WBJEE Chemistry Sample Paper-7

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

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Categories**.
- **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 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. If the kinetic energy of an electron is increased four times, the de Broglie wavelength associated with it changes by a factor of:

(A) 4

(B) 2

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

(D) $\frac{1}{4}$

Q3. The formal charges on the central oxygen atom and the two terminal oxygen atoms in the ozone molecule (O_3), moving from left to right in a standard Lewis structure showing a single and double bond ($O = O - O$), are respectively:

(A) $0, +1, -1$

(B) $+1, 0, -1$

(C) $-1, +1, 0$ D $0, 0, 0$

Q4. Equal masses of methane (CH_4) and oxygen (O_2) are mixed in an empty container at 25°C. The fraction of the total pressure exerted by oxygen is:

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

(B) $\frac{1}{3}$

(C) $\frac{2}{3}$

(D) $\frac{1}{9}$

Q5. For the reversible adiabatic expansion of an ideal gas, the correct relationship between pressure (P) and volume (V) where $\gamma = \frac{C_p}{C_v}$ is given by $PV^\gamma = \text{constant}$. If the gas undergoes a reversible isothermal expansion instead, the work done by the system compared to the adiabatic process between the same initial and final volumes is:

(A) Exactly equal

(B) Less than the adiabatic work

(C) Greater than the adiabatic work

(D) Dependent purely on the molar mass of the gas

Q6. For the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, the degree of dissociation at a certain temperature is α when the total pressure is P. The equilibrium constant K_p is given by the expression:

(A) $\frac{\alpha^2 P}{1-\alpha^2}$

(B) $\frac{\alpha^2 P^2}{1-\alpha}$

(C) $\frac{\alpha P}{1-\alpha^2}$

(D) $\frac{\alpha^2}{1-\alpha^2}$

Q7. For a first-order parallel decomposition reaction where substance A converts simultaneously to B and C with rate constants $k_1 = 2.0 \times 10^{-4}\ s^{-1}$ and $k_2 = 3.0 \times 10^{-4}\ s^{-1}$ respectively, the percentage of B in the product mixture at any time interval is:

(A) 20%

(B) 40%

(C) 60%

(D) 50%

Q8. In a permanganometric titration, 20 mL of 0.02 M $KMnO_4$ in an acidic medium completely oxidizes 25 mL of a given $FeSO_4$ solution. The molarity of the $FeSO_4$ solution is:

(A) 0.016 M

(B) 0.080 M

(C) 0.032 M

(D) 0.100 M

Q9. The standard reduction potentials of three metallic cations X, Y, and Z are +0.52 V, −2.87 V, and −0.44 V respectively. The correct order of their reducing power as neutral metals is:

(A) $X > Z > Y$

(B) $Y > Z > X$

(C) $Y > X > Z$

(D) $Z > Y > X$

Q10. Among the alkaline earth metal carbonates, the thermal stability increases down the group. The correct order of their decomposition temperatures is:

(A) $BaCO_3 < SrCO_3 < CaCO_3 < MgCO_3$

(B) $MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$

(C) $CaCO_3 < MgCO_3 < BaCO_3 < SrCO_3$

(D) $MgCO_3 < SrCO_3 < CaCO_3 < BaCO_3$

Q11. Orthoboric acid (H_3BO_3) behaves as a weak monobasic acid in aqueous solution because:

(A) It self-ionizes to release a proton.

(B) It acts as a Lewis acid, accepting OH^- from water molecules and releasing a hydronium ion.

(C) It contains three replaceable hydrogen atoms but only one is active.

(D) It forms an insoluble polymeric network upon contact with water.

Q12. When $K_2Cr_2O_7$ is heated with concentrated H_2SO_4 in the presence of a chloride salt, deep red vapors of a volatile compound X are evolved. Compound X is:

(A) $CrCl_3$

(B) CrO_2Cl_2

(C) CrO_3

(D) Cr_2O_3

Q13. The correct IUPAC name of the coordination complex $[Co(NH_3)_4(H_2O)Cl]Cl_2$ is:

(A) Tetraamminechloroaquacobalt(III) chloride

(B) Tetraammineaquachlorocobalt(III) chloride

(C) Chlorotetraammineaquacobalt(II) chloride

(D) Tetraammineaquachlorocobalt(II) chloride

Q14. Photochemical smog, a widespread air pollution phenomenon in warm, dry, and sunny climates, is primarily initiated by the action of sunlight on:

(A) SO_2 and water vapor

(B) Nitrogen oxides and unburnt hydrocarbons

(C) Carbon dioxide and methane

(D) Chlorofluorocarbons and ozone

Q15. The correct order of stability of the following carbocations is: (I) $CH_3 - CH_2 - \overset{+}{C}H_2$, (II) $CH_2 = CH - \overset{+}{C}H_2$, (III) $C_6H_5 - \overset{+}{C}H_2$

(A) I > II > III

(B) III > II > I

(C) II > III > I

(D) III > I > II

Q16. When 1-butyne is treated with dilute H_2SO_4 in the presence of $HgSO_4$ at 60°C, the major product obtained is:

(A) Butanal

(B) Butan-2-one

(C) Butan-1-ol

(D) Butan-2-ol

Q17. The reaction of chlorobenzene with an excess of liquid ammonia in the presence of sodamide ($NaNH_2$) at low temperature proceeds via which intermediate mechanism?

(A) Carbocation intermediate

(B) Carbanion intermediate

(C) Benzyne intermediate

(D) Free radical intermediate

Q18. Acid-catalyzed dehydration of 2-methylbutan-2-ol yields a major alkene product X. Ozonolysis of X followed by reductive workup with Zn/H_2O gives:

(A) Formaldehyde and Butanone

(B) Acetone and Acetaldehyde

(C) Propanal and Ethanol

(D) Two equivalents of Acetaldehyde

Q19. An organic compound P (C_4H_8O) gives a positive iodoform test but does not reduce Tollens' reagent. When treated with $NaBH_4$, it forms compound Q. Compound Q upon heating with concentrated H_2SO_4 produces 2-butene as the major product. The compound P is:

(A) Butanal

(B) 2-Methylpropanal

(C) Butan-2-one

(D) Cyclobutanol

Q20. Gabriel phthalimide synthesis cannot be successfully deployed for the preparation of aniline because:

(A) Phthalimide does not react with potassium hydroxide.

(B) Potassium phthalimide fails to undergo nucleophilic substitution (S_N2) with aryl halides.

(C) Aryl halides are highly volatile and escape the reaction vessel.

(D) The intermediate aromatic amide is unstable and decomposes under reaction conditions.

Q21. Sucrose is a non-reducing sugar because:

(A) It is a synthetic disaccharide that lacks glucose units.

(B) The reducing groups of both glucose and fructose are involved in the glycosidic linkage.

(C) It undergoes mutarotation instantaneously in water.

(D) It contains only α-linkages which are resistant to mild chemical oxidation.

Q22. The homopolymer Buna-N is a synthetic rubber elastomer. The monomeric structural units that undergo co-polymerization to synthesize Buna-N are:

(A) Styrene and 1,3-butadiene

(B) Chloroprene and Styrene

(C) 1,3-Butadiene and Acrylonitrile

(D) Isoprene and Acrylonitrile

Q23. The total number of structural isomers possible for an alkane with the molecular formula C_6H_{14} is:

(A) 4

(B) 5

(C) 6

(D) 7

Q24. In the extraction of copper from its sulfide ore, the self-reduction process taking place in the Bessemer converter is represented by the chemical equation:

(A) $Cu_2S + 2CuO \rightarrow 4Cu + SO_2$

(B) $Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2$

(C) $FeS + Cu_2O \rightarrow FeO + Cu_2S$

(D) $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

Q25. Which one of the following compounds exhibits the highest dipole moment?

(A) *trans*-1,2-dichloroethene

(B) *cis*-1,2-dichloroethene

(C) 1,4-dichlorobenzene

(D) Tetrachloroethene

Q26. For an ideal solution showing no deviation from Raoult's law, the thermodynamic parameters associated with the mixing of two pure volatile liquids components are:

(A) $\Delta H_{\text{mix}} = 0, \Delta V_{\text{mix}} = 0, \Delta S_{\text{mix}} > 0$

(B) $\Delta H_{\text{mix}} > 0, \Delta V_{\text{mix}} = 0, \Delta S_{\text{mix}} = 0$

(C) $\Delta H_{\text{mix}} = 0, \Delta V_{\text{mix}} < 0, \Delta S_{\text{mix}} > 0$

(D) $\Delta H_{\text{mix}} < 0, \Delta V_{\text{mix}} < 0, \Delta S_{\text{mix}} < 0$

Q27. The ground state electronic configuration of the central iron atom in $K_4[Fe(CN)_6]$ contains how many unpaired electrons according to Crystal Field Theory (CFT)?

(A) 4

(B) 0

(C) 2

(D) 5

Q28. The conversion of a liquid into its vapor state below its boiling point is evaporation. Which of the following factors decreases the rate of evaporation of water from an open container?

(A) An increase in surface area exposed to air

(B) An increase in ambient temperature

(C) An increase in humidity of the surrounding air

(D) An increase in wind speed across the surface

Q29. According to the Bohr model of the hydrogen atom, the radius of the electronic orbit is proportional to:

(A) $\frac{n}{Z}$

(B) $\frac{n^2}{Z}$

(C) $\frac{Z}{n^2}$

(D) n^2Z^2

Q30. The standard enthalpy of formation ($\Delta_f H^\circ$) of $CO_2(g)$, $H_2O(l)$, and $CH_4(g)$ are −393.5, −285.8, and −74.8 kJ mol^{-1} respectively. The standard enthalpy of combustion ($\Delta_c H^\circ$) of methane in kJ mol^{-1} is:

(A) −890.3

(B) −604.5

(C) +890.3

(D) −965.1

Section B - 5 Questions × 2 Mark Each
(Negative Marking: −0.5) [Single Correct]

Q31. The solubility product (K_{sp}) of a sparingly soluble salt MX_2 in water is 4.0×10^{-12} at 25°C. The solubility of this salt in a 0.01 M solution of a strong electrolyte NX_2 (assuming complete dissociation) is:

(A) 1.0×10^{-4} M

(B) 2.0×10^{-5} M

(C) 4.0×10^{-8} M

(D) 1.0×10^{-8} M

Q32. For a second-order reaction of the type $2A \rightarrow$ Products, a plot of $\frac{1}{[A]}$ versus time (t) yields a straight line with a positive slope equal to k. If the initial concentration of A is doubled, the half-life ($t_{1/2}$) of the reaction changes by a factor of:

(A) 2

(B) 4

(C) 0.5

(D) Remains completely unchanged

Q33. A cell is constructed as follows at 298 K: $Zn(s)|Zn^{2+}(0.1\ M)||Cu^{2+}(0.01\ M)|Cu(s)$. If the standard reduction potentials are $E^\circ_{Zn^{2+}/Zn} = -0.76$ V and $E^\circ_{Cu^{2+}/Cu} =$

+0.34 V, the electromotive force (emf) of this cell is closest to (Given: $\frac{2.303RT}{F} = 0.0591$ V):

(A) 1.10 V

(B) 1.07 V

(C) 1.13 V

(D) 0.76 V

Q34. When Xenon gas reacts with an excess of Fluorine gas in a 1:20 molar ratio at 400°C and 5–6 bar pressure in a nickel vessel, it forms a crystalline volatile white solid X. The hybridization of the central atom and the geometry of compound X are respectively:

(A) sp^3d^2, Octahedral

(B) sp^3d^3, Distorted octahedral

(C) sp^3d^3, Pentagonal planar

(D) sp^3d, See-saw

Q35. An aromatic organic compound A ($C_7H_6O_2$) reacts with PCl_5 to give compound B. Compound B reacts with H_2 in the presence of Pd/$BaSO_4$ (poisoned with sulfur) to yield compound C. When compound C is treated with concentrated NaOH solution followed by acidification, it yields two compounds D and E. Compound D can also be obtained directly by reduction of C. The compounds C and E are:

(A) Benzyl alcohol and Benzoic acid

(B) Benzaldehyde and Sodium benzoate

(C) Benzaldehyde and Benzyl alcohol

(D) Benzoyl chloride and Benzaldehyde

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

Q36. Which of the following statements regarding the kinetic theory of gases and real gas behavior is/are correct?

(A) At very high pressures, the compressibility factor (Z) for most gases becomes greater than 1 because the molecular volume term cannot be neglected.

(B) The inversion temperature (T_i) of a gas is related to its van der Waals constants by the expression $T_i = \frac{2a}{Rb}$.

(C) Real gases approach ideal gas behavior closely at exceptionally low temperatures and high pressures.

(D) The average kinetic energy of gas molecules depends solely on the absolute temperature, independent of the nature of the gas.

Q37. Which of the following pairs of molecules/ions are both isostructural and isoelectronic?

(A) CO_3^{2-} and NO_3^-

(B) ClO_3^- and SO_3

(C) NF_3 and H_3O^+

(D) XeF_2 and I_3^-

Q38. Identify the correct statement(s) regarding the chemistry of d-block transition metals and their complexes:

(A) Cr^{2+} is a strong reducing agent because it easily converts to the stable t_{2g}^3 configuration of Cr^{3+}.

(B) $K_2Cr_2O_7$ is an orange crystalline solid whose color arises due to $d - d$ transitions of the Cr(VI) ion.

(C) In the transition series, interstitial compounds show higher electrical conductivity and chemical reactivity than parent pure metals.

(D) Cu^+ salts are generally white and diamagnetic because of their completely filled $3d^{10}$ shell.

Q39. Which of the following chemical reactions will yield a primary amine as a major product?

(A) Hoffmann bromamide degradation of benzamide.

(B) Reduction of ethyl isocyanide (CH_3CH_2NC) with $LiAlH_4$.

(C) Reduction of nitrobenzene with Fe and concentrated HCl.

(D) Reaction of methyl bromide with excess ammonia gas.

Q40. Which of the following statements is/are correct concerning solutions and their colligative properties?

(A) The osmotic pressure of a 0.1 M aqueous sucrose solution is equal to that of a 0.1 M aqueous NaCl solution at the same temperature.

(B) The elevation in boiling point (ΔT_b) is a colligative property that depends entirely on the total number of solute particles in a fixed amount of solvent.

(C) An aqueous solution of HNO_3 and water exhibits a negative deviation from Raoult's law, forming a maximum boiling azeotrope.

(D) The van 't Hoff factor (i) for a dilute solution of $BaCl_2$ undergoing 100% dissociation is equal to 3.

Detailed Solutions

Q1.

Solution

Concept:
Empirical formula gives the simplest whole-number atomic ratio, while molecular formula gives the exact atomic count. Mass percentages of C and H are derived from combustion products (CO_2 and H_2O), with remaining mass assigned to O. Molecular mass equals $2 \times$ vapor density.

Solution:
Determine the mass of each constituent element from the combustion data:

$$\text{Mass of C} = \frac{12}{44} \times 0.44 \text{ g} = 0.12 \text{ g}$$
$$\text{Mass of H} = \frac{2}{18} \times 0.18 \text{ g} = 0.02 \text{ g}$$
$$\text{Mass of O} = 0.30 \text{ g} - (0.12 \text{ g} + 0.02 \text{ g}) = 0.16 \text{ g}$$

Calculate the molar amounts to find the simplest atomic ratio:

$$\text{Moles of C} = \frac{0.12}{12} = 0.01, \quad \text{Moles of H} = \frac{0.02}{1} = 0.02, \quad \text{Moles of O} = \frac{0.16}{16} = 0.01$$

The ratio C : H : O = 0.01 : 0.02 : 0.01 = 1 : 2 : 1 $\implies$ **Empirical Formula** = CH_2O
Determine the molecular formula scaling factor (n):

$$\text{Empirical Formula Mass} = 12 + (2 \times 1) + 16 = 30 \text{ g mol}^{-1}$$
$$\text{Molecular Mass} = 2 \times \text{Vapor Density} = 2 \times 30 = 60 \text{ g mol}^{-1}$$
$$n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}} = \frac{60}{30} = 2$$

$$\text{Molecular Formula} = 2 \times (CH_2O) = C_2H_4O_2$$

Final Answer: $\boxed{C_2H_4O_2}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

The de Broglie hypothesis establishes that a moving particle exhibits wave-like properties. The wavelength (λ) associated with a particle of mass m moving with momentum p is given by $\lambda = \frac{h}{p}$, where h is Planck's constant. Since momentum is directly related to kinetic energy (K), we can express the momentum as $p = \sqrt{2mK}$. Substituting this relation into the de Broglie equation gives $\lambda = \frac{h}{\sqrt{2mK}}$, demonstrating an inverse square root relationship between the wavelength and the kinetic energy.

Solution:

Step 1: Write down the proportional relationship between the de Broglie wavelength (λ) and the kinetic energy (K) of the electron:

$$\lambda \propto \frac{1}{\sqrt{K}}$$

Step 2: Let the initial kinetic energy be K_1 and the initial de Broglie wavelength be λ_1. The final kinetic energy is increased four times, so we have:

$$K_2 = 4K_1$$

Step 3: Set up the ratio of the final wavelength (λ_2) to the initial wavelength (λ_1) using the inverse square root relation:

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{K_2}}$$

Step 4: Substitute the value of K_2 into the ratio equation and simplify:

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{4K_1}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Step 5: Solve for the final de Broglie wavelength λ_2:

$$\lambda_2 = \frac{1}{2}\lambda_1$$

Thus, the de Broglie wavelength changes by a factor of $\frac{1}{2}$.

Final Answer: $\boxed{\frac{1}{2}}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:

Formal Charge $= V - N - \frac{1}{2}B$, where V = valence e^-, N = non-bonding e^-, and B = bonding e^-.

Solution:

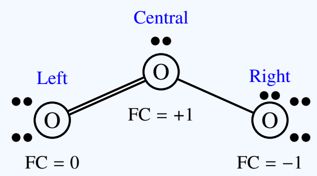
Step 1: Write the Lewis structure for ozone ($O_{(1)} = O_{(2)} - O_{(3)}$) from left to right:

- O_1 (Left): Double bonded $\implies$ 2 lone pairs $(N = 4)$, 4 bonding e^- $(B = 4)$.
- O_2 (Central): One double, one single bond $\implies$ 1 lone pair $(N = 2)$, 6 bonding e^- $(B = 6)$.
- O_3 (Right): Single bonded $\implies$ 3 lone pairs $(N = 6)$, 2 bonding e^- $(B = 2)$.

Step 2: Calculate individual formal charges ($V = 6$ for all oxygen atoms):

- $FC(O_1) = 6 - 4 - \frac{1}{2}(4) = 0$
- $FC(O_2) = 6 - 2 - \frac{1}{2}(6) = +1$
- $FC(O_3) = 6 - 6 - \frac{1}{2}(2) = -1$

The sequential values from left to right are $0, +1, -1$.



Final Answer: $\boxed{0, +1, -1}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:

According to Dalton's Law of Partial Pressures, the partial pressure exerted by an individual component gas in a non-reactive gaseous mixture is directly proportional to its mole fraction in the mixture. The mole fraction of a component is defined as the number of moles of that component divided by the total number of moles of all components present in the system. Therefore, the fraction of the total pressure exerted by oxygen is numerically equivalent to the mole fraction of oxygen gas in the mixture.

Solution:

Step 1: Let the mass of both methane (CH_4) and oxygen (O_2) mixed in the empty container be m grams.

Step 2: Find the molar masses of both gases. The molar mass of methane (CH_4) is $12 + (4 \times 1) = 16$ g mol^{-1}. The molar mass of oxygen gas (O_2) is $2 \times 16 = 32$ g mol^{-1}.

Step 3: Express the number of moles of each gas in terms of the mass m:

$$\text{Moles of methane } (n_{CH_4}) = \frac{m}{16}$$

$$\text{Moles of oxygen } (n_{O_2}) = \frac{m}{32}$$

Step 4: Determine the total number of moles (n_{total}) present in the container mixture:

$$n_{total} = n_{CH_4} + n_{O_2} = \frac{m}{16} + \frac{m}{32} = \frac{2m + m}{32} = \frac{3m}{32}$$

Step 5: Calculate the mole fraction of oxygen (χ_{O_2}), which represents the fraction of the total pressure exerted by oxygen gas:

$$\text{Pressure Fraction} = \chi_{O_2} = \frac{n_{O_2}}{n_{total}} = \frac{\frac{m}{32}}{\frac{3m}{32}} = \frac{1}{3}$$

Final Answer: $\boxed{\frac{1}{3}}$

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept:

When comparing reversible thermodynamic pathways on a pressure-volume ($P - V$) indicator diagram, the magnitude of expansion work done by a gas is equal to the area under the specific process curve. For an ideal gas expanding from an identical initial state to the same final volume, an isothermal process maintains a constant temperature by absorbing heat from the surroundings. In contrast, an adiabatic expansion performs work purely at the expense of its internal energy, causing a steep drop in temperature. As a result, the isothermal curve lies entirely above the adiabatic curve on a $P - V$ plot.

Solution:

Step 1: Analyze the slopes of the two processes on a $P - V$ diagram. The derivative for an isothermal process is $\left(\frac{\partial P}{\partial V}\right)_{\text{iso}} = -\frac{P}{V}$, whereas the derivative for an adiabatic process is $\left(\frac{\partial P}{\partial V}\right)_{\text{adia}} = -\gamma\frac{P}{V}$.

Step 2: Since $\gamma > 1$ for all real and ideal gases, the adiabatic curve has a steeper negative slope compared to the isothermal curve during expansion.

Step 3: Consider the expansion from an initial volume V_1 to a final volume V_2. Because the adiabatic pressure falls much more rapidly than the isothermal pressure, the pressure of the gas at any intermediate volume during the expansion is higher in the isothermal pathway.

Step 4: Relate the pressure values to the work integrals. The work done during expansion is defined by $W = \int_{V_1}^{V_2} P\,dV$. Since $P_{\text{isothermal}} > P_{\text{adiabatic}}$ throughout the expansion range, the area under the isothermal curve is systematically larger.

Step 5: Conclude that the work performed by the system during a reversible isothermal expansion is greater than the work performed during a reversible adiabatic expansion between the same initial and final volumes.

Final Answer: Greater than the adiabatic work

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:

For a gas-phase equilibrium, the equilibrium constant K_p is expressed using partial pressures, where the partial pressure of a gas is the product of its mole fraction and total pressure (P). Equilibrium moles are determined using the initial moles and the degree of dissociation (α).

Solution:

Consider the dissociation table starting with 1 mole of $PCl_5(g)$:

Reaction:	$PCl_5(g)$	$\rightleftharpoons PCl_3(g)$	$+ Cl_2(g)$
Initial Moles:	1	0	0
Equilibrium Moles:	$1-\alpha$	α	α

$$\text{Total Moles at Equilibrium} = (1-\alpha) + \alpha + \alpha = 1 + \alpha$$

Determine the equilibrium partial pressures:

$$p_{PCl_5} = \left(\frac{1-\alpha}{1+\alpha}\right)P, \quad p_{PCl_3} = \left(\frac{\alpha}{1+\alpha}\right)P, \quad p_{Cl_2} = \left(\frac{\alpha}{1+\alpha}\right)P$$

Substitute the partial pressures into the K_p expression and simplify:

$$K_p = \frac{p_{PCl_3} \cdot p_{Cl_2}}{p_{PCl_5}} = \frac{\left[\left(\frac{\alpha}{1+\alpha}\right)P\right] \cdot \left[\left(\frac{\alpha}{1+\alpha}\right)P\right]}{\left(\frac{1-\alpha}{1+\alpha}\right)P}$$

$$= \frac{\alpha^2 P^2}{(1+\alpha)^2} \cdot \frac{1+\alpha}{(1-\alpha)P} = \frac{\alpha^2 P}{(1+\alpha)(1-\alpha)} = \frac{\alpha^2 P}{1-\alpha^2}$$

Final Answer: $\boxed{\dfrac{\alpha^2 P}{1-\alpha^2}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:
In a parallel or competing first-order reaction where a single reactant decomposes simultaneously into two or more distinct products via independent pathways, each path possesses its own specific rate constant. The overall rate of consumption of the reactant is governed by the sum of these individual rate constants. Furthermore, because both pathways operate concurrently within the same reaction volume, the ratio of the amounts of products formed at any instant is equal to the ratio of their respective rate constants.

Solution:
Step 1: Write down the rate differential equations for the formation of products B and C from reactant A:

$$\frac{d[B]}{dt} = k_1[A]$$

$$\frac{d[C]}{dt} = k_2[A]$$

Step 2: Divide the rate of formation of B by the rate of formation of C to eliminate the concentration term of reactant A:

$$\frac{d[B]/dt}{d[C]/dt} = \frac{d[B]}{d[C]} = \frac{k_1}{k_2}$$

Step 3: Integrate the relationship assuming the initial concentrations of the products are zero. The ratio of the concentration of B to the concentration of C at any arbitrary time t remains constant and is explicitly given by:

$$\frac{[B]}{[C]} = \frac{k_1}{k_2}$$

Step 4: Formulate the expression for the percentage fractional abundance of product B within the total accumulated product mixture $(B + C)$:

$$\% \text{ of } B = \frac{[B]}{[B] + [C]} \times 100\% = \frac{k_1}{k_1 + k_2} \times 100\%$$

Step 5: Substitute the numerical values of the given rate constants ($k_1 = 2.0 \times 10^{-4}\ \text{s}^{-1}$ and $k_2 = 3.0 \times 10^{-4}\ \text{s}^{-1}$) into the percentage formula:

$$\% \text{ of } B = \frac{2.0 \times 10^{-4}}{(2.0 \times 10^{-4}) + (3.0 \times 10^{-4})} \times 100\% = \frac{2.0 \times 10^{-4}}{5.0 \times 10^{-4}} \times 100\% = \frac{2}{5} \times 100\% = 40\%$$

Final Answer: 40%

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

The principle of equivalence during a volumetric redox titration dictates that at the complete equivalence endpoint, the total number of milli-equivalents of the oxidizing agent must be exactly equal to the total number of milli-equivalents of the reducing agent. The number of equivalents is calculated as the product of normality and volume, where normality is equal to molarity multiplied by the valence factor (n-factor).

Solution:

Step 1: Determine the n-factor for the oxidizing agent, potassium permanganate ($KMnO_4$), in an acidic medium. The permanganate anion (MnO_4^-) undergoes reduction to form the manganese(II) cation (Mn^{2+}):

$$\overset{+7}{MnO_4^-} + 8H^+ + 5e^- \longrightarrow \overset{+2}{Mn}^{2+} + 4H_2O$$

The oxidation state of manganese changes from +7 to +2, resulting in an n-factor (n_1) of 5.

Step 2: Determine the n-factor for the reducing agent, ferrous sulfate ($FeSO_4$). The ferrous ion (Fe^{2+}) undergoes oxidation to form the ferric ion (Fe^{3+}):

$$\overset{+2}{Fe}^{2+} \longrightarrow \overset{+3}{Fe}^{3+} + e^-$$

The oxidation state of iron changes from +2 to +3, resulting in an n-factor (n_2) of 1. Step 3: State the law of equivalence linking the normality (N) and volume (V) of the interacting components:

$$N_1V_1\,(KMnO_4) = N_2V_2\,(FeSO_4)$$

$$(M_1 \times n_1) \times V_1 = (M_2 \times n_2) \times V_2$$

Step 4: Substitute the known parameters into the equivalence equation ($M_1 = 0.02$ M, $V_1 = 20$ mL, $n_1 = 5$, $V_2 = 25$ mL, and $n_2 = 1$):

$$(0.02 \times 5) \times 20 = (M_2 \times 1) \times 25$$

$$0.1 \times 20 = 25 \times M_2$$

$$2 = 25 \times M_2$$

Step 5: Solve for the unknown molarity (M_2) of the ferrous sulfate solution:

$$M_2 = \frac{2}{25} = 0.080 \text{ M}$$

Final Answer: $\boxed{0.080 \text{ M}}$

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:

The standard reduction potential (E°) is a quantitative measure of the tendency of a chemical species to gain electrons and undergo reduction. A lower or more negative standard reduction potential indicates that the oxidized form of the species is highly unstable and resistant to receiving electrons, which implies that its corresponding reduced metallic form has a strong tendency to lose electrons and undergo oxidation. Therefore, the lower the standard reduction potential of a metal cation, the stronger the reducing power of the corresponding neutral metal atom.

Solution:

Step 1: Tabulate and arrange the given standard reduction potentials (E°) for the metallic species X, Y, and Z:

$$E^\circ_X = +0.52 \text{ V}$$

$$E^\circ_Y = -2.87 \text{ V}$$

$$E^\circ_Z = -0.44 \text{ V}$$

Step 2: Understand the inverse relationship governing the thermodynamic power of a reducing agent with respect to reduction potential values:

$$\text{Reducing Power} \propto \frac{1}{E^\circ_{\text{reduction}}}$$

Step 3: Compare the values to identify the species with the lowest reduction potential. Metal Y has the most negative value (-2.87 V), meaning it loses electrons most readily and is the strongest reducing agent.

Step 4: Compare the remaining values. Metal Z has a negative potential (-0.44 V), which is lower than the positive reduction potential of metal X ($+0.52$ V). Therefore, metal Z possesses a higher reducing capacity than metal X.

Step 5: Arrange the metals in descending order of their reducing strengths based on the established sequence:

$$Y\ (-2.87 \text{ V}) > Z\ (-0.44 \text{ V}) > X\ (+0.52 \text{ V})$$

Final Answer: $\boxed{Y > Z > X}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
The thermal stability of alkaline earth metal carbonates (MCO_3) is determined by the lattice energy of the solid carbonate and the decomposition products, as well as the polarizing power of the metal cation. As we move down Group 2, the ionic radius of the metal cation (M^{2+}) increases, while its charge density decreases. A smaller cation with high charge density exerts a strong polarizing distortion on the large, polarizable carbonate anion (CO_3^{2-}), weakening the carbon-oxygen bonds within the anion and lowering the decomposition temperature.

Solution:
Step 1: Examine the trend in ionic radii for the Group 2 alkaline earth metal cations:

$$Mg^{2+} < Ca^{2+} < Sr^{2+} < Ba^{2+}$$

Step 2: Relate the ionic size to the charge density and polarizing power. The magnesium cation (Mg^{2+}), being the smallest, possesses the highest charge density and the strongest polarizing capacity. Conversely, the barium cation (Ba^{2+}) has the lowest polarizing power due to its larger size.

Step 3: Analyze the effect of polarization on the stability of the carbonate anion. High polarization destabilizes the carbonate framework, shifting the equilibrium toward the formation of the corresponding stable metal oxide and carbon dioxide gas:

$$MCO_3(s) \xrightarrow{\Delta} MO(s) + CO_2(g)$$

Step 4: Connect polarization trends to thermal decomposition temperatures. Because Mg^{2+} strongly distorts the carbonate cloud, $MgCO_3$ decomposes at a relatively low temperature. As polarization decreases down the group, the carbonates require significantly higher temperatures to decompose.

Step 5: Arrange the carbonates in order of increasing thermal stability and decomposition temperature:

$$MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$$

Final Answer: $\boxed{MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3}$

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:

Orthoboric acid (H_3BO_3) is a weak, non-protic acid that does not act as a proton donor in the traditional Arrhenius sense. Instead, the central boron atom has an electron deficiency with only six valence electrons in its outer shell, leaving a vacant p-orbital. This allows it to function as a Lewis acid by accepting an electron pair from a nucleophilic water molecule, which indirectly releases a hydronium ion into the solution.

Solution:

Step 1: Write down the ground-state electronic configuration of boron ($Z = 5$), which is $1s^2 2s^2 2p^1$. In the trivalent state of H_3BO_3, boron forms three covalent bonds with hydroxyl groups, leaving one vacant $2p$-orbital.

Step 2: When dissolved in water, orthoboric acid interacts with the lone pairs on the oxygen atom of a water molecule rather than dissociating its own $O-H$ bonds:

$$B(OH)_3 + 2H_2O \rightleftharpoons [B(OH)_4]^- + H_3O^+$$

Step 3: Analyze the role of the water molecule in this reaction. Water acts as a Lewis base, donating a lone pair from its oxygen atom into the vacant orbital of the boron atom.

Step 4: This coordination creates a tetrahedral borate complex, $[B(OH)_4]^-$, and weakens the coordinated water molecule's $O-H$ bond, which releases a proton (H^+) that is immediately captured by another water molecule to form H_3O^+.

Step 5: Conclude that orthoboric acid behaves as a monobasic acid because it accepts a hydroxyl ion (OH^-) from a water molecule, rather than releasing its own native protons.

Final Answer: It acts as a Lewis acid, accepting OH^- from water molecules and releasing a hydronium ion.

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:

The reaction of a solid chloride salt with potassium dichromate ($K_2Cr_2O_7$) and concentrated sulfuric acid (H_2SO_4) is known as the chromyl chloride test, which serves as a qualitative detection method for chloride anions. In this reaction, the dichromate ion is converted into a volatile, deep red-orange covalent liquid called chromyl chloride (CrO_2Cl_2), where chromium retains its high +6 oxidation state.

Solution:

Step 1: Write the chemical equation for the generation of hydrogen chloride gas (HCl) from a representative metal chloride salt (such as NaCl) using concentrated sulfuric acid:

$$2NaCl + H_2SO_4 \rightarrow 2HCl + Na_2SO_4$$

Step 2: Write the reaction of potassium dichromate with concentrated sulfuric acid to generate chromium trioxide (CrO_3), an acidic oxide intermediate:

$$K_2Cr_2O_7 + H_2SO_4 \rightarrow 2CrO_3 + K_2SO_4 + H_2O$$

Step 3: Combine these intermediates to show the formation of the volatile chromyl chloride product via the reaction of chromium trioxide with hydrogen chloride gas:

$$CrO_3 + 2HCl \rightarrow CrO_2Cl_2 + H_2O$$

Step 4: Express the complete balanced molecular equation for the entire chemical transformation:

$$K_2Cr_2O_7 + 4NaCl + 6H_2SO_4 \rightarrow 2CrO_2Cl_2 \uparrow +2KHSO_4 + 4NaHSO_4 + 3H_2O$$

Step 5: Identify compound X as the volatile chemical species responsible for the deep red vapors, which is chromyl chloride (CrO_2Cl_2).

Final Answer: $\boxed{CrO_2Cl_2}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
The naming of coordination compounds follows strict IUPAC nomenclature guidelines. In a coordination complex, ligands are listed in alphabetical order, disregarding any numerical prefixes such as di-, tri-, or tetra-. This is followed by the name of the central transition metal atom and its oxidation state, enclosed in parentheses as a Roman numeral. Finally, the counter-ions outside the coordination sphere are named.

Solution:
Step 1: Identify and list the three ligands bound within the coordination sphere along with their IUPAC names:

$$NH_3 \longrightarrow \text{ammine}$$

$$H_2O \longrightarrow \text{aqua}$$

$$Cl^- \longrightarrow \text{chlorido (or chloro)}$$

Step 2: Arrange these three ligands in alphabetical order. Comparing "ammine", "aqua", and "chloro", the alphabetical order is ammine $\longrightarrow$ aqua $\longrightarrow$ chloro. Since there are four ammine ligands, we add the prefix "tetra", giving: "tetraamminechloroaqua" (or "tetraammineaquachloro").

Step 3: Determine the oxidation state of the central cobalt metal atom. Let its oxidation state be x. Ammine and aqua are neutral ligands (charge = 0), while the chlorido ligand and the two outer chloride counter-ions carry a -1 charge each:

$$x + 4(0) + 1(0) + 1(-1) + 2(-1) = 0 \implies x - 1 - 2 = 0 \implies x = +3$$

Thus, the metal is named as cobalt(III).

Step 4: Assemble the full name of the complex cation by combining the alphabetically ordered ligands with the metal atom and its oxidation state: tetraamminechloroaquacobalt(III).

Step 5: Complete the IUPAC name by appending the name of the external counter-anion, which is "chloride", yielding: Tetraamminechloroaquacobalt(III) chloride.
Final Answer: Tetraamminechloroaquacobalt(III) chloride

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept:
Photochemical smog is a brown, hazy air pollution mixture that develops in warm, densely populated urban areas with high levels of solar radiation. Unlike industrial smog, which is driven by sulfur dioxide and coal smoke, photochemical smog is formed through primary pollutants emitted by internal combustion engines, such as nitrogen oxides (NO_x) and volatile unburnt hydrocarbons. These compounds undergo complex secondary reactions driven by ultraviolet sunlight.

Solution:
Step 1: Identify the primary pollutants emitted from automobile exhausts, which are nitrogen monoxide (NO) and various volatile unburnt hydrocarbon fragments.

Step 2: Trace the initial photochemical reaction. Atmospheric nitrogen monoxide reacts with oxygen or undergoes photochemical oxidation to form nitrogen dioxide (NO_2), a brown gas:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Step 3: Analyze the effect of solar radiation on nitrogen dioxide. Under sunlight, NO_2 absorbs ultraviolet light and breaks down into nitrogen monoxide and a highly reactive nascent oxygen free radical:

$$NO_2(g) \xrightarrow{h\nu} NO(g) + O(g)$$

Step 4: Understand the subsequent secondary transformations. The reactive atomic oxygen radical combines with atmospheric oxygen to produce ozone (O_3):

$$O(g) + O_2(g) \rightarrow O_3(g)$$

This ozone then reacts with unburnt hydrocarbons to form toxic lacrimatory compounds such as peroxyacetyl nitrate (PAN), acrolein, and formaldehyde.

Step 5: Conclude that the formation of photochemical smog is initiated by the action of sunlight on nitrogen oxides and unburnt hydrocarbons.

Final Answer: Nitrogen oxides and unburnt hydrocarbons

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:

Stability of carbocations governed by resonance delocalization and inductive/hyperconjugative effects.

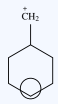
Solution:

Step 1: Analyze Carbocation (III) $C_6H_5 - \overset{+}{C}H_2$ (Benzyl carbocation). The positive charge on the benzylic carbon is highly stabilized via resonance, as it can be delocalized into the π-system of the aromatic benzene ring across three different positions (*ortho* and *para*). This extensive delocalization over an aromatic ring makes it the most stable among the three.

Step 2: Analyze Carbocation (II) $CH_2 = CH - \overset{+}{C}H_2$ (Allyl carbocation). The positive charge is stabilized by resonance with an adjacent carbon-carbon double bond, which yields two equivalent contributing structures ($CH_2 = CH - \overset{+}{C}H_2 \longleftrightarrow \overset{+}{C}H_2 - CH = CH_2$). While stable, this delocalization is restricted to just two carbons, making it less stable than the benzylic system.

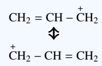
Step 3: Analyze Carbocation (I) $CH_3 - CH_2 - \overset{+}{C}H_2$ (n-Propyl carbocation). This is a primary aliphatic carbocation. It lacks any resonance stabilization. It is only weakly stabilized by the inductive effect ($+I$) and hyperconjugation (2 α-hydrogens) of the adjacent ethyl group, making it the least stable.

Step 4: Combining these factors, the true order of stability decreases as follows: III > II > I.



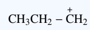
(III) Benzyl

(Extensive ring resonance)



(II) Allyl

(Alkenyl resonance)



(I) n-Propyl

(No resonance, $+I$ only)

Final Answer: III > II > I

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:

The hydration of alkynes under acidic conditions in the presence of mercuric sulfate ($HgSO_4$) is known as Kucherov's reaction. This process involves the electrophilic addition of a water molecule across the carbon-carbon triple bond following Markovnikov's rule. The initial product formed is an unstable enol intermediate, which rapidly undergoes keto-enol tautomerization to yield a more stable carbonyl compound.

Solution:

Step 1: Identify the starting material, 1-butyne ($CH_3CH_2C \equiv CH$), which is an unsymmetrical terminal alkyne.

Step 2: Apply Markovnikov's rule for the addition of H_2O (H^+ and OH^-). The electrophilic proton (H^+) attacks the terminal carbon atom to form a more stable secondary vinylic carbocation on the second carbon atom:

$$CH_3CH_2C \equiv CH \xrightarrow{Hg^{2+}, H^+} CH_3CH_2\overset{+}{C} = CH_2$$

Step 3: Attack of the nucleophilic water molecule onto this secondary carbocation intermediate yields an enol intermediate, 1-buten-2-ol:

$$CH_3CH_2\overset{+}{C} = CH_2 \xrightarrow{H_2O} CH_3CH_2C(OH) = CH_2$$

Step 4: Analyze the stability of this vinylic alcohol (enol). Enols are thermodynamically unstable relative to their carbonyl structural isomers and undergo rapid, irreversible keto-enol tautomerization:

$$CH_3CH_2C(OH) = CH_2 \rightleftharpoons CH_3CH_2C(=O) - CH_3$$

Step 5: Conclude that the shift of the proton to the terminal carbon and the formation of the carbon-oxygen double bond results in the major stable product, butan-2-one.

Final Answer: Butan-2-one

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:
Aryl halides are generally unreactive toward nucleophilic substitution under standard conditions due to partial double-bond character of the carbon-halogen bond. However, when treated with exceptionally strong bases like sodamide ($NaNH_2$) in liquid ammonia, chlorobenzene undergoes an elimination-addition mechanism. This pathway proceeds via a highly reactive, neutral hydrocarbon intermediate called benzyne (dehydrobenzene), which features a formal triple bond within the aromatic ring system.

Solution:
Step 1: Analyze the role of the amide ion (NH_2^-). The amide anion acts as a powerful base rather than a nucleophile in the first step, abstracting an ortho-proton relative to the chlorine atom from chlorobenzene.

Step 2: Trace the elimination step. The loss of the ortho-proton creates an ortho-carbanion, which then expels the chloride leaving group (Cl^-) in a concerted or stepwise fashion to form the transient benzyne intermediate:

$$C_6H_5Cl + NH_2^- \rightarrow [C_6H_4]\ \text{(benzyne)} + NH_3 + Cl^-$$

Step 3: Track the addition step. The benzyne intermediate is highly strained and unstable due to the distortion of the sp^2 orbitals forming the weak, sideways-overlapping formal triple bond. A molecule of ammonia (NH_3) quickly attacks one of the triply bonded carbons.

Step 4: Proton transfer from the newly attached nitrogen species to the adjacent carbanion site completes the nucleophilic aromatic substitution, yielding aniline ($C_6H_5NH_2$).

Step 5: Identify the reaction intermediate as the benzyne intermediate, confirming that the transformation takes place via an elimination-addition pathway.
Final Answer: Benzyne intermediate

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept:
Acid-catalyzed dehydration of secondary/tertiary alcohols according to Saytzeff's rule, followed by reductive ozonolysis of the resulting alkene.

Solution:
Step 1: Dehydration of 2-methylbutan-2-ol ($CH_3-C(OH)(CH_3)-CH_2-CH_3$). Under acidic conditions, the alcohol gets protonated and loses water to form a stable 3° carbocation. Elimination of a proton (H^+) occurs preferentially from the adjacent carbon with fewer hydrogen atoms (Saytzeff's rule) to yield the highly substituted and more stable alkene as the major product X.

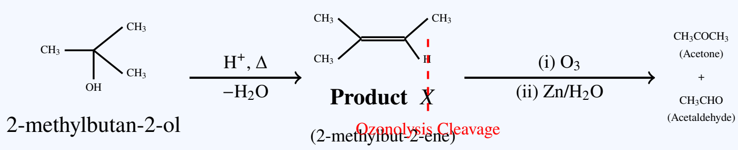
$$\text{Product } X = \text{2-methylbut-2-ene } ((CH_3)_2C=CH-CH_3)$$

Step 2: Reductive ozonolysis of 2-methylbut-2-ene. Ozonolysis cleaves the carbon-carbon double bond ($C=C$). Reductive workup with Zn/H_2O converts the ozonide intermediate directly into carbonyl groups without further oxidation:

- The $(CH_3)_2C=$ fragment is converted into acetone (CH_3COCH_3).
- The $=CH-CH_3$ fragment is converted into acetaldehyde (CH_3CHO).

Step 3: Combining the outcomes:

$$(CH_3)_2C=CH-CH_3 \xrightarrow[\text{(ii) Zn/H}_2\text{O}]{\text{(i) O}_3} CH_3COCH_3\text{ (Acetone)} + CH_3CHO\text{ (Acetaldehyde)}$$



Final Answer: Acetone and Acetaldehyde

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:

The structural elucidation of unknown carbonyl compounds relies on selective functional group tests. A positive iodoform test indicates the presence of a methyl ketone (R-C(= O)CH_3) or a methyl carbinol group. A negative Tollens' test rules out aldehydes, establishing that the compound must be a ketone. Reduction of a ketone with sodium borohydride ($NaBH_4$) yields a secondary alcohol, which can undergo acid-catalyzed dehydration to form an alkene.

Solution:

Step 1: Analyze the chemical tests for compound P (C_4H_8O). Since it fails to reduce Tollens' reagent but gives a positive iodoform test, P must be a ketone containing a methyl ketone segment (-C(= O)CH_3). The only four-carbon ketone matching this criterion is butan-2-one ($CH_3COCH_2CH_3$).

Step 2: Trace the reduction step. Treating butan-2-one (P) with the reducing agent $NaBH_4$ converts the carbonyl group into a secondary alcohol, yielding butan-2-ol (Q):

$$CH_3\text{-}CO\text{-}CH_2CH_3 \xrightarrow{NaBH_4} CH_3\text{-}CH(OH)\text{-}CH_2CH_3\ (Q)$$

Step 3: Analyze the dehydration step of compound Q using concentrated sulfuric acid (H_2SO_4) under thermal conditions. Protonation of the hydroxyl group followed by loss of water generates a secondary carbocation:

$$CH_3\text{-}\overset{+}{C}H\text{-}CH_2CH_3$$

Step 4: Apply Saytzeff's rule to find the major alkene. Eliminating a proton from the internal CH_2 group yields the more highly substituted, symmetric, and stable alkene, 2-butene ($CH_3CH = CHCH_3$), rather than 1-butene.

Step 5: Match this behavior with the problem statement. The generation of 2-butene confirms that compound P is indeed butan-2-one.

Final Answer: Butan-2-one

Answer: (C)

Go Back to Question 19

Q20.

Solution

Concept:
The Gabriel phthalimide synthesis is a classic laboratory method used for preparing pure primary aliphatic amines without contamination from secondary or tertiary amines. The mechanism relies on the nucleophilic substitution (S_N2) of an alkyl halide by the strongly nucleophilic potassium phthalimide ion. For this synthesis to succeed, the organic halide must be highly reactive toward backside bimolecular nucleophilic attack.

Solution:
Step 1: Understand the structure and activation of the reagent. Phthalimide is treated with potassium hydroxide (KOH) to generate potassium phthalimide, which contains a nucleophilic nitrogen atom carrying a full negative charge.

Step 2: Examine the requirement for the organic halide partner. In a standard synthesis, this nitrogen nucleophile attacks an unhindered alkyl halide via an S_N2 pathway to displace the halide leaving group.

Step 3: Evaluate the scenario where aniline ($C_6H_5NH_2$) is the desired product. To synthesize aniline, the required organic halide starting material would have to be an aryl halide, such as chlorobenzene (C_6H_5Cl).

Step 4: Analyze the reactivity of aryl halides toward S_N2 substitution. In aryl halides, the lone pairs on the halogen atom are delocalized into the π-system of the aromatic ring. This resonance imparts a partial double-bond character to the carbon-halogen bond, making it extremely strong and difficult to cleave.

Step 5: Conclude that because of this resonance stabilization and the steric hindrance of the aromatic ring preventing backside attack, potassium phthalimide fails to undergo nucleophilic substitution with aryl halides, making the synthesis of aniline impossible via this method.

Final Answer: Potassium phthalimide fails to undergo nucleophilic substitution (S_N2) with aryl halides.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
Sugars are classified as reducing or non-reducing based on their ability to reduce mild oxidizing agents such as Tollens' or Fehling's reagents. A sugar acts as a reducing agent only if it possesses a free, unlinked anomeric carbon atom capable of opening up into an active aldehyde or ketone form in aqueous solution. In disaccharides, if the anomeric carbons of both constituent monosaccharide units are mutually locked in a glycosidic linkage, the sugar cannot undergo mutarotation or open into a chain, rendering it non-reducing.

Solution:
Step 1: Identify the chemical components of sucrose. Sucrose is a disaccharide formed by the condensation of one unit of α-D-glucose and one unit of β-D-fructose.

Step 2: Locate the anomeric carbon positions for each monosaccharide unit. For D-glucose, the aldehyde carbon at position C_1 is the reducing anomeric center. For D-fructose, the ketone carbon at position C_2 is the reducing anomeric center.

Step 3: Analyze the nature of the glycosidic bond connecting these units in sucrose. The linkage is structurally formed between the C_1 anomeric carbon of glucose and the C_2 anomeric carbon of fructose.

Step 4: Evaluate the availability of the functional groups after bond formation. Because this linkage involves both of the potential hemiacetal and hemiketal anomeric centers, neither monosaccharide ring can open up to regenerate the free carbonyl functional groups.

Step 5: Conclude that because the reducing centers of both glucose and fructose are mutually tied up in the glycosidic linkage, sucrose is a non-reducing sugar.

Final Answer: The reducing groups of both glucose and fructose are involved in the glycosidic linkage.

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:

Synthetic rubbers are high-molecular-weight elastomeric polymers generated via addition or condensation polymerization pathways. Buna-N is a common synthetic copolymer widely known for its exceptional resistance to oils, fuel, and other organic solvents. The nomenclature "Buna-N" reveals its composition: "Bu" refers to 1,3-butadiene, "Na" stands for sodium, which historically served as the polymerization catalyst, and "N" signifies acrylonitrile, the nitrogen-containing monomer.

Solution:

Step 1: Analyze the question's premise. The question mentions that Buna-N is a "homopolymer," which is a typographical error in the original exam text; Buna-N is actually a copolymer built from two distinct repeating monomer units.

Step 2: Write down the chemical formulas and structures for the true starting materials. The primary component is 1,3-butadiene ($CH_2 = CH - CH = CH_2$). The secondary component is acrylonitrile ($CH_2 = CH - CN$).

Step 3: Trace the free-radical addition copolymerization mechanism. Under the action of a catalyst or peroxide initiator, the double bonds of both molecules homolytically cleave to couple together.

Step 4: Formulate the repeating polymer unit showing the alignment of the chains:

$$n\,CH_2 = CH{-}CH = CH_2 + n\,CH_2 = CH{-}CN \rightarrow [-CH_2 - CH = CH - CH_2 - CH_2 - CH(CN)-]_n$$

Step 5: Identify the correct pair of monomer structural units from the options, which matches 1,3-butadiene and acrylonitrile perfectly.

Final Answer: 1,3-Butadiene and Acrylonitrile

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept:

Structural isomers are molecules that share an identical molecular formula but differ significantly in the connectivity and sequencing of their constituent atoms. For alkanes with the general formula C_nH_{2n+2}, structural isomerism manifests primarily as chain isomerism, where the length of the principal carbon backbone is varied and methyl or ethyl groups are arranged as branched side chains at different positions.

Solution:

Step 1: Analyze the given molecular formula, C_6H_{14}, which fits the saturated alkane series ($n = 6$). We systematically construct all possible carbon skeletons by varying the length of the parent chain.

Step 2: Draw the straight six-carbon unbranched alkane chain. This represents the regular continuous chain isomer:

$$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3 \quad \text{(n-hexane)}$$

Step 3: Shorten the parent chain to five carbon atoms and attach a single methyl group (-CH_3) at different unique positions along the backbone. This yields two separate chain isomers:

$$CH_3 - CH(CH_3) - CH_2 - CH_2 - CH_3 \quad \text{(2-methylpentane)}$$

$$CH_3 - CH_2 - CH(CH_3) - CH_2 - CH_3 \quad \text{(3-methylpentane)}$$

Step 4: Reduce the parent chain length further to four carbon atoms and distribute two methyl branches across the chain. This gives two more distinct isomers:

$$CH_3 - C(CH_3)_2 - CH_2 - CH_3 \quad \text{(2,2-dimethylbutane)}$$

$$CH_3 - CH(CH_3) - CH(CH_3) - CH_3 \quad \text{(2,3-dimethylbutane)}$$

Step 5: Verify if any further distinct configurations can be drawn without replicating existing IUPAC names. The total count of unique structural arrangements constructed is $1 + 2 + 2 = 5$.

Final Answer: $\boxed{5}$

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:

The pyrometallurgical extraction of copper from sulfide ores like copper pyrites ($CuFeS_2$) involves roasting, smelting, and bessemerization. In the Bessemer converter, a process called self-reduction (or auto-reduction) occurs. Here, no external reducing agent like carbon or carbon monoxide is introduced. Instead, a portion of the copper(I) sulfide ore is initially oxidized by air into copper(I) oxide, which then reacts directly with the remaining unreacted copper(I) sulfide to produce metallic copper.

Solution:

Step 1: Identify the chemical composition of the roasted copper matte, which consists mainly of copper(I) sulfide (Cu_2S) along with trace amounts of iron(II) sulfide (FeS).

Step 2: Examine the partial oxidation step occurring inside the Bessemer converter. Blasts of air convert a portion of the copper(I) sulfide into copper(I) oxide:

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

Step 3: Analyze the self-reduction step. The supply of oxygen is adjusted so that the newly formed copper(I) oxide reacts immediately with the remaining copper(I) sulfide in the high-temperature melt.

Step 4: Write out the balanced equation for this self-reduction process, where the sulfur atom acts as the reducing agent, shifting from an oxidation state of −2 to +4, while copper is reduced from +1 to its elemental state (0):

$$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2$$

Step 5: Match this chemical transformation with the options to identify the correct self-reduction equation.

Final Answer: $\boxed{Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2}$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept:

The net dipole moment (μ) of a molecule is the vector sum of its individual bond dipole moments. It depends on the spatial arrangement of the polar bonds and the overall symmetry of the molecule. Highly symmetrical structures allow opposing bond dipoles to completely cancel each other out, resulting in a net dipole moment of zero. Conversely, unsymmetrical geometries prevent cancellation, leading to a permanent net dipole moment.

Solution:

Step 1: Evaluate option (A), *trans*-1,2-dichloroethene. Due to its symmetric inversion center, the two polar $C-Cl$ bond dipoles point in exactly opposite directions, canceling out completely to give $\mu = 0$.

Step 2: Evaluate option (C), 1,4-dichlorobenzene. The two chlorines are positioned para to each other across the planar aromatic benzene ring, meaning their individual pull vectors cancel along the primary axis, resulting in $\mu = 0$.

Step 3: Evaluate option (D), tetrachloroethene ($Cl_2C = CCl_2$). This molecule is planar and highly symmetrical, meaning the four identical $C-Cl$ dipoles cancel out perfectly, leading to a net dipole moment of $\mu = 0$.

Step 4: Evaluate option (B), *cis*-1,2-dichloroethene. In the *cis* configuration, both highly electronegative chlorine atoms are located on the same side of the carbon-carbon double bond.

Step 5: Analyze the vector addition for the *cis* isomer. The individual $C-Cl$ bond dipoles reinforce each other rather than canceling out. This constructive vector addition gives *cis*-1,2-dichloroethene a substantial, non-zero permanent net dipole moment, the highest among the choices.

Final Answer: *cis*-1,2-dichloroethene

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:
An ideal solution is defined as a solution that obeys Raoult's law exactly across the entire range of concentrations and temperatures. At the molecular level, an ideal solution forms when the intermolecular attractive forces between the solute and solvent molecules (A − B interactions) are identical in magnitude to the forces present within the pure components (A − A and B − B interactions). Consequently, mixing the components causes no overall changes in enthalpy or volume, while the entropy increases because the system becomes more disordered.

Solution:
Step 1: Analyze the enthalpy of mixing (ΔH_{mix}). Since the breaking of old intermolecular attractions requires the exact same amount of thermal energy as the energy released during the formation of new attractions, no heat is absorbed or evolved:

$$\Delta H_{\text{mix}} = 0$$

Step 2: Analyze the volume change upon mixing (ΔV_{mix}). Because the molecular packing and forces remain unchanged, the total volume of the solution is exactly equal to the sum of the volumes of the individual pure liquids before mixing:

$$\Delta V_{\text{mix}} = 0$$

Step 3: Analyze the entropy of mixing (ΔS_{mix}). Mixing two pure components increases the disorder and randomness of the molecular positions. According to the second law of thermodynamics, the entropy of a spontaneous mixing process must be positive:

$$\Delta S_{\text{mix}} > 0$$

Step 4: Verify the Gibbs free energy change (ΔG_{mix}) using the fundamental relation $\Delta G_{\text{mix}} = \Delta H_{\text{mix}} - T\Delta S_{\text{mix}}$. Since $\Delta H_{\text{mix}} = 0$ and $\Delta S_{\text{mix}} > 0$, ΔG_{mix} becomes negative, confirming spontaneous dissolution.

Step 5: Match these criteria with the thermodynamic conditions for an ideal solution: $\Delta H_{\text{mix}} = 0$, $\Delta V_{\text{mix}} = 0$, and $\Delta S_{\text{mix}} > 0$.
Final Answer: $\boxed{\Delta H_{\text{mix}} = 0, \Delta V_{\text{mix}} = 0, \Delta S_{\text{mix}} > 0}$

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept:

Crystal Field Theory (CFT) splitting for an octahedral d^6 complex featuring a strong-field ligand.

Solution:

Step 1: Identify the oxidation state of the central iron atom in $K_4[Fe(CN)_6]$:

$$4(+1) + x + 6(-1) = 0 \implies x = +2$$

The central metal ion is Fe^{2+}.

Step 2: Determine the d-electron configuration of Fe^{2+}:

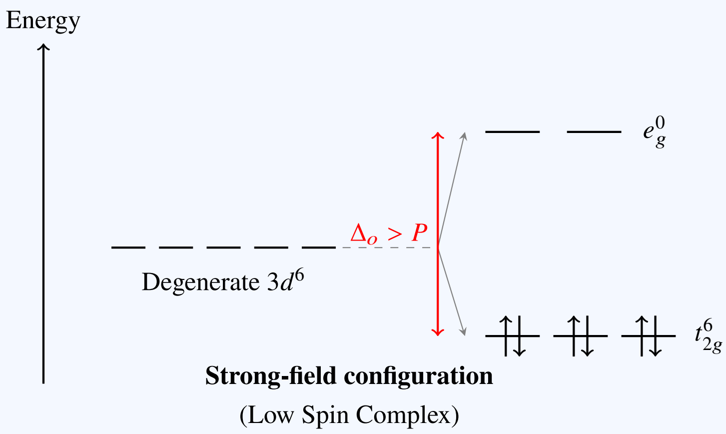
$$\text{Ground state of Fe} = [\text{Ar}]\,3d^6 4s^2 \implies Fe^{2+} = [\text{Ar}]\,3d^6$$

Step 3: Analyze ligand strength and field splitting. The cyanide ion (CN^-) is a strong-field ligand located high up in the spectrochemical series. It creates a massive crystal field splitting energy (Δ_o) in the octahedral coordination environment that exceeds the electron pairing energy (P), meaning $\Delta_o > P$.

Step 4: Distribute the 6 electrons within the split d-orbitals (t_{2g} and e_g): Because pairing is energetically favored over moving up to the higher energy level, all 6 electrons completely fill the lower energy t_{2g} triplet state, leaving the higher energy e_g doublet completely vacant.

$$\text{Electronic configuration} = t_{2g}^6\, e_g^0$$

As a result, every single electron in the t_{2g} sublevel matches up with a partner, yielding exactly 0 unpaired electrons.



Final Answer: 0

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:
Evaporation is a surface phenomenon in which molecules at the surface of a liquid gain enough kinetic energy to overcome the intermolecular attractive forces of their neighbors and escape into the vapor phase at any temperature below the boiling point. The rate of evaporation depends on factors such as surface area, temperature, wind speed, and the humidity of the surrounding air. Humidity measures the concentration of water vapor already present in the atmosphere.

Solution:
Step 1: Evaluate the effect of surface area. An increase in surface area exposes more liquid molecules to the boundary layer, which directly increases the rate of evaporation.

Step 2: Evaluate the effect of temperature. Higher temperatures increase the average kinetic energy of the molecules, allowing a larger fraction to escape the liquid surface and increasing evaporation.

Step 3: Evaluate the effect of wind speed. Moving air sweeps away newly formed water vapor from the surface, preventing local saturation and increasing the rate of evaporation.

Step 4: Evaluate the effect of humidity. Humidity represents the amount of water vapor already present in the surrounding air. If the air is highly humid, it is already close to its maximum water capacity at that temperature.

Step 5: Conclude that a highly humid atmosphere reduces the concentration gradient of water vapor between the liquid surface and the air, which limits the net escape of molecules and slows down the rate of evaporation.

Final Answer: An increase in humidity of the surrounding air

Answer: (C)

Go Back to Question 28

Q29.

Solution

Concept:
The Bohr model of the atom describes electrons moving in fixed circular orbits around a central nucleus under the influence of electrostatic attraction. By balancing the centripetal force with the Coulombic force and applying the quantization condition for orbital angular momentum ($mvr = \frac{nh}{2\pi}$), we can derive expressions for both the radius and energy of these stationary states.

Solution:
Step 1: State the condition for the quantization of angular momentum for an electron of mass m moving at velocity v in an orbit of radius r:

$$mvr = \frac{nh}{2\pi} \implies v = \frac{nh}{2\pi mr}$$

Step 2: Equate the electrostatic force of attraction between the nucleus (charge Ze) and the electron (charge e) to the centripetal force required for circular motion:

$$\frac{mv^2}{r} = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

Step 3: Substitute the velocity expression from Step 1 into the centripetal force equation:

$$\frac{m}{r}\left(\frac{nh}{2\pi mr}\right)^2 = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

$$\frac{mn^2h^2}{4\pi^2m^2r^3} = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

Step 4: Simplify the expression to solve directly for the orbital radius r:

$$\frac{n^2h^2}{\pi mr} = \frac{Ze^2}{\varepsilon_0}$$

$$r = \left(\frac{\varepsilon_0 h^2}{\pi me^2}\right) \cdot \frac{n^2}{Z}$$

Step 5: Identify the constants within the parentheses. The terms ε_0, h, π, m, and e are fundamental constants, meaning the radius depends on the principal quantum number n and the atomic number Z through the following proportional relationship:

$$r \propto \frac{n^2}{Z}$$

Final Answer: $\boxed{\frac{n^2}{Z}}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept:

The standard enthalpy of combustion ($\Delta_c H^\circ$) of a substance is the enthalpy change that accompanies the complete oxidation of one mole of the substance under standard states. According to Hess's Law of Constant Heat Summation, the overall enthalpy change of a chemical reaction can be calculated by subtracting the sum of the standard enthalpies of formation ($\Delta_f H^\circ$) of all reactants from the sum of the standard enthalpies of formation of all products:

$$\Delta H^\circ_{\text{reaction}} = \sum \Delta_f H^\circ \text{ (Products)} - \sum \Delta_f H^\circ \text{ (Reactants)}$$

Solution:

Step 1: Write down the balanced chemical equation for the complete combustion of one mole of gaseous methane (CH_4):

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

Step 2: Set up the thermodynamic enthalpy equation based on Hess's Law for this combustion reaction:

$$\Delta_c H^\circ = \left[\Delta_f H^\circ(CO_2) + 2 \cdot \Delta_f H^\circ(H_2O)\right] - \left[\Delta_f H^\circ(CH_4) + 2 \cdot \Delta_f H^\circ(O_2)\right]$$

Step 3: Recall that by thermodynamic convention, the standard enthalpy of formation of any element in its most stable elemental standard state is zero. Therefore, for oxygen gas:

$$\Delta_f H^\circ(O_2) = 0 \text{ kJ mol}^{-1}$$

Step 4: Substitute the given numerical values ($\Delta_f H^\circ(CO_2) = -393.5$ kJ mol^{-1}, $\Delta_f H^\circ(H_2O) = -285.8$ kJ mol^{-1}, and $\Delta_f H^\circ(CH_4) = -74.8$ kJ mol^{-1}) into the equation:

$$\Delta_c H^\circ = [-393.5 + 2(-285.8)] - [-74.8 + 0]$$

$$\Delta_c H^\circ = [-393.5 - 571.6] - [-74.8]$$

Step 5: Complete the arithmetic operations to find the final value:

$$\Delta_c H^\circ = -965.1 + 74.8 = -890.3 \text{ kJ mol}^{-1}$$

Final Answer: $\boxed{-890.3}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:

The solubility of a sparingly soluble salt is significantly reduced in the presence of a soluble strong electrolyte that shares a common ion. This phenomenon is known as the common-ion effect and is a direct consequence of Le Chatelier's principle. The solubility product constant (K_{sp}) is an equilibrium constant that remains constant at a specific temperature.

Solution:

Step 1: Write out the heterogeneous dissolution equilibrium for the sparingly soluble salt MX_2 and express its solubility product constant (K_{sp}):

$$MX_2(s) \rightleftharpoons M^{2+}(aq) + 2X^-(aq)$$

$$K_{sp} = [M^{2+}][X^-]^2$$

Step 2: Identify the concentration of ions contributed by the completely soluble strong electrolyte NX_2. A 0.01 M solution of NX_2 dissociates fully to yield:

$$NX_2(aq) \longrightarrow N^{2+}(aq) + 2X^-(aq)$$

$$\text{Concentration of } X^- \text{ from } NX_2 = 2 \times 0.01 \text{ M} = 0.02 \text{ M}$$

Step 3: Let s be the molar solubility of MX_2 in this solution. Set up the total equilibrium concentrations for each ion type in the mixture:

$$[M^{2+}] = s$$

$$[X^-] = 2s + 0.02$$

Step 4: substitute these equilibrium expressions into the K_{sp} equation. Since MX_2 is sparingly soluble and its dissolution is further suppressed by the common-ion effect, we can assume that $2s \ll 0.02$, which simplifies the concentration term to $[X^-] \approx 0.02$ M:

$$K_{sp} = s \cdot (0.02)^2$$

$$4.0 \times 10^{-12} = s \cdot (4.0 \times 10^{-4})$$

Step 5: Solve for the suppressed molar solubility s of the salt:

$$s = \frac{4.0 \times 10^{-12}}{4.0 \times 10^{-4}} = 1.0 \times 10^{-8} \text{ M}$$

Final Answer: $\boxed{1.0 \times 10^{-8} \text{ M}}$

Answer: (D)

Go Back to Question 31

Q32.

Solution

Concept:

The half-life ($t_{1/2}$) of a chemical reaction is defined as the time required for the reactant concentration to decrease to exactly half of its initial value. The functional relationship between half-life and initial concentration depends entirely on the overall order of the reaction. For a second-order reaction, the half-life is inversely proportional to the initial concentration of the reactant, meaning that increasing the starting concentration causes a proportional decrease in the time required to consume half of it.

Solution:

Step 1: Write down the integrated rate equation for a second-order reaction of the type $2A \longrightarrow$ Products:

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

Step 2: Apply the definition of half-life to the integrated rate equation. At time $t = t_{1/2}$, the remaining concentration of the reactant is exactly half of the initial concentration:

$$[A]_t = \frac{[A]_0}{2}$$

Step 3: Substitute this concentration value back into the integrated rate equation and simplify the algebraic fractions:

$$\frac{1}{\frac{[A]_0}{2}} - \frac{1}{[A]_0} = kt_{1/2}$$

$$\frac{2}{[A]_0} - \frac{1}{[A]_0} = kt_{1/2} \implies \frac{1}{[A]_0} = kt_{1/2}$$

Step 4: Rearrange the equation to isolate the half-life variable ($t_{1/2}$), which reveals its dependence on the initial concentration $[A]_0$:

$$t_{1/2} = \frac{1}{k[A]_0} \implies t_{1/2} \propto \frac{1}{[A]_0}$$

Step 5: Determine the effect of doubling the initial concentration. If the initial concentration is changed from $[A]_0$ to $2[A]_0$, the new half-life becomes:

$$t'_{1/2} = \frac{1}{k(2[A]_0)} = \frac{1}{2}\left(\frac{1}{k[A]_0}\right) = 0.5 \cdot t_{1/2}$$

Thus, the half-life changes by a factor of 0.5.

Final Answer: $\boxed{0.5}$

Answer: (C)

Go Back to Question 32

Q33.

Solution

Concept:

The electromotive force (emf) of an electrochemical cell operating under non-standard conditions can be calculated using the Nernst equation. The Nernst equation relates the cell potential (E_{cell}) to the standard cell potential (E°_{cell}) and the activities or concentrations of the reacting chemical species in solution.

Solution:

Step 1: Write down the individual oxidation and reduction half-cell reactions and combine them to obtain the overall balanced net cell reaction:

$$\text{Anode (Oxidation):} \quad \text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2e^-$$

$$\text{Cathode (Reduction):} \quad \text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s)$$

$$\text{Net Cell Reaction:} \quad \text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s)$$

The total number of electrons transferred in this balanced process is $n = 2$. Step 2: Calculate the standard cell potential (E°_{cell}) from the given standard reduction potentials of the electrodes:

$$E^\circ_{\text{cell}} = E^\circ_{\text{Cu}^{2+}/\text{Cu}} - E^\circ_{\text{Zn}^{2+}/\text{Zn}} = +0.34 \text{ V} - (-0.76 \text{ V}) = +1.10 \text{ V}$$

Step 3: State the Nernst equation at 298 K and set up the reaction quotient (Q), which is the ratio of the product ion concentration to the reactant ion concentration:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0591}{n} \log Q$$

$$Q = \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]}$$

Step 4: Substitute the given molar concentrations ($[\text{Zn}^{2+}] = 0.1$ M and $[\text{Cu}^{2+}] = 0.01$ M) into the reaction quotient and evaluate the logarithm:

$$Q = \frac{0.1}{0.01} = 10 \implies \log(10) = 1$$

Step 5: Substitute the values of E°_{cell}, n, and $\log Q$ into the Nernst equation to find the cell potential:

$$E_{\text{cell}} = 1.10 \text{ V} - \frac{0.0591}{2}(1) = 1.10 \text{ V} - 0.02955 \text{ V} = 1.07045 \text{ V}$$

Final Answer: $\boxed{1.07 \text{ V}}$

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

Preparation and VSEPR structure of Xenon fluorides.

Solution:

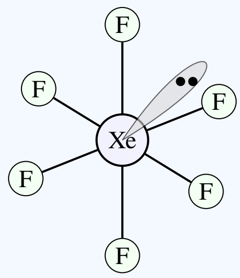
Step 1: Identify the compound formed (X). When xenon gas reacts with an excess of fluorine gas in a high molar ratio of 1 : 20 at 400°C and 5–6 bar pressure, xenon hexafluoride (XeF_6) is produced as the crystalline volatile white solid:

$$Xe(g) + 3F_2(g) \xrightarrow[400°C,\ 5\text{–}6\ \text{bar}]{\text{Excess } F_2\ (1:20)} XeF_6(s)$$

Step 2: Determine the hybridization and steric number.

- Xenon (Xe) has 8 valence electrons. It uses 6 electrons to form 6 single bonds with fluorine atoms, leaving 2 non-bonding electrons (1 lone pair).
- Steric number (S_n) = Bond pairs + Lone pairs = 6 + 1 = 7.
- A steric number of 7 corresponds to sp^3d^3 hybridization.

Step 3: Deduce the geometry. An ideal steric number of 7 gives a pentagonal bipyramidal electron-pair geometry. However, according to VSEPR theory, the presence of 1 lone pair causes structural distortion. The lone pair moves dynamically over the faces of the octahedron, distorting the positions of the six fluorine atoms. This creates a **distorted octahedral** (or capped octahedral) molecular geometry.



Distorted Octahedral geometry of XeF_6

Final Answer: $\boxed{sp^3d^3\text{, Distorted octahedral}}$

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:
This problem involves a sequence of classic organic reactions starting from a substituted aromatic compound. The transformation steps include the conversion of a carboxylic acid to an acyl chloride, followed by Rosenmund reduction to form an aldehyde. Finally, an aldehyde lacking α-hydrogens undergoes a Cannizzaro reaction when treated with a concentrated base, experiencing simultaneous self-oxidation and self-reduction to yield a mixture of an alcohol and a carboxylic acid salt.

Solution:
Step 1: Identify compound A ($C_7H_6O_2$), which is benzoic acid (C_6H_5COOH). Reacting benzoic acid with phosphorus pentachloride (PCl_5) converts the hydroxyl group into a chloride, yielding benzoyl chloride as compound B:

$$C_6H_5COOH + PCl_5 \rightarrow C_6H_5COCl\ (B) + POCl_3 + HCl$$

Step 2: Trace the Rosenmund reduction of compound B. Treating the acyl chloride with hydrogen gas over a poisoned palladium catalyst ($Pd/BaSO_4$) selectively reduces it to an aldehyde, producing benzaldehyde as compound C:

$$C_6H_5COCl + H_2 \xrightarrow{Pd/BaSO_4} C_6H_5CHO\ (C) + HCl$$

Step 3: Analyze the reaction of compound C (benzaldehyde) with a concentrated solution of sodium hydroxide (NaOH). Since benzaldehyde lacks α-hydrogens, it cannot undergo aldol condensation and instead undergoes a Cannizzaro reaction.

Step 4: Trace the self-oxidation and self-reduction steps of the Cannizzaro reaction. One molecule of benzaldehyde is reduced to benzyl alcohol (compound D), while another molecule is oxidized to sodium benzoate (compound E):

$$2C_6H_5CHO \xrightarrow{\text{conc. NaOH}} C_6H_5CH_2OH\ (D) + C_6H_5COONa\ (E)$$

Subsequent acidification of the mixture converts the sodium salt E into benzoic acid.

Step 5: Identify the requested compounds C and E from the sequence, which correspond to benzaldehyde and sodium benzoate respectively.
Final Answer: Benzaldehyde and Sodium benzoate

Answer: (B)
Go Back to Question 35

Q36.

Solution

Concept:
The rate of an nucleophilic substitution (S_N1) reaction depends on the stability of the carbocation intermediate formed during the slow, rate-determining step. Carbocations are stabilized by structural factors such as inductive effects, hyperconjugation, and resonance delocalization. Allylic and benzylic carbocations are highly stable due to resonance with adjacent π-systems, while tertiary (3°) carbocations are stabilized by hyperconjugation and inductive effects from three surrounding alkyl groups.

Solution:
Step 1: Analyze option (A), 3-chloroprop-1-ene ($CH_2 = CH - CH_2Cl$). Loss of the chloride leaving group generates the allyl carbocation ($CH_2 = CH - \overset{+}{C}H_2$). This intermediate is highly stabilized by resonance, as the positive charge is delocalized over both terminal carbon atoms:

$$CH_2 = CH - \overset{+}{C}H_2 \longleftrightarrow \overset{+}{C}H_2 - CH = CH_2$$

Because of this resonance stabilization, allylic halides undergo rapid solvolysis via the S_N1 pathway.

Step 2: Analyze option (B), 2-chloro-2-methylpropane ($(CH_3)_3CCl$). Ionization of this tertiary alkyl halide yields the *tert*-butyl carbocation, $(CH_3)_3C^+$. This tertiary (3°) carbocation is highly stabilized by the strong $+I$ inductive effect of three methyl groups and 9 hyperconjugative α-hydrogens, leading to high reactivity via an S_N1 mechanism.

Step 3: Analyze option (C), chlorobenzene (C_6H_5Cl). In aryl halides, the lone pairs on the chlorine atom are in resonance with the π-system of the aromatic ring, giving the $C - Cl$ bond partial double-bond character. This makes the bond extremely strong and difficult to break, so chlorobenzene does not undergo S_N1 substitution under standard conditions.

Step 4: Analyze option (D), 1-chloropropane ($CH_3CH_2CH_2Cl$). Ionization would produce a primary (1°) propyl carbocation ($CH_3CH_2\overset{+}{C}H_2$), which is unstable due to minimal hyperconjugation and inductive support. Primary alkyl halides react predominantly via the concerted S_N2 pathway rather than S_N1.

Step 5: Conclude that both 3-chloroprop-1-ene and 2-chloro-2-methylpropane form highly stable carbocation intermediates, making both options reactive via the S_N1 mechanism.

Final Answer: A and B

Answer: (A, B)

Go Back to Question 36

Q37.

Solution

Concept:

Electrophilic aromatic substitution (EArS) involves the attack of an aromatic ring on an electron-deficient electrophile. The rate of this reaction depends on the electron density of the benzene ring. Substituents already present on the ring alter this electron density through a combination of inductive effects ($\pm I$) and resonance effects ($\pm M$). Groups that donate electron density into the ring activate it toward electrophilic attack, whereas groups that withdraw electron density deactivate the ring.

Solution:

Step 1: Analyze option (A), toluene ($C_6H_5CH_3$). The methyl group (-CH_3) acts as an electron-donating group through hyperconjugation and its weak $+I$ inductive effect. This increases the electron density on the benzene ring, making toluene more reactive toward electrophiles than unsubstituted benzene.

Step 2: Analyze option (B), phenol (C_6H_5OH). The hydroxyl group (-OH) possesses lone pairs on the oxygen atom that are directly conjugated with the aromatic π-system. This creates a powerful $+M$ positive mesomeric effect that overrides oxygen's electronegative $-I$ effect, donating substantial electron density into the ring and making phenol highly activated.

Step 3: Analyze option (C), nitrobenzene ($C_6H_5NO_2$). The nitro group (-NO_2) contains a positively charged nitrogen atom linked to highly electronegative oxygen atoms. It acts as a powerful electron-withdrawing group via both strong $-M$ and $-I$ effects, strongly deactivating the aromatic ring and decreasing its reactivity toward electrophilic substitution.

Step 4: Analyze option (D), chlorobenzene (C_6H_5Cl). For halogens, the electronegative $-I$ inductive effect is stronger than their $+M$ resonance donation. As a result, the chlorine atom causes a net withdrawal of electron density, deactivating the ring relative to benzene.

Step 5: Identify the activated rings. Both toluene and phenol have electron-donating groups that increase the ring's electron density, making them more reactive than benzene toward electrophilic aromatic substitution.

Final Answer: A and B

Answer: (A, B)

Go Back to Question 37

Q38.

Solution

Concept:
The kinetic theory of gases describes the macroscopic properties of an ideal gas based on the motion of its individual molecules. According to this model, the average kinetic energy ($\overline{K}$) of gas molecules depends solely on the absolute temperature (T) of the system, regardless of the chemical identity or molar mass of the gas. Conversely, the root-mean-square velocity (v_{rms}) is inversely proportional to the square root of the molar mass (M), meaning that lighter molecules move faster than heavier ones at the same temperature.

Solution:
Step 1: State the mathematical equation for the average kinetic energy of a gas molecule based on the kinetic molecular theory:

$$\overline{K} = \frac{3}{2}k_B T$$

Here, k_B is the Boltzmann constant and T is the absolute temperature in Kelvin. This equation shows that average kinetic energy is a function of temperature alone.

Step 2: Compare the average kinetic energies of helium (He) and methane (CH_4) at the same temperature T. Since the temperature is identical, their average translational kinetic energies must be equal:

$$\overline{K}_{\text{He}} = \overline{K}_{\text{CH}_4}$$

Therefore, the statement that they have the same average kinetic energy is correct.

Step 3: State the mathematical expression for the root-mean-square velocity (v_{rms}) of a gas:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

Here, R is the universal gas constant and M is the molar mass of the gas species.

Step 4: Analyze the dependence of v_{rms} on molar mass at a constant temperature. Since $v_{\text{rms}} \propto \frac{1}{\sqrt{M}}$, the gas with the lower molar mass will have a higher velocity.

Step 5: Compare the molar masses of the two gases: $M_{\text{He}} = 4$ g mol^{-1} and $M_{\text{CH}_4} = 16$ g mol^{-1}. Because helium has a smaller molar mass, its molecules have a higher root-mean-square velocity than those of methane at the same temperature ($v_{\text{rms, He}} > v_{\text{rms, CH}_4}$). Thus, both the statements concerning identical kinetic energy and differing velocities are correct.

Final Answer: They have the same average kinetic energy, and Helium molecules have a higher root-mean-square velocity.

Answer: (A, C)

Go Back to Question 38

Q39.

Solution

Concept:

Intermolecular forces are the attractive or repulsive forces that act between neighboring particles (atoms, molecules, or ions). These forces are electrostatic in nature and vary in strength. Dipole-dipole interactions occur between molecules with permanent dipoles, while hydrogen bonding is a specific, strong type of dipole-dipole interaction that forms when hydrogen is covalently bonded to highly electronegative elements (N, O, or F). London dispersion forces are weak, transient attractions present between all molecules, including nonpolar ones, due to instantaneous dipole fluctuations.

Solution:

Step 1: Analyze the chemical structure and intermolecular forces of water (H_2O). Water contains highly polar $O-H$ bonds due to the large electronegativity difference between oxygen and hydrogen. The small size and high electronegativity of oxygen allow water molecules to form strong intermolecular hydrogen bonds. Additionally, like all molecular species, water experiences weak London dispersion forces.

Step 2: Analyze the chemical structure and intermolecular forces of ethyl alcohol (CH_3CH_2OH). Ethanol also features a polar hydroxyl (-OH) group, which enables it to participate in intermolecular hydrogen bonding with other ethanol molecules. It also possesses a nonpolar ethyl group that interacts via London dispersion forces.

Step 3: Analyze the behavior of a liquid mixture containing both water and ethyl alcohol. When these two liquids are mixed, the hydroxyl groups of ethanol readily form new intermolecular hydrogen bonds with water molecules.

Step 4: Examine the choices regarding the predominant forces holding the mixture components together. The primary cohesive forces in this solution are hydrogen bonding networks alongside weaker dipole-dipole attractions and London dispersion forces.

Step 5: Conclude that both hydrogen bonding and London dispersion forces are active intermolecular attractions within an aqueous ethanol solution, making statements identifying these forces correct.

Final Answer: Hydrogen bonding and London dispersion forces

Answer: (A, D)

Go Back to Question 39

Q40.

Solution

Concept:

The rate of a chemical reaction is governed by the Arrhenius equation, which models the temperature dependence of reaction rate constants:

$$k = Ae^{-\frac{E_a}{RT}}$$

Here, k is the rate constant, A is the pre-exponential frequency factor, E_a is the activation energy, R is the gas constant, and T is the absolute temperature. Taking the natural logarithm of both sides converts this exponential relationship into a linear form, allowing for graphical analysis of kinetic parameters.

Solution:

Step 1: Write down the logarithmic form of the Arrhenius equation by applying natural logarithms (ln) to both sides:

$$\ln k = \ln\left(Ae^{-\frac{E_a}{RT}}\right) = \ln A + \ln\left(e^{-\frac{E_a}{RT}}\right) = \ln A - \frac{E_a}{RT}$$

Step 2: Compare this expression to the standard equation for a straight line ($y = mx + c$), plotting $\ln k$ on the vertical y-axis and the inverse absolute temperature $\left(\frac{1}{T}\right)$ on the horizontal x-axis:

$$y = \ln k, \quad x = \frac{1}{T}, \quad m = -\frac{E_a}{R}, \quad c = \ln A$$

This confirms that a plot of $\ln k$ versus $\frac{1}{T}$ yields a straight line with a negative slope equal to $-\frac{E_a}{R}$.

Step 3: Convert the expression into common logarithms ($\log_{10}$) using the base change relationship $\ln k = 2.303 \log_{10} k$:

$$2.303 \log_{10} k = \ln A - \frac{E_a}{RT} \implies \log_{10} k = \frac{\ln A}{2.303} - \frac{E_a}{2.303RT}$$

$$\log_{10} k = \log_{10} A - \left(\frac{E_a}{2.303R}\right)\frac{1}{T}$$

Step 4: Align this base-10 equation with the straight-line equation ($y = mx + c$), where $y = \log_{10} k$ and $x = \frac{1}{T}$:

$$m = -\frac{E_a}{2.303R}, \quad c = \log_{10} A$$

This shows that a plot of $\log_{10} k$ versus $\frac{1}{T}$ also forms a straight line, but with a modified slope of $-\frac{E_a}{2.303R}$. Step 5: Conclude that both linear graphical plots are mathematically valid representations derived from the Arrhenius equation, meaning both options are correct.

Final Answer: A plot of $\ln k$ versus $\frac{1}{T}$ has a slope of $-\frac{E_a}{R}$, and a plot of $\log_{10} k$ versus $\frac{1}{T}$ has a slope of $-\frac{E_a}{2.303R}$.

Answer: (A, B)

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Answer Key

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

Note: Section C (Q36–Q40): One or more correct options may be correct. Full marks only if all correct options are marked. Partial marking is not applicable.