main components of acid rain and industrial winter smog.

(e) Because sulfur dioxide is not a necessary participant in the sunlight-induced free radical reactions that define photochemical summer smog, it is excluded from the list of key components, making option C the correct choice.

Final Answer: Sulfur dioxide is not a key chemical component involved in photochemical smog.

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:

The systematic nomenclature of organic molecules follows rigid rules established by the International Union of Pure and Applied Chemistry. To determine the correct name, the principal functional group must first be identified to establish the suffix and the primary carbon chain. The chain is numbered from the end that gives the principal group the lowest possible locant, and all other substituents are appended alphabetically with their appropriate positional numbers.

Solution:

(a) Identify the functional groups present in the given structural formula. The molecule possesses a carboxylic acid group at one terminus and a secondary hydroxyl group along the carbon backbone.

(b) According to the IUPAC priority rules for functional groups, the carboxylic acid group takes precedence over the hydroxyl group. Therefore, the compound is classified fundamentally as a carboxylic acid, and the suffix of the parent chain will be -anoic acid.

(c) Select the longest continuous carbon chain that contains the principal functional group carbon atom. The chain starts at the carboxylic acid carbon and extends across five carbon atoms, making the parent alkane pentane.

(d) Number the principal carbon chain starting with the carboxylic acid carbon as position number 1. Moving along the chain, the quaternary carbon holding two methyl groups becomes position 2, the methylene carbon is position 3, the carbon with the hydroxyl group is position 4, and the terminal methyl carbon is position 5.

(e) Identify and arrange the substituents alphabetically. There are two methyl groups at position 2, designated as 2,2-dimethyl, and one hydroxyl group acting as a substituent at position 4, designated as 4-hydroxy. Arranging alphabetically places hydroxy before methyl, yielding 4-hydroxy-2,2-dimethylpentanoic acid.

Final Answer: The correct IUPAC name is 4-hydroxy-2,2-dimethylpentanoic acid.

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:

The structure of an unknown unsaturated hydrocarbon can be deduced by analyzing its chemical reactivity and the products of its oxidative cleavage. Hydrogenation reveals the degree of unsaturation by indicating how many pi-bonds or rings are present. Reductive ozonolysis splits carbon-carbon double bonds entirely, converting each alkene carbon into a carbonyl carbon, allowing the fragments to be reassembled like puzzle pieces to find the original structure.

Solution:

(a) The molecular formula of the original hydrocarbon is C6H10. It reacts with exactly one equivalent of hydrogen gas to form a product with the formula C6H12, which matches the general formula for a mono-alkene or a cycloalkane. This demonstrates that the original molecule contains exactly one carbon-carbon double bond and one ring system.

(b) Reductive ozonolysis of the alkene splits the double bond to form aldehydes or ketones. The problem specifies that a single organic product is isolated: 3-methylpentanedial. The fact that only one product is formed from a six-carbon reactant implies that the starting material must be a cyclic alkene.

(c) Draw the structure of the product, 3-methylpentanedial. It is a five-carbon dialdehyde chain with a methyl substituent located on the third carbon atom. The aldehyde carbons represent the points where the cyclic double bond was originally situated.

(d) To reconstruct the original cyclic alkene, connect the two terminal carbonyl carbon atoms of 3-methylpentanedial together with a double bond, while eliminating the oxygen atoms.

(e) Counting the resulting ring size reveals a five-membered ring containing a single double bond. Numbering from the double bond carbons toward the substituent places the methyl group at position 4. Therefore, the original hydrocarbon is 4-methylcyclopentene, corresponding to option A.

Final Answer: The structural arrangement of the original hydrocarbon is 4-methylcyclopentene.

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
Nucleophilic substitution reactions of alkyl halides can proceed via different mechanistic pathways depending on the structure of the substrate, the strength of the nucleophile, and the nature of the solvent. A secondary alkyl halide treated with a strong nucleophile like sodium hydroxide in a polar aprotic solvent favors a bimolecular nucleophilic substitution mechanism. This concerted pathway features a backside attack by the nucleophile, resulting in a predictable stereochemical outcome.

Solution:

(a) The substrate provided is (R)-2-bromobutane, which is an optically active secondary alkyl halide. The carbon atom bonded to the bromine atom is a chiral center, possessing four distinct groups: a hydrogen atom, a methyl group, an ethyl group, and a bromine atom.

(b) The reagent is sodium hydroxide, which provides the strongly nucleophilic hydroxide anion. The solvent specified is acetone, which is a classic polar aprotic solvent. Polar aprotic solvents stabilize cations well but leave anions relatively destabilized and highly reactive, strongly favoring the SN2 mechanism over the SN1 pathway.

(c) In a classical SN2 mechanism, the reaction happens in a single, concerted step without the formation of a carbocation intermediate. The hydroxide nucleophile approaches the stereocenter from the side exactly opposite to the departing bromide leaving group.

(d) As the new carbon-oxygen bond forms and the old carbon-bromine bond breaks, the other three substituents on the chiral carbon invert their spatial orientation, similar to an umbrella being turned inside out by the wind.

(e) This backside attack causes a complete inversion of configuration at the asymmetric carbon atom. Therefore, starting with the pure (R) enantiomer of 2-bromobutane results exclusively in the production of (S)-butan-2-ol, which aligns perfectly with option A.

Final Answer: The main organic product isolated is (S)-butan-2-ol with complete inversion of configuration.

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:
The reaction described is the Reimer-Tiemann reaction, which is a classic method for the ortho-formylation of phenols. When phenol is treated with chloroform in an alkaline medium, a highly reactive, neutral, divalent carbon intermediate is generated in situ through an alpha-elimination pathway. This electron-deficient species acts as a powerful electrophile that attacks the electron-rich aromatic ring of the phenoxide ion, leading to the formation of salicylaldehyde.

Solution:

(a) The first stage of the mechanism involves the reaction between chloroform and the strong base, hydroxide ion. The base abstracts the relatively acidic proton from the chloroform molecule, generating a temporary trichloromethyl carbanion.

(b) This carbanion is unstable and rapidly undergoes an alpha-elimination process, where it spontaneously expels a chloride leaving group from the same carbon atom. This loss of a chloride ion yields dichlorocarbene.

(c) Dichlorocarbene possesses a vacant p-orbital and a non-bonding lone pair of electrons on its central carbon atom, making it a neutral but highly electron-deficient electrophile.

(d) Meanwhile, phenol is converted by the base into the more reactive phenoxide ion. The phenoxide ion delocalizes its negative charge into the aromatic ring, making the ortho position highly nucleophilic. The ortho carbon then attacks the vacant orbital of the dichlorocarbene intermediate.

(e) Subsequent hydrolysis of the resulting dichloromethyl derivative in the basic medium replaces the two chlorine atoms with hydroxyl groups, which eliminate a molecule of water to form the final aldehyde group, yielding salicylaldehyde as the principal product.

Final Answer: The active electrophilic intermediate involved is dichlorocarbene (:CCl2).

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:
Aromatic aldehydes that lacks an alpha-hydrogen atom cannot undergo a conventional aldol condensation reaction when exposed to a concentrated base. Instead, they participate in the Cannizzaro reaction, which is an organic redox transformation. In this reaction, one molecule of the aldehyde undergoes nucleophilic attack by a hydroxide ion and subsequently transfers a hydride ion to a second molecule of the aldehyde, resulting in a simultaneous oxidation and reduction.

Solution:

(a) Benzaldehyde features a carbonyl group attached directly to a benzene ring. Because the alpha carbon is part of the aromatic ring and already forms four covalent bonds, it contains no alpha-hydrogen atoms, preventing enolate formation.

(b) When treated with a concentrated aqueous sodium hydroxide solution, a hydroxide ion acts as a nucleophile and attacks the electrophilic carbonyl carbon of one benzaldehyde molecule, forming a tetrahedral intermediate.

(c) This intermediate undergoes deprotonation by the base to form a highly unstable dianion. The reformation of the carbon-oxygen double bond prompts the expulsion of a hydride ion from this species.

(d) The departing hydride ion is transferred directly to the carbonyl carbon of a second benzaldehyde molecule in a concerted step. This reduces the second molecule into a benzyl oxide anion while the first molecule is oxidized into benzoic acid.

(e) Rapid proton exchange between the benzoic acid and the benzyl oxide anion produces benzyl alcohol and a sodium benzoate salt. Final acid workup converts the salt into benzoic acid, yielding an equimolar mixture of benzyl alcohol and benzoic acid.

Final Answer: The reaction yields an equimolar mixture of benzyl alcohol and sodium benzoate (which yields benzoic acid upon workup).

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept:

The identity of an unknown amine can be established by studying its diagnostic organic transformations. Primary aliphatic amines react with ice-cold nitrous acid to generate highly unstable alkyldiazonium salts, which break down rapidly at room temperature to liberate nitrogen gas and form a mixture of carbocation-derived products, dominated by primary alcohols. Furthermore, primary amines are uniquely capable of undergoing the carbylamine reaction when heated with chloroform and base.

Solution:

(a) The molecular formula C3H9N corresponds to a saturated aliphatic amine, which could structurally represent a primary, secondary, or tertiary amine.

(b) The reaction with nitrous acid at room temperature provides a crucial structural clue. Only primary aliphatic amines react with nitrous acid to quantitatively liberate nitrogen gas through the decomposition of a diazonium intermediate, leaving behind an alcohol. Secondary and tertiary amines form yellow nitrosamines or soluble salts without gas evolution.

(c) The second diagnostic test mentioned is the Hoffmann carbylamine reaction. When a primary amine is heated with chloroform and ethanolic potassium hydroxide, it undergoes a multi-step elimination and substitution pathway.

(d) This pathway converts the primary amino functional group into an isocyanide group, which is a functional group characterized by an intensely foul, repulsive, and choking odor. Secondary and tertiary amines completely fail this test because they lack the two amino protons required for the elimination steps.

(e) Among the structural options provided, only n-propylamine is a straight-chain primary aliphatic amine that matches the molecular formula C3H9N and satisfies both experimental observations, confirming its structure as CH3CH2CH2NH2.

Final Answer: The structure of compound (X) is CH3CH2CH2NH2.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept:

Deoxyribonucleic acid and Ribonucleic acid are the primary nucleic acid biopolymers responsible for storing and expressing genetic information in living organisms. While both polymers are composed of nucleotide subunits linked together via phosphodiester bridges, they exhibit precise chemical differences in the molecular structures of their constituent pentose sugars and nitrogenous heterocyclic bases.

Solution:

(a) Examine the structural differences in the carbohydrate backbone. DNA contains a modified five-carbon sugar known as D-2-deoxyribose, which lacks a hydroxyl group at the second carbon position. In contrast, RNA contains an unmodified D-ribose sugar that retains this secondary hydroxyl group.

(b) Analyze the distribution of nitrogenous bases. Both nucleic acids share three heterocyclic bases: adenine, guanine, and cytosine. However, they differ in their fourth base. DNA utilizes the methylated pyrimidine base thymine, whereas RNA utilizes uracil, which lacks the methyl group.

(c) Consider the higher-order macromolecular architecture. DNA naturally adopts a stable, double-stranded helical structure stabilized by inter-strand hydrogen bonding between complementary base pairs. RNA typically exists as a shorter, single-stranded molecule that folds into intricate three-dimensional shapes.

(d) Review the chemical bonding in the backbone. Both DNA and RNA are held together by covalent phosphodiester linkages connecting the third and fifth carbon atoms of adjacent sugar rings, not peptide bonds, which are unique to proteins.

(e) Comparing these biochemical rules against the given choices reveals that statement B is completely accurate, as it correctly identifies the base substitution where RNA uses uracil instead of thymine.

Final Answer: DNA contains the pyrimidine base thymine, whereas RNA contains uracil instead.

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

Go Back to Question 19

Q20.

Solution

Concept:
Teflon is a synthetic fluoropolymer noted for its exceptional chemical inertness, high thermal resistance, and extremely low coefficient of friction, making it invaluable for non-stick cookware and industrial coatings. It is classified as an addition polymer, which means it is formed by the sequential linkage of unsaturated monomer units without the elimination of small molecular byproducts. The polymerization proceeds via a chain-growth mechanism initiated by free radicals.

Solution:

(a) The chemical name for the addition polymer Teflon is polytetrafluoroethylene. The prefix poly- indicates a macro-molecular chain composed of repeating structural blocks derived directly from the corresponding alkene monomer.

(b) Isolate the fundamental repeating unit of the polymer, which is a pair of carbon atoms where every remaining valency is occupied by a fluorine atom. This structure corresponds to a -CF2-CF2- repeating sequence.

(c) To deduce the monomer, the single covalent carbon-carbon bonds within the polymer backbone are theoretically converted back into a carbon-carbon double bond, restoring the unsaturation required for chain-growth polymerization.

(d) This process identifies the monomer as tetrafluoroethylene, which possesses a symmetrical molecular structure represented by the chemical formula CF2=CF2.

(e) During industrial synthesis, gaseous tetrafluoroethylene is heated under high pressure in the presence of a free-radical initiator such as persulfate salts. The initiator homolytically cleaves the pi-bond of the monomer, triggering a rapid chain-propagation cascade that builds the linear polymer chains of Teflon.

Final Answer: Teflon is synthesized via the free-radical polymerization of CF2=CF2.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
Dalton's Law of Partial Pressures states that the total pressure exerted by a mixture of non-reacting ideal gases is equal to the sum of the partial pressures of the individual gases. The partial pressure of any component in a gas mixture is directly proportional to its mole fraction. The mole fraction is defined as the number of moles of that specific gas divided by the total number of moles of all gases present in the mixture.

Solution:

(a) Let the mass of methane and oxygen gas mixed in the vessel be represented by the variable m. This allows us to set up a ratio based on their respective molecular weights.

(b) Calculate the number of moles of methane gas present in the mixture. The molecular weight of methane is 12 plus 4, which equals 16 grams per mole. Therefore, the number of moles of methane is equal to m divided by 16.

(c) Calculate the number of moles of oxygen gas present in the mixture. The molecular weight of diatomic oxygen gas is 16 multiplied by 2, which equals 32 grams per mole. Therefore, the number of moles of oxygen is equal to m divided by 32.

(d) Determine the total number of moles in the gaseous mixture by adding the individual mole values together. This gives the sum of m divided by 16 and m divided by 32, which simplifies to 3m divided by 32 total moles.

(e) The fraction of the total pressure contributed by the oxygen molecules is equivalent to its mole fraction. This is found by dividing the moles of oxygen by the total moles, which means dividing m over 32 by 3m over 32. Simplifying this fraction yields exactly 1/3.

Final Answer: The fraction of the total pressure contributed by the oxygen molecules is 1/3.

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:

The mole fraction of solute particles in an electrolyte solution depends on the total concentration of all distinct ionic species produced upon dissolution. When a strong electrolyte dissolves in water, it dissociates completely into its constituent cations and anions. To determine the true mole fraction of solute particles, the colligative behavior must be considered by multiplying the initial moles of the salt by its van 't Hoff factor.

Solution:

(a) Calculate the initial number of moles of sodium chloride solute. The given mass is 5.85 g, and the molecular weight is 58.5 grams per mole. Dividing 5.85 by 58.5 yields exactly 0.10 moles of sodium chloride.

(b) Account for the complete dissociation of the electrolyte. Sodium chloride breaks down in water to produce one sodium cation and one chloride anion per formula unit. This means the van 't Hoff factor is equal to 2, yielding 0.20 moles of active solute particles.

(c) Calculate the number of moles of the pure water solvent. The mass of water is 90.0 g, and its molecular weight is 18 grams per mole. Dividing 90.0 by 18 gives exactly 5.0 moles of water solvent.

(d) Determine the total number of moles of all particles present in the solution by adding the moles of dissociated ions to the moles of solvent. This gives 0.20 plus 5.0, which equals 5.20 total moles.

(e) The mole fraction of the solute particles is calculated by dividing the total moles of ions by the total moles of the entire system. Dividing 0.20 by 5.20 gives a value of approximately 0.03846, which rounds precisely to 0.0385.

Final Answer: The mole fraction of the solute particles is 0.0385.

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:

According to the de Broglie hypothesis, any moving material particle exhibits wave-like properties, and its wavelength is inversely proportional to its momentum. In the Bohr model of the hydrogen atom, this wave behavior is constrained by a standing wave boundary condition. This condition mandates that the total circumference of an electron's circular orbit must be an integral multiple of its associated de Broglie wavelength to prevent destructive interference.

Solution:

(a) State the quantization condition proposed by Louis de Broglie for a stable Bohr orbit. The mathematical relationship dictates that the circumference of the orbit, 2 multiplied by pi multiplied by the radius r, must equal the principal quantum number n multiplied by the wavelength lambda.

(b) Express the radius of a specific Bohr orbit as a function of the principal quantum number. The radius of the nth orbit in a hydrogen atom is directly proportional to the square of n, which can be written mathematically as r equals a0 multiplied by n squared.

(c) Substitute the given orbit number into the radius expression. For the third Bohr orbit, the value of n is equal to 3. Therefore, the radius of this orbit is equal to a0 multiplied by 3 squared, which simplifies to 9a0.

(d) Substitute the calculated radius and the quantum number back into the standing wave circumference equation. This yields 2 multiplied by pi multiplied by 9a0 equals 3 multiplied by the de Broglie wavelength lambda.

(e) Isolate the wavelength variable by dividing both sides of the equation by 3. This gives 18 multiplied by pi multiplied by a0 divided by 3, which simplifies beautifully to 6 multiplied by pi multiplied by a0.

Final Answer: The de Broglie wavelength associated with the electron is $6\pi a_0$.

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:
The spatial geometry and hybridization state of a polyatomic ion can be predicted using Valence Shell Electron Pair Repulsion theory. This model counts the total number of valence electrons to determine the steric number of the central atom. The steric number, which is the sum of sigma bonds and lone pairs, dictates the arrangement of electron pairs and the corresponding hybrid orbitals, while the actual geometry describes only the positions of the atomic nuclei.

Solution:

(a) Determine the total number of valence electrons present in the triiodide anion. Iodine belongs to group 17 and possesses 7 valence electrons. For three iodine atoms plus the single negative charge, the total count is 3 multiplied by 7 plus 1, which equals 22 valence electrons.

(b) Identify the bonding arrangement. One central iodine atom forms single covalent sigma bonds with two surrounding terminal iodine atoms. This consumes 4 bonding electrons, leaving 18 electrons to be distributed as non-bonding lone pairs.

(c) Distribute the remaining electrons to satisfy the octet rule. Each of the two terminal iodine atoms receives 3 lone pairs to complete its outer shell, consuming 12 electrons. The final 6 electrons are placed on the central iodine atom as 3 lone pairs.

(d) Calculate the steric number for the central iodine atom. The central atom possesses 2 sigma bonds and 3 lone pairs, giving a steric number of 5. A steric number of 5 requires five atomic orbitals to hybridize, resulting in an sp3d hybridization state.

(e) The five electron pairs adopt a trigonal bipyramidal orientation. To minimize lone pair-lone pair repulsions, the 3 lone pairs occupy the equatorial positions at 120-degree angles, forcing the 2 axial iodine atoms into a linear geometry with a 180-degree bond angle.

Final Answer: The geometry and hybridization state of the triiodide ion are linear and sp3d.

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:

The boiling point of a molecular compound is determined by the magnitude of its intermolecular attractive forces, which must be overcome to transition the substance from the liquid phase to the gas phase. Hydrogen bonding is an exceptionally strong type of dipole-dipole attraction that occurs when a hydrogen atom is bonded covalently to a highly electronegative atom like nitrogen, oxygen, or fluorine, creating a strong localized positive charge.

Solution:

(a) Analyze the intermolecular forces present in propane. Propane is a non-polar hydrocarbon whose molecules interact solely via weak London dispersion forces, giving it the lowest boiling point among the choices.

(b) Analyze the intermolecular forces present in dimethyl ether. This compound is a structural isomer of ethanol but possesses a symmetrical ether linkage. It exhibits weak dipole-dipole interactions because it lacks a hydrogen atom bonded directly to oxygen.

(c) Analyze the intermolecular forces present in ethanal. Ethanal features a polar carbonyl group that creates permanent dipole-dipole attractions between molecules, but it cannot form intermolecular hydrogen bonds because its hydrogen atoms are attached to carbon.

(d) Analyze the intermolecular forces present in ethanol. Ethanol possesses a highly polar hydroxyl group where a hydrogen atom is bonded directly to an electronegative oxygen atom. This structural feature allows ethanol molecules to form a vast, dynamic network of intermolecular hydrogen bonds.

(e) Because hydrogen bonds are significantly stronger than ordinary dipole-dipole interactions or dispersion forces, a large amount of thermal energy is required to disrupt this network during vaporization, giving ethanol a remarkably high boiling point compared to the other compounds.

Final Answer: Ethanol exhibits the highest boiling point due to extensive intermolecular hydrogen bonding.

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:
The mathematical relationship between the chemical rate constant and the absolute temperature can be visualized by taking the natural logarithm of the Arrhenius equation. This transformation converts the exponential function into a linear equation that fits the standard slope-intercept form of a straight line. By plotting the natural logarithm of the rate constant against the reciprocal of the absolute temperature, the activation energy of the reaction can be extracted directly from the resulting slope.

Solution:

(a) Write the linear form of the Arrhenius equation. The equation states that the natural logarithm of the rate constant k is equal to the natural logarithm of the pre-exponential factor A minus the quantity activation energy Ea divided by the product of the gas constant R and the absolute temperature T.

(b) Compare this relationship to the equation of a straight line, y equals mx plus c. In this plot, the dependent variable y represents the natural logarithm of k, and the independent variable x represents the reciprocal temperature term, 1 divided by T.

(c) The y-intercept of this linear graph is equal to the natural logarithm of the pre-exponential factor, while the slope of the straight line is represented by the constant term minus Ea divided by the universal gas constant R.

(d) The problem states that the calculated slope of the straight line is equal to minus 6000 Kelvin. Set this value equal to the theoretical expression for the slope: minus 6000 equals minus Ea divided by R. The negative signs on both sides cancel out.

(e) Solve for the activation energy by multiplying the slope value by the gas constant. This gives 6000 multiplied by 8.314 J per mole per Kelvin, which yields 49884 Joules per mole. Converting this value to kilojoules gives 49.88 kJ per mole.

Final Answer: The activation energy of the reaction is 49.88 kJ mol^{-}1.

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

Go Back to Question 26

Q27.

Solution

Concept:
Acidified potassium dichromate solution is a strong oxidizing agent frequently used to detect the presence of reducing gases. When an electron donor such as sulfur dioxide gas is introduced into the solution, a redox reaction takes place. The hexavalent chromium atoms within the dichromate polyatomic anion accept electrons and undergo reduction, resulting in a distinct visual change as the coordination environment changes.

Solution:

(a) Identify the initial oxidation states of the key elements. In the potassium dichromate reactant, the chromium atoms exist in a plus six oxidation state, which imparts a characteristic bright orange color to the aqueous solution.

(b) Identify the behavior of the reducing agent. The sulfur atom in sulfur dioxide gas starts with an oxidation state of plus four. As it bubbles through the liquid, it undergoes oxidation to form the sulfate anion, where the sulfur atom reaches a plus six oxidation state.

(c) Trace the electron transfer to the oxidizing agent. To balance the oxidation of sulfur, the orange dichromate anion captures electrons. This process breaks down the dichromate frame and reduces the chromium atoms from plus six to a plus three oxidation state.

(d) Analyze the final coordination complex formed in the solution. The newly generated trivalent chromium ions form a stable, green-colored hexaqua complex with the surrounding water molecules in the acidic aqueous medium.

(e) The distinct color transition from bright orange to deep green serves as a classic diagnostic test for identifying reducing gases. The species directly responsible for the green appearance is the hydrated trivalent chromium ion, matching option B.

Final Answer: The species responsible for the final green color is Cr^3+.

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:

The total number of stereoisomers for an octahedral coordination complex depends on the spatial arrangements of its ligands. Stereoisomerism includes both geometric isomers, which differ in the relative positions of the ligands, and optical isomers, which are non-superimposable mirror images of each other. Bidentate ligands like ethylenediamine introduce structural constraints because they can only span adjacent coordination sites.

Solution:

(a) Analyze the structure of the complex [Pt(en)Cl2Br2]. Platinum is in a plus four oxidation state, forming a stable six-coordinate octahedral complex. The ethylenediamine ligand is a symmetrical bidentate chelating ring that must occupy cis positions.

(b) Determine the geometric isomers by looking at the arrangement of the remaining monodentate ligands. First, consider the isomer where the two chloride ligands are trans to each other. In this arrangement, the two bromide ligands are forced into cis positions, resulting in a single achiral geometric isomer.

(c) Second, consider the arrangement where the two bromide ligands are trans to each other. In this configuration, the two chloride ligands are forced into cis positions relative to one another, producing another distinct, achiral geometric isomer.

(d) Third, consider the arrangement where both pairs of monodentate ligands are cis to each other. This means the two chloride ligands are cis, and the two bromide ligands are also cis. This specific geometric arrangement lacks any plane or center of symmetry.

(e) Because this fully cis isomer is asymmetric, it exists as a pair of non-superimposable mirror images, or enantiomers, which are optically active. Adding the two achiral geometric isomers to the pair of enantiomers gives a total of 3 stereoisomers.

Final Answer: The total number of stereoisomers possible for the complex is 3.

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:
Nucleophilic acyl substitution reactions proceed via a two-step addition-elimination mechanism at the carbonyl carbon of carboxylic acid derivatives. A nucleophile attacks the electrophilic carbonyl carbon to form a tetrahedral intermediate, which then collapses to regenerate the carbon-oxygen double bond while expelling a leaving group. The relative reactivity of these derivatives depends on the electron-withdrawing capacity and leaving-group ability of the substituent.
Solution:

(a) Analyze the structure of the leaving groups across the four functional derivatives. For acetyl chloride, the leaving group is the chloride ion. For acetamide, it is the amide ion. For acetic anhydride, it is the acetate ion, and for ethyl acetate, it is the ethoxide ion.

(b) Evaluate the leaving group ability based on basicity. Weak bases are stable anions and act as excellent leaving groups. The chloride ion is the conjugate base of a strong mineral acid, making it an exceptionally weak base and an outstanding leaving group.

(c) The acetate ion is stabilized by resonance, making it a moderately weak base and a good leaving group. The ethoxide ion is a strong base because of the electron-donating alkyl group, and the amide ion is an extremely strong base because nitrogen is less electronegative than oxygen.

(d) Consider the resonance stabilization of the starting material. In acetamide, the nitrogen lone pair strongly delocalizes into the carbonyl group, reducing its electrophilicity. This resonance is weaker in esters and anhydrides, and minimal in acyl chlorides due to poor orbital overlap between carbon and chlorine.

(e) Combining the high electrophilicity and superior leaving group ability places acetyl chloride as the most reactive, followed by acetic anhydride, ethyl acetate, and lastly acetamide, establishing the sequence given in option A.

Final Answer: The decreasing order of relative reactivity is (i) > (iii) > (iv) > (ii).

Answer: (A)

Go Back to Question 29

Q30.

Solution

Concept:

An acidic buffer solution resists changes in pH when small amounts of acid or base are added. It is typically prepared by mixing a weak acid with its conjugate base, or by generating this mixture in situ through a partial neutralization reaction. For an effective buffer to exist in solution after mixing, the weak acid must remain in excess relative to a limiting amount of added strong base.

Solution:

(a) Analyze the reaction that occurs when mixing equal volumes of solutions. Let the volume of each solution be represented by V liters. This allows us to calculate the final molar amounts of reactants after mixing.

(b) In option B, mixing 0.2 M acetic acid with 0.1 M sodium hydroxide provides 0.2V moles of weak acid and 0.1V moles of strong base. The strong base reacts completely with the weak acid in a one-to-one stoichiometric ratio.

(c) The neutralization reaction consumes all 0.1V moles of the sodium hydroxide limiting reactant, leaving behind 0.1V moles of unreacted acetic acid in the solution.

(d) This reaction produces exactly 0.1V moles of sodium acetate, which dissociates completely to supply the conjugate base acetate anions to the solution.

(e) The resulting solution contains a mixture of unreacted weak acid and its conjugate base salt. Because both components are present in comparable quantities, the system satisfies the requirements of the Henderson-Hasselbalch equation and functions as an effective acidic buffer.

Final Answer: The pair that forms an effective acidic buffer is 0.2 M CH3COOH and 0.1 M NaOH.

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept:
The common-ion effect describes the reduction in the solubility of a sparingly soluble ionic salt when a soluble electrolyte containing a common ion is introduced into the solution. This behavior is governed by Le Chatelier's principle regarding chemical equilibria. The solubility product constant, Ksp, remains fixed at a constant temperature, meaning that an increase in the concentration of one constituent ion forces the equilibrium to shift backward, drastically lowering the concentration of the other ion.

Solution:

(a) Write the heterogeneous dissolution equilibrium for the sparingly soluble salt MX2 in water. Solid MX2 dissociates reversibly into one divalent metal cation M2+ and two monovalent anions X-.

(b) Express the solubility product constant in terms of the equilibrium ion concentrations. The mathematical formulation is Ksp equals the concentration of M2+ multiplied by the square of the concentration of X-.

(c) Account for the presence of the fully soluble sodium haloid salt NaX. This strong electrolyte completely dissociates in solution, contributing a fixed baseline concentration of 0.01 M for the common anion X-.

(d) Let the molar solubility of the salt MX2 under these common-ion conditions be represented by the variable s. Dissolving s moles of MX2 yields s moles of M2+ cations and 2s moles of X- anions. The total equilibrium concentration of X- becomes the sum of 0.01 and 2s.

(e) Since the salt is sparingly soluble, its solubility s is extremely small, allowing us to approximate 0.01 plus 2s as simply 0.01 M. Substitute these values into the Ksp expression: 4.0 times $10^-12equalssmultipliedbythesquareof0.01.Solvingforsyieldsexactly4.0times10^-8M.$

Final Answer: The molar solubility of the salt in the NaX solution is 4.0 $\times 10^{-8} M$.

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:
A reversible adiabatic expansion of an ideal gas involves a thermal transformation where no heat is exchanged between the system and its surroundings. During this work-driven process, the gas consumes its own internal kinetic energy to expand against the boundaries, resulting in a temperature drop. The quantitative relationship between temperature and volume variations is governed by the adiabatic Poisson equations, which depend on the heat capacity ratio of the gas.
Solution:

(a) Identify the molar heat capacity at constant volume provided in the prompt, which is 3/2 R. This value signifies that the gas behaves as a classic monoatomic ideal gas.

(b) Use the Mayer relation to determine the molar heat capacity at constant pressure. Cp is equal to Cv plus R, which gives 3/2 R plus R, resulting in 5/2 R. The adiabatic index, denoted by the Greek letter gamma, is the ratio of Cp to Cv, which equals 5/3.

(c) State the specific Poisson equation that links the temperature and volume states during an adiabatic path. The relationship dictates that the product of temperature and volume raised to the power of gamma minus one remains constant throughout the process.

(d) Set up the ratio for the initial and final states: T2 divided by T1 equals the quantity V1 divided by V2 raised to the power of gamma minus one. Substitute the value of gamma to find the exponent: 5/3 minus 1 equals 2/3.

(e) The problem states that the total volume increases by a factor of 8, meaning the ratio V1 over V2 is exactly 1/8. Substitute the known values into the equation: T2 divided by 300 equals 1/8 raised to the power of 2/3. Since the cube root of 1/8 is 1/2, and squaring it yields 1/4, T2 equals 300 divided by 4, which simplifies to 75 K.

Final Answer: The final temperature of the gas is 75 K.

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:

Stoichiometry calculations for gaseous reactions require identifying the limiting reactant based on the molar ratios of the balanced chemical equation. At standard temperature and pressure, one mole of any ideal gas occupies a fixed volume of 22.4 liters. Once the maximum moles of product are determined, the molar concentration or molarity of the resulting solution can be calculated by dividing the total moles of solute by the volume of the solution in liters.

Solution:

(a) Convert the initial volumes of the reacting gases at standard temperature and pressure into moles. For hydrogen gas, dividing 22.4 liters by the standard molar volume of 22.4 liters per mole yields exactly 1.0 mole of hydrogen.

(b) For chlorine gas, dividing the given volume of 11.2 liters by the standard molar volume of 22.4 liters per mole yields exactly 0.5 moles of chlorine gas.

(c) Write the balanced chemical equation for the synthesis reaction: one mole of diatomic hydrogen gas reacts with one mole of diatomic chlorine gas to produce two moles of hydrogen chloride gas.

(d) Compare the available molar amounts to the stoichiometric coefficients. Since the reaction requires a one-to-one ratio, chlorine gas is present in a smaller amount and acts as the limiting reactant, while hydrogen gas is in excess.

(e) The production of the product is governed entirely by the limiting reactant. According to the stoichiometry, 0.5 moles of chlorine gas will react completely to produce twice that amount of hydrogen chloride, yielding exactly 1.0 mole of gas. Dissolving this 1.0 mole of solute in 500 mL of water, which is 0.5 liters, gives a molarity of 1.0 divided by 0.5, resulting in 2.0 M.

Final Answer: The molarity of the hydrochloric acid solution obtained is 2.0 M.

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:
This synthetic sequence showcases a multi-step transformation involving aromatic oxidation, functional group conversion, selective reduction, and a base-catalyzed condensation. Toluene is first converted to a carboxylic acid, which is then transformed into an acyl chloride. A selective partial reduction converts this to an aromatic aldehyde, which finally undergoes a self-condensation reaction under basic conditions because it lacks alpha-hydrogens, creating an alpha, beta-unsaturated carbonyl compound.

Solution:

(a) In the first step, toluene is heated with alkaline potassium permanganate, which is a powerful oxidizing agent. This reaction selectively oxidizes the benzylic alkyl side chain completely, transforming toluene into benzoic acid, labeled as intermediate W.

(b) In the second step, benzoic acid is treated with thionyl chloride. This reagent substitutes the hydroxyl group of the carboxylic acid with a chlorine atom, converting benzoic acid into benzoyl chloride, labeled as intermediate X.

(c) In the third step, benzoyl chloride undergoes partial reduction using hydrogen gas over a palladium catalyst poisoned with barium sulfate and quinoline, a process known as the Rosenmund reduction. This selective catalyst reduces the acyl chloride into benzaldehyde, intermediate Y, without reducing it further to an alcohol.

(d) In the final step, benzaldehyde is treated with a dilute solution of sodium hydroxide. Since benzaldehyde lacks alpha-hydrogen atoms, it cannot form an enolate ion to undergo a standard self-aldol addition. Instead, under these specific heating and concentration conditions, it undergoes a crossed or self-condensation.

(e) The condensation between two molecules of benzaldehyde in the presence of base involves a sequence of nucleophilic additions followed by dehydration, which eliminates a molecule of water to establish a conjugated system, yielding cinnamaldehyde as the final major organic product Z.

Final Answer: The final major organic product (Z) is Cinnamaldehyde.

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:

Radioactive decay processes involve the spontaneous transformation of an unstable atomic nucleus into a more stable state through the emission of subatomic particles. An alpha-particle is equivalent to a helium-four nucleus, consisting of two protons and two neutrons, meaning its emission reduces both the atomic number and the mass number. A beta-minus particle is an electron ejected when a neutron converts into a proton, which increases the atomic number without altering the mass number.

Solution:

(a) Start with the initial parent nucleus represented by the notation where A is the mass number and Z is the atomic number. We must trace the sequential changes imposed on these two values by the particle emissions.

(b) Analyze the impact of emitting alpha-particles. The problem states that the radioactive decay chain involves the emission of exactly 3 alpha-particles. Each individual alpha event reduces the nuclear mass number by 4 and the atomic number by 2.

(c) Calculate the total reduction caused by the alpha emissions. The cumulative loss in mass number is 3 multiplied by 4, which equals 12. The cumulative loss in atomic number is 3 multiplied by 2, which equals 6. This brings the temporary coordinates to a mass of A minus 12 and an atomic number of Z minus 6.

(d) Analyze the impact of emitting beta-minus particles. The decay chain involves the emission of exactly 2 beta-minus particles. Each beta-minus emission represents the conversion of a neutron into a proton within the nucleus, which increases the atomic number by 1 while keeping the mass number constant.

(e) Calculate the total adjustments caused by the beta emissions. The mass number remains completely unchanged at A minus 12. The atomic number increases by 2 multiplied by 1, which equals 2. Adding this to the intermediate atomic number gives Z minus 6 plus 2, which simplifies to Z minus 4, matching option A.

Final Answer: The resulting daughter nucleus has an Atomic number = Z-4 and a Mass number = A-12.

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept:

The structural and chemical properties of group 15 hydrides change systematically down the column. Thermal stability decreases as the element-hydrogen bond lengths increase, causing reducing power to increase. Boiling points reflect a competition between molecular size and intermolecular hydrogen bonding. Bond angles drop down the group due to the diminishing hybrid character of the central atom, while Lewis basicity decreases as the lone pair becomes more diffuse.

Solution:

(a) Statement A is correct. Going down group 15, the size of the central atom increases, which significantly weakens the E-H bond strength. As a result, BiH3 has the lowest thermal stability and decomposes most readily to liberate hydrogen, making it the strongest reducing agent among these hydrides.

(b) Statement B is correct. Ammonia exhibits an anomalously high boiling point because the strong electronegativity of nitrogen enables extensive intermolecular hydrogen bonding. Phosphine lacks this capability and relies only on weaker dispersion forces, resulting in a lower boiling point than ammonia.

(c) Statement C is incorrect. The H-E-H bond angle actually decreases down the group from nearly 107 degrees in NH3 to approximately 91 degrees in SbH3. According to Drago's rule, the heavier elements use nearly pure p-orbitals for bonding, leaving the lone pair in an unhybridized s-orbital.

(d) Statement D is correct. Nitrogen is small with a high electron density, making its lone pair highly concentrated and readily available for donation. Down the group, the lone pair occupies a larger, more diffuse orbital, reducing its nucleophilic ability and making NH3 a much stronger Lewis base than PH3.

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

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

Go Back to Question 36

Q37.

Solution

Concept:

For any spontaneous electrochemical process operating under standard conditions, the second law of thermodynamics requires that the total entropy change of the universe must be positive. This structural requirement dictates that the standard Gibbs free energy change must be negative. The free energy is linked directly to the standard cell potential and the equilibrium constant through fundamental logarithmic and electrochemical relations.

Solution:

(a) Statement A is correct. The standard free energy change is related to the standard cell potential by the equation where delta G equals minus nFE-cell. For a spontaneous process where free energy is lost, the standard cell potential must be strictly greater than zero.

(b) Statement B is correct. A negative change in standard Gibbs free energy is the definitive criterion for chemical spontaneity under constant temperature and pressure conditions, indicating that the system can perform useful electrical work.

(c) Statement C is correct. The standard free energy change is related to the equilibrium constant by the equation where delta G equals minus RT ln K-eq. Since delta G is negative for a spontaneous process, the natural logarithm of K-eq must be positive, which requires K-eq to be greater than 1.

(d) Statement D is correct. The second law of thermodynamics establishes that the total entropy change of the universe, which is the sum of the entropy changes of the system and the surroundings, must increase for any spontaneous real-world pathway.

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

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

Go Back to Question 37

Q38.

Solution

Concept:

The chemical and physical behaviors of transition metals and inner transition elements are governed by electron configurations and effective nuclear charge. The filling of 4f inner shells provides imperfect shielding, causing a steady contraction in atomic radii across the lanthanide series. Oxidation states are determined by the accessibility of valence electrons, while magnetic characteristics depend directly on the presence or absence of unpaired spins.

Solution:

(a) Statement A is correct. The lanthanum trivalent ion loses its valence electrons to achieve an empty shell configuration [Xe] 4f0, while the lutetium trivalent ion achieves a completely filled [Xe] 4f14 configuration. Since neither ion possesses unpaired electrons, both are entirely diamagnetic.

(b) Statement B is correct. Transition metals exhibit multiple oxidation states because the energy difference between the inner (n-1)d orbitals and the outer ns orbitals is remarkably small, allowing electrons from both subshells to participate in chemical bonding.

(c) Statement C is correct. Zirconium is a 4d transition metal and Hafnium is a 5d transition metal. Normally, atomic size increases down a group, but the intervention of the lanthanide contraction increases the effective nuclear charge of Hafnium, pulling its electrons inward and making its radius nearly identical to that of Zirconium.

(d) Statement D is incorrect. The Mn3+ ion has a d4 configuration and readily accepts an electron to form the highly stable, half-filled d5 Mn2+ ion, making it a strong oxidizing agent. Conversely, Cr3+ has a stable t2g3 half-filled subshell configuration, making it reluctant to gain electrons.

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

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

Go Back to Question 38

Q39.

Solution

Concept:
Carbocations are highly reactive, electron-deficient organic intermediates that can undergo skeletal rearrangements to achieve a state of lower potential energy. A rearrangement occurs if an adjacent carbon atom can transfer a substituent along with its bonding electron pair via a hydride shift or an alkyl shift. This intramolecular migration is driven entirely by the transformation of a less stable carbocation into a more thermodynamically stable intermediate.

Solution:

(a) Statement A is correct. The n-propyl carbocation is a primary carbocation, which is relatively unstable due to minimal hyperconjugation. It undergoes a spontaneous 1,2-hydride shift from the adjacent secondary carbon, transforming into the much more stable secondary isopropyl carbocation.

(b) Statement B is correct. The initial intermediate is a secondary carbocation. The adjacent carbon is a quaternary center bonded to three methyl groups. To relieve steric strain and increase electronic stabilization, a 1,2-methyl shift occurs, creating a highly stable tertiary carbocation.

(c) Statement C is incorrect. The isopropyl carbocation is a secondary carbocation stabilized symmetrically by six hyperconjugative alpha-hydrogens. Any hydride shift would merely recreate an identical secondary carbocation or transform it into an unstable primary carbocation, so no favorable rearrangement pathway exists.

(d) Statement D is incorrect. The benzyl carbocation is a primary intermediate, but its vacant p-orbital is directly conjugated with the pi-system of the aromatic ring. This extensive resonance delocalization provides exceptional stability, meaning it does not rearrange via simple aliphatic shifts.

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

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

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Q40.

Solution

Concept:

The compressibility factor Z serves as a mathematical measure of how much a real gas deviates from ideal gas behavior. For a perfectly ideal gas, Z is equal to 1 under all conditions. Real gas molecules, however, possess finite volumes and exert mutual intermolecular attractive forces. The magnitude of these factors depends heavily on the external temperature and pressure variables, causing the gas to behave non-ideally when these constraints are varied.

Solution:

(a) Statement A describes conditions where a real gas behaves almost ideally. At very low pressures and high temperatures, the kinetic energy of the molecules is massive compared to their weak attractive forces, and the volume of the container is so large that molecular volume is negligible, making Z close to 1.

(b) Statement B is correct. Under high pressure conditions, gas molecules are forced extremely close together. The finite volume occupied by the gas molecules themselves becomes a significant fraction of the total container volume and can no longer be ignored, leading to a positive deviation where Z is greater than 1.

(c) Statement C is correct. At low temperatures, the average kinetic energy of the gas molecules drops significantly. This deceleration allows intermolecular attractive forces to become active and pull the molecules together, reducing the pressure exerted on the walls and causing a negative deviation where Z is less than 1.

(d) Statement D is correct. At the critical point of a gas, the boundaries between the liquid and gaseous phases disappear, and intermolecular interactions reach a maximum threshold. The gas exhibits extreme non-ideal behavior, and the compressibility factor deviates significantly from unity.

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

Answer: (B,C,D)

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Answer Key

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