# UPCATET Chemistry Sample Paper-6

**Duration: 45 Minutes** **Maximum Marks: 200**

## Instructions

- This paper contains **50** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **−1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

**Q1.** An organic compound '$A$' with molecular formula $C_3H_8O$ on treatment with Lucas reagent at room temperature does not show any turbidity immediately, but gives a turbid solution after heating. When '$A$' is passed over heated copper at 573 K, it forms compound '$B$'. What is the structure of '$B$'?

(A) $CH_3CH_2CHO$
(B) $CH_3COCH_3$
(C) $CH_3CH = CH_2$
(D) $CH_3CH_2CH_2Cl$

**Q2.** The standard reduction potentials of four metallic elements $A$, $B$, $C$, and $D$ are $-3.05$ V, $-1.66$ V, $-0.40$ V, and $+0.80$ V respectively. Which of these elements will act as the strongest reducing agent?

(A) $A$
(B) $B$
(C) $C$
(D) $D$

**Q3.** The rate constant of a first-order reaction is $4.606 \times 10^{-3}$ s$^{-1}$. How much time (in seconds) will it take for the initial concentration of the reactant to reduce to one-tenth of its initial value?

(A) 100 s

(B) 230.3 s

(C) 500 s

(D) 1000 s

**Q4.** Which of the following oxoacids of phosphorus contains a direct $P-P$ bond and exhibits a total oxidation state of +4 on each phosphorus atom?

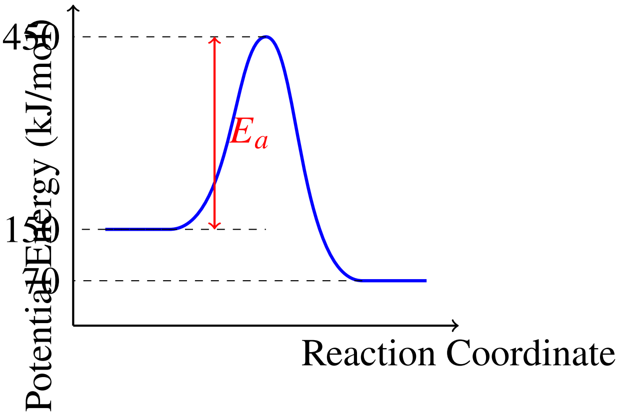
(A) $H_4P_2O_7$

(B) $H_4P_2O_6$

(C) $H_3P_2O_5$

(D) $H_4P_2O_5$

**Q5.** Consider the following potential energy profile for a reversible chemical reaction:



Based on the diagram, calculate the activation energy ($E_a$) for the backward reaction.

(A) 300 kJ/mol

(B) 380 kJ/mol

(C) 230 kJ/mol

(D) 450 kJ/mol

**Q6.** According to the Molecular Orbital Theory (MOT), which of the following diatomic species possesses a bond order of 2.5 and is paramagnetic in nature?

(A) $O_2$

(B) $N_2^+$

(C) $O_2^{2-}$

(D) $C_2$

**Q7.** When an aqueous solution of $CoCl_3 \cdot 4NH_3$ is treated with an excess of silver nitrate ($AgNO_3$) solution, exactly one mole of AgCl precipitate is formed per mole of the complex. The secondary valency of Cobalt in this complex is:

(A) 4

(B) 5

(C) 6

(D) 3

**Q8.** Which of the following compounds will not undergo an aldol condensation reaction when treated with a dilute aqueous solution of sodium hydroxide?

(A) $CH_3CH_2CHO$

(B) $CH_3COCH_3$

(C) $C_6H_5CHO$

(D) $CH_3CH_2COCH_3$

**Q9.** An element crystallizes in a face-centered cubic (fcc) lattice with an edge length of 400 pm. What is the closest distance of approach between two adjacent atoms in this metallic crystal?

(A) 200 pm

(B) 282.8 pm

(C) 141.4 pm

(D) 346.4 pm

**Q10.** Freundlich adsorption isotherm is given by the expression $\frac{x}{m} = kp^{1/n}$. What is the permissible value and physical significance of the exponent $1/n$ under normal adsorption conditions?

(A) Always 0

(B) Always 1

(C) Between 0 and 1

(D) Variable from 1 to 5

**Q11.** Which of the following electronic configurations represents an element that exhibits the maximum number of variable oxidation states among the $3d$-transition series?

(A) $3d^3 4s^2$

(B) $3d^5 4s^1$

(C) $3d^5 4s^2$

(D) $3d^7 4s^2$

**Q12.** Which of the following pollutants is primarily responsible for the phenomenon of classical (London) smog, which typically occurs in cool, humid climates?

(A) Oxides of nitrogen ($NO_x$)

(B) Sulfur dioxide ($SO_2$) and particulate matter

(C) Ozone ($O_3$)

(D) Volatile organic compounds (VOCs)

**Q13.** The vapor pressure of pure liquid water at 298 K is 23.8 mmHg. A non-volatile, non-electrolyte solute is dissolved in water to make a solution where the mole fraction of water is 0.95. Calculate the vapor pressure lowering of this solution.

(A) 1.19 mmHg

(B) 22.61 mmHg

(C) 2.38 mmHg

(D) 0.95 mmHg

**Q14.** What is the total number of spherical (radial) nodes and angular nodes present in a $4p$ atomic orbital of a hydrogenic atom?

(A) 2 radial, 1 angular

(B) 3 radial, 0 angular

(C) 1 radial, 2 angular

(D) 2 radial, 2 angular

**Q15.** The major organic product obtained from the reaction of bromobenzene with magnesium metal in dry ether, followed by treatment with dry ice (solid $CO_2$) and subsequent acid hydrolysis is:

(A) Benzyl alcohol

(B) Benzoic acid

(C) Phenol

(D) Acetophenone

**Q16.** The correct descending order of the fundamental base strengths of the hydride molecules of Group 15 elements is:

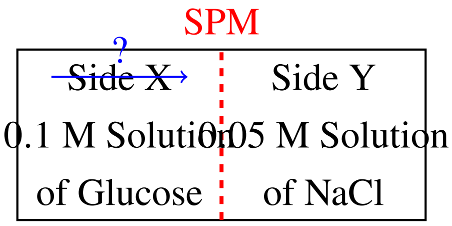
(A) $NH_3 > PH_3 > AsH_3 > SbH_3$

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

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

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

**Q17.** For the configuration shown below involving a semi-permeable membrane (SPM):



In which direction will the net movement of solvent particles occur across the semi-permeable membrane if both sides are maintained at the same external temperature and pressure?

(A) Solvent will flow continuously from Side X to Side Y

(B) Solvent will flow continuously from Side Y to Side X

(C) There will be no net movement of solvent because both solutions exert identical osmotic pressures

(D) Solute particles will migrate through the membrane until equilibrium is achieved

**Q18.** Which of the following compounds will react fastest via an $S_N1$ mechanism upon treatment with an aqueous solution of silver nitrate?

(A) $CH_3CH_2CH_2CH_2Cl$

(B) $(CH_3)_3C-Cl$

(C) $CH_3CH_2CH(Cl)CH_3$

(D) $(CH_3)_2CHCH_2Cl$

**Q19.** What is the correct molecular geometry and the hybridisation state of the central Iodine atom in the triiodide polyatomic anion ($I_3^-$)?

(A) Linear, $sp^3d$

(B) Bent, $sp^3$

(C) Linear, $sp^3d^2$

(D) T-shaped, $sp^3d$

**Q20.** During the commercial metallurgical extraction of copper metal, silica ($SiO_2$) is explicitly added to the copper matte in the reverberatory furnace. The primary function of silica here is to act as a:

(A) Basic flux to remove alumina impurity

(B) Reducing agent to convert $Cu_2O$ to metallic copper

(C) Acidic flux to remove iron oxide (FeO) impurity as a fusible slag

(D) Oxidizing agent to remove sulfur impurities as $SO_2$

**Q21.** The mass of sodium hydroxide (NaOH, molar mass = 40 g/mol) required to completely neutralize 100 mL of a 0.5 M aqueous sulfuric acid ($H_2SO_2$) solution is:

(A) 2.0 g

(B) 4.0 g

(C) 8.0 g

(D) 1.0 g

**Q22.** Which of the following carbohydrate molecules is classified as a non-reducing sugar and does not form an osazone when treated with excess phenylhydrazine?

(A) Maltose

(B) Lactose

(C) Sucrose

(D) Glucose

**Q23.** Gold sol prepared by the reduction method is an example of which type of colloidal system based on the properties of the dispersed phase?

(A) Macromolecular colloid

(B) Associated colloid (Micelle)

(C) Multimolecular lyophobic colloid

(D) Lyophilic gel

**Q24.** Which of the following options represents the correct sequence of the elements in terms of increasing first ionization enthalpy values?

(A) $B < C < O < N$

(B) $B < C < N < O$

(C) $B < O < C < N$

(D) $C < B < N < O$

**Q25.** An organic compound '$X$' on reductive ozonolysis yields a equimolar mixture of methanal (HCHO) and 2-oxopropanal ($CH_3COCHO$). What is the structure of the hydrocarbon '$X$'?

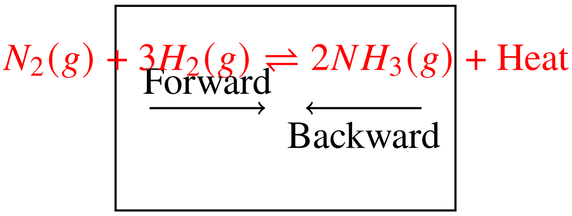
(A) $CH_3CH = CH - CH = CH_2$

(B) $CH_2 = C(CH_3) - CH = CH_2$

(C) $CH_3 - C(CH_3) = CH_2$

(D) $CH_2 = CH - CH_2 - CH = CH_2$

**Q26.** Consider the following phase equilibrium distribution representation for a reversible gaseous process:



$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{Heat}$$

According to Le Chatelier's principle, which combined set of conditions will shift this equilibrium towards the maximum yield of the product ammonia ($NH_3$)?

(A) Low temperature and low total pressure

(B) High temperature and high total pressure

(C) Low temperature and high total pressure

(D) High temperature and low total pressure

**Q27.** The d-electronic configuration of the central iron atom in the low-spin octahedral complex anion $[Fe(CN)_6]^{3-}$ according to Crystal Field Theory (CFT) is described as:

(A) $t_{2g}^3 e_g^2$

(B) $t_{2g}^5 e_g^0$

(C) $t_{2g}^4 e_g^1$

(D) $t_{2g}^6 e_g^0$

**Q28.** The principles of ’Green Chemistry’ advocate for minimizing chemical hazards and maximizing atom economy. Which of the following processes is a prime example of a green synthetic methodology?

(A) Industrial synthesis of bleaching powder using chlorine gas

(B) Bleaching of paper pulp using hydrogen peroxide ($H_2O_2$) instead of chlorine gas

(C) Use of traditional organic solvents like carbon tetrachloride ($CCl_4$) in extraction

(D) Synthesis of synthetic polymers using fossil-fuel based petrochemical intermediates

**Q29.** How many structural isomer molecules can be formed by the acyclic alkene hydrocarbon containing the molecular formula $C_4H_8$ (excluding stereoisomers)?

(A) 2

(B) 3

(C) 4

(D) 5

**Q30.** The ionic product constant of water ($K_w$) at an elevated temperature of 333 K is found to be $1.0 \times 10^{-12}$. What is the calculated pH value of pure neutral water at this temperature?

(A) 7.0

(B) 6.0

(C) 8.0

(D) 6.5

**Q31.** Which of the following electronic transitions within a atomic hydrogen system will result in the emission of a photon possessing the maximum frequency?

(A) $n = 2 \rightarrow n = 1$

(B) $n = 4 \rightarrow n = 2$

(C) $n = 5 \rightarrow n = 3$

(D) $n = 3 \rightarrow n = 2$

**Q32.** When phenol is treated with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide (NaOH) at 340 K followed by acidification, salicylaldehyde is formed. What is the active electrophilic intermediate involved in this reaction?

(A) Carbonium ion ($^+CHCl_2$)

(B) Dichlorocarbene ($: CCl_2$)

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

(D) Formyl cation ($^+CHO$)

**Q33.** What is the overall order of a chemical reaction whose rate law expression is explicitly defined as Rate $= k[A]^{3/2}[B]^{-1}$?

(A) 1.5

(B) 0.5

(C) 2.5

(D) 0.0

**Q34.** The type of structural isomerism that arises due to the differential distribution of alkyl carbon chains on either side of a divalent functional heteroatom group in an organic molecule is known as:

(A) Functional isomerism

(B) Metamerism

(C) Tautomerism

(D) Position isomerism

**Q35.** Which of the following chemical statements regarding the properties of lanthanide elements is incorrect?

(A) The primary stable oxidation state for all lanthanides is +3

(B) Due to lanthanide contraction, Zr and Hf have almost identical atomic radii

(C) All members of the lanthanide series are highly radioactive synthetic elements

(D) Basic character of lanthanide hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$

**Q36.** Equal volumes of 0.2 M HCl and 0.1 M NaOH are thoroughly mixed together. What will be the final resultant pH value of this mixed solution at 298 K?

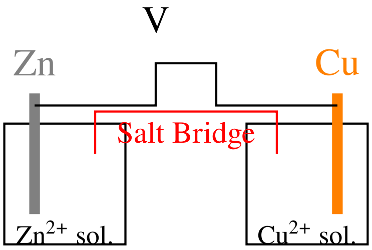
(A) 1.00

(B) 1.30

(C) 2.00

(D) 7.00

**Q37.** For the specific galvanic cell assembly shown below:



The calculated standard cell potential ($E^\circ_{cell}$) for this standard Zinc-Copper cell configuration [$E^\circ_{Zn^{2+}/Zn} = -0.76$ V, $E^\circ_{Cu^{2+}/Cu} = +0.34$ V] is equal to:

(A) +0.42 V

(B) −1.10 V

(C) +1.10 V

(D) −0.42 V

**Q38.** The specific sequence of amino acid residues in a polypeptide biomolecule chain held together by covalent peptide bonds constitutes its:

(A) Primary structure

(B) Secondary structure

(C) Tertiary structure

(D) Quaternary structure

**Q39.** Which of the following compounds exhibits the highest value of dipole moment ($\mu$) owing to its molecular shape and electronegativity vector alignments?

(A) $BF_3$

(B) $NF_3$

(C) $NH_3$

(D) $CCl_4$

**Q40.** When an aniline molecule is treated with a mixture of concentrated $HNO_3$ and concentrated $H_2SO_4$ at 288 K, a significant amount (47%) of *m*-nitroaniline is obtained. This unexpected formation of a large amount of meta-isomer is due to:

(A) Strong meta-directing nature of the $-NH_2$ group

(B) Protonation of aniline to form the highly deactivating anilinium ion

(C) Deactivation of the meta position by the nitrating mixture

(D) Demethylation occurring during the highly specialized nitration process

**Q41.** How many total structural and stereoisomers are possible for a coordination complex containing the formula $[Co(en)_2Cl_2]Cl$ (where 'en' stands for ethylenediamine)?

(A) 2

(B) 3

(C) 4

(D) 1

**Q42.** The solubility product ($K_{sp}$) of a sparingly soluble binary salt $AB_2$ in water is $4.0 \times 10^{-12}$ at a particular temperature. What is the molar solubility ($S$, in mol $L^{-1}$) of this salt?

(A) $1.0 \times 10^{-4}$

(B) $2.0 \times 10^{-6}$

(C) $1.0 \times 10^{-6}$

(D) $4.0 \times 10^{-4}$

**Q43.** According to the Hardy-Schulze rule for the coagulation of lyophobic colloidal dispersions, which of the following electrolytic ions will possess the maximum flocculating power for a negatively charged arsenious sulfide ($As_2S_3$) sol?

(A) $Na^+$

(B) $Mg^{2+}$

(C) $Al^{3+}$

(D) $PO_4^{3-}$

**Q44.** The electronic configuration of a central atom in a molecule involves four pairs of valence electrons. If the molecule adopts a see-saw molecular shape, what is the count of bond pairs and lone pairs on the central atom respectively?

(A) 3 bond pairs, 1 lone pair

(B) 4 bond pairs, 1 lone pair

(C) 3 bond pairs, 2 lone pairs

(D) 4 bond pairs, 2 lone pairs

**Q45.** What is the total mass of carbon dioxide gas ($CO_2$) generated when exactly 20 g of a pure sample of calcium carbonate ($CaCO_3$, molar mass = 100 g/mol) is completely decomposed thermally?

(A) 44 g

(B) 8.8 g

(C) 22 g

(D) 4.4 g

**Q46.** The major organic product obtained when a molecule of ethyl chloride ($CH_3CH_2Cl$) is heated with an aqueous-alcoholic solution of potassium cyanide (KCN) is:

(A) Ethyl isocyanide

(B) Propanenitrile

(C) Ethylamine

(D) Propanoic acid

**Q47.** Which of the following compounds contains the highest percentage of nitrogen content by weight, making it highly valuable as a nitrogenous agricultural fertilizer?

(A) Ammonium sulfate, $(NH_4)_2SO_4$

(B) Ammonium nitrate, $NH_4NO_3$

(C) Urea, $NH_2CONH_2$

(D) Calcium nitrate, $Ca(NO_3)_2$

**Q48.** Which of the following sets of quantum numbers uniquely represents the outermost valence electron of a ground state sodium atom (Z = 11)?

(A) $n = 3, l = 1, m = 0, s = +\frac{1}{2}$

(B) $n = 3, l = 0, m = 0, s = +\frac{1}{2}$

(C) $n = 2, l = 1, m = 1, s = -\frac{1}{2}$

(D) $n = 4, l = 0, m = 0, s = +\frac{1}{2}$

**Q49.** The values of the van 't Hoff factor ($i$) for completely dissociated dilute aqueous solutions of Potassium Ferricyanide $[K_3Fe(CN)_6]$ and Urea respectively are:

(A) 4 and 1

(B) 3 and 1

(C) 5 and 1

(D) 4 and 2

**Q50.** Which of the following elements belongs to the $p$-block of the periodic table but exhibits a uniquely stable lower oxidation state due to the intervention of the inert pair effect?

(A) Aluminium (Al)
(B) Thallium (Tl)
(C) Boron (B)
(D) Phosphorus (P)

## Detailed Solutions

## Q1.

### Solution

**Concept:**
The structure and classification of aliphatic monohydric alcohols dictate their reactivity patterns toward specific chemical test reagents. Lucas reagent, which consists of a mixture of concentrated hydrochloric acid and anhydrous zinc chloride, functions via an nucleophilic substitution mechanism to differentiate primary, secondary, and tertiary alcohols based on the relative stability of their intermediate carbocations. Subsequent controlled catalytic dehydrogenation over red-hot copper metal selectively converts these structural isomers into distinct carbonyl derivatives depending on the positioning of the hydroxyl group.

**Solution:**

(a) The molecular formula $C_3H_8O$ represents an acyclic saturated monohydric alcohol. The two possible structural isomers are propan-1-ol (a primary alcohol) and propan-2-ol (a secondary alcohol).

(b) When treated with Lucas reagent at room temperature, primary alcohols do not produce turbidity at all due to the instability of primary carbocations. Secondary alcohols do not produce turbidity immediately but form a turbid layer of alkyl chloride within 5 to 10 minutes, or much faster upon gentle heating. Hence, compound $A$ is identified as the secondary alcohol, propan-2-ol ($CH_3CH(OH)CH_3$).

(c) When vapours of a secondary alcohol are passed over heated copper catalysts at 573 K, it undergoes a clean catalytic dehydrogenation reaction.

(d) The oxidation process removes two hydrogen atoms from the molecular structure—one from the hydroxyl group and one from the alpha-carbon atom—thereby converting the secondary alcohol group into a keto group.

(e) Consequently, propan-2-ol is converted into propanone, commonly referred to as acetone. The structural formula for compound $B$ is therefore $CH_3COCH_3$.

**Final Answer:** The structure of compound B is propanone ($CH_3COCH_3$).

**Answer: (B)**

**Go Back to Question 1**

# Q2.

## Solution

**Concept:**
The chemical reactivity, oxidizing behavior, and reducing capacity of metallic elements can be quantitatively evaluated using the standard electrochemical series. The standard reduction potential ($E^\circ$) represents the thermodynamic tendency of a chemical species to gain electrons and undergo reduction under standard state conditions. Elements possessing highly negative reduction potentials exhibit a strong propensity to lose valence electrons, meaning they are easily oxidized and consequently function effectively as reducing agents for other chemical species in a reaction medium.

**Solution:**

(a) A reducing agent is a substance that readily donates electrons to another reactant, causing that reactant to be reduced while the reducing agent itself undergoes oxidation.

(b) The relative strength of a reducing agent is inversely proportional to its standard reduction potential value. A lower, more negative standard reduction potential signifies that the oxidized form of the species is highly unstable relative to its reduced form, pushing the equilibrium toward electron loss.

(c) Evaluating the given numerical values of the standard reduction potentials for the four elements: $E^\circ(A) = -3.05\text{ V}$, $E^\circ(B) = -1.66\text{ V}$, $E^\circ(C) = -0.40\text{ V}$, and $E^\circ(D) = +0.80\text{ V}$.

(d) Comparing these values shows that element $A$ possesses the lowest and most negative standard reduction potential among the entire set.

(e) This highly negative value indicates that element $A$ has the highest thermodynamic driving force to undergo oxidation and release electrons. Therefore, element $A$ will behave as the strongest reducing agent among the choices provided.

**Final Answer:** Element A will act as the strongest reducing agent.

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

**Go Back to Question 2**

# Q3.

## Solution

**Concept:**

Chemical kinetics deals with the quantitative study of reaction rates and the mathematical expressions governing reactant consumption over time. For a first-order chemical reaction, the rate of the reaction is directly proportional to the instantaneous concentration of a single reactant. The integrated rate equation provides a logarithmic relationship between the elapsed time, the first-order rate constant, the initial concentration of the reactant, and the remaining concentration of that reactant at any specific time interval.

**Solution:**

(a) The integrated rate expression for a first-order reaction is mathematically defined by the formula: $t = \frac{2.303}{k} \log_{10}\left(\frac{[A]_0}{[A]_t}\right)$, where $[A]_0$ represents the initial concentration and $[A]_t$ represents the remaining concentration at time $t$.

(b) The problem states that the initial concentration of the reactant is reduced to one-tenth of its initial value. This condition can be written as $[A]_t = \frac{1}{10}[A]_0$, which simplifies the ratio to $\frac{[A]_0}{[A]_t} = 10$.

(c) Substituting this concentration ratio into the integrated rate expression yields: $t = \frac{2.303}{k} \log_{10}(10)$. Since the base-10 logarithm of 10 is exactly equal to 1, the equation simplifies to $t = \frac{2.303}{k}$.

(d) The value of the first-order rate constant $k$ is given as $4.606 \times 10^{-3}\ \text{s}^{-1}$. Substituting this constant value into the simplified formula gives: $t = \frac{2.303}{4.606 \times 10^{-3}}$.

(e) Performing the final numerical division gives $t = 0.5 \times 10^3$, which equals exactly 500 seconds.

**Final Answer:** The time taken is 500 seconds.

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

**Go Back to Question 3**

## Q4.

### Solution

**Concept:**
The structural chemistry of oxoacids of phosphorus involves specific coordination environments where the central phosphorus atoms are covalently bound to oxygen and hydrogen atoms. In these chemical structures, phosphorus consistently maintains a tetrahedral geometry, utilizing its valence orbitals to form bonds. Analyzing the connectivity, such as the presence of direct phosphorus-to-phosphorus ($P - P$) bonds versus oxygen-bridged ($P - O - P$) linkages, is essential for determining the formal oxidation states of the central atoms and predicting the chemical behavior of the acid.

**Solution:**

(a) The molecule hypophosphoric acid is represented by the chemical formula $H_4P_2O_6$. The structural architecture of this oxoacid consists of two symmetrical groups linked together.

(b) In $H_4P_2O_6$, the two central phosphorus atoms are directly bonded to each other via a single covalent $P - P$ bond. Each individual phosphorus atom is also bonded to two hydroxyl groups ($-OH$) and one oxo oxygen atom ($= O$) through a coordinate or double bond.

(c) Since the direct bond is between identical phosphorus atoms, it contributes zero to the calculation of their formal oxidation state.

(d) To calculate the oxidation state of phosphorus ($x$), we establish the charge balance equation based on the known states of hydrogen ($+1$) and oxygen ($-2$): $4(+1) + 2(x) + 6(-2) = 0$.

(e) Simplifying this algebraic expression gives $+4 + 2x - 12 = 0$, which reduces to $2x = +8$, resulting in $x = +4$. Therefore, each phosphorus atom possesses an oxidation state of $+4$.

**Final Answer:** The oxoacid is hypophosphoric acid ($H_4P_2O_6$).

**Answer: (B)**

**Go Back to Question 4**

# Q5.

## Solution

**Concept:**

Energy profile diagrams visually illustrate the thermodynamic and kinetic changes that occur along the reaction coordinate of a chemical process. The activation energy ($E_a$) represents the minimum kinetic energy barrier that colliding reactant molecules must overcome to form the high-energy activated complex, or transition state, before converting into products. For a reversible reaction, both the forward and backward paths pass through the exact same transition state peak, but their starting potential energy levels depend on whether they begin as reactants or products.

**Solution:**

(a) According to the provided potential energy diagram, the potential energy level corresponding to the transition state (the peak of the curve) is clearly marked at 450 kJ/mol.

(b) The initial potential energy level of the forward reactants is positioned at an energy value of 150 kJ/mol along the vertical axis.

(c) The final potential energy level of the products, which act as the starting materials for the reverse reaction, is located at an energy value of 70 kJ/mol.

(d) The activation energy for the backward reaction ($E_{a,\text{ backward}}$) is defined as the potential energy difference between the peak transition state and the energy level of the products.

(e) Mathematically, this change is calculated by subtracting the energy of the products from the total energy of the transition state: $E_{a,\text{ backward}} = 450\text{ kJ/mol} - 70\text{ kJ/mol} = 380\text{ kJ/mol}$.

**Final Answer:** The activation energy for the backward reaction is 380 kJ/mol.

**Answer: (B)**

**Go Back to Question 5**

## Q6.

### Solution

**Concept:**

Molecular Orbital Theory (MOT) provides a quantum mechanical description of chemical bonding in homonuclear and heteronuclear diatomic molecules by mixing atomic orbitals to generate bonding and antibonding molecular orbitals. The sequence of molecular orbital energy levels for lighter diatomic molecules changes slightly compared to heavier molecules due to $s - p$ orbital mixing. Magnetic properties and formal bond orders are derived directly from the final distribution of valence electrons within these molecular orbitals.

**Solution:**

(a) The total number of electrons present in the $N_2^+$ cation is calculated as $14 - 1 = 13$ electrons, since a neutral nitrogen molecule contains 14 electrons.

(b) For diatomic species containing 14 or fewer electrons, the filling order of molecular orbitals follows the sequence: $\sigma_{1s}^2\ \sigma_{1s}^{*2}\ \sigma_{2s}^2\ \sigma_{2s}^{*2}\ (\pi_{2p_x}^2 = \pi_{2p_y}^2)\ \sigma_{2p_z}^1$.

(c) Counting the electron populations from this distribution, the total number of bonding electrons ($N_b$) is equal to 9, and the total number of antibonding electrons ($N_a$) is equal to 4.

(d) The formal bond order of a species is determined using the formula: $\text{Bond Order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(9 - 4) = 2.5$.

(e) Inspecting the highest occupied molecular orbital ($\sigma_{2p_z}$), it contains a single unpaired electron. The presence of this unpaired electron causes the $N_2^+$ diatomic cation to exhibit paramagnetic behavior.

**Final Answer:** The diatomic species is the $N_2^+$ cation.

**Answer: (B)**

Go Back to Question 6

# Q7.

## Solution

**Concept:**
Werner's coordination theory explains the structural bonding characteristics of transition metal complexes by defining two distinct types of valency: primary valency and secondary valency. Primary valency corresponds to the formal oxidation state of the central metal ion and is typically satisfied by negative anions. Secondary valency corresponds directly to the coordination number of the metal ion, representing the total number of coordinate bonds formed between the central metal atom and the surrounding electron-donating ligands. Secondary valencies are directional and remain intact when the complex dissolves in a solvent.

**Solution:**

(a) The precipitation reaction with silver nitrate targets only the ionic chloride ions located outside the coordination sphere. Since one mole of the complex produces exactly one mole of $AgCl$ precipitate, only one chloride ion is present as a free counter-ion in solution.

(b) This experimental observation allows us to deduce the correct coordination formula for the compound, which must be written as $[\mathrm{Co(NH_3)_4Cl_2}]\mathrm{Cl}$.

(c) Inside the square brackets, which delineate the coordination sphere, the central Cobalt ion is directly bonded to several ligands.

(d) Specifically, there are four neutral ammonia ($\mathrm{NH_3}$) ligands and two anionic chloride ($\mathrm{Cl^-}$) ligands acting as monodentate coordinators.

(e) The total number of coordinate bonds terminating on the central Cobalt ion is calculated by adding these ligands together ($4 + 2 = 6$). Therefore, the coordination number, or secondary valency, of Cobalt in this complex is equal to 6.

**Final Answer:** The secondary valency of Cobalt is 6.

**Answer: (C)**

**Go Back to Question 7**

# Q8.

## Solution

**Concept:**
The aldol condensation reaction is a fundamental carbon-carbon bond-forming organic reaction that occurs when carbonyl compounds are treated with a dilute base. The mechanism requires the initial removal of a weakly acidic hydrogen atom from the carbon atom directly adjacent to the carbonyl group, known as the alpha-carbon position. This deprotonation generates a nucleophilic enolate anion intermediate. Carbonyl molecules that lack hydrogen atoms at this specific alpha position cannot form an enolate ion and therefore cannot undergo self-aldol condensation reactions.

**Solution:**

(a) Examining the structural formulas of the given options helps identify the positions of their volatile hydrogen atoms. Propanal ($CH_3CH_2CHO$) possesses two alpha-hydrogens on its methylene carbon.

(b) Propanone ($CH_3COCH_3$) contains six equivalent alpha-hydrogens distributed across its two terminal methyl groups. Butanone ($CH_3CH_2COCH_3$) possesses five alpha-hydrogens split between its primary and secondary carbon positions.

(c) Benzaldehyde is represented by the structural formula $C_6H_5CHO$. Here, the carbonyl carbon is directly attached to the C-1 carbon of the aromatic phenyl ring.

(d) The C-1 carbon of the benzene ring participates in three aromatic double bonds and one single bond to the carbonyl group, meaning it carries no attached hydrogen atoms.

(e) Because benzaldehyde lacks alpha-hydrogens, it cannot form an enolate intermediate when treated with dilute sodium hydroxide. As a result, it will not undergo a self-aldol condensation reaction.

**Final Answer:** Benzaldehyde ($C_6H_5CHO$) will not undergo an aldol condensation reaction.

**Answer: (C)**

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# Q9.

## Solution

**Concept:**
Solid-state chemistry involves analyzing the geometric arrangements of atoms within regular crystalline lattices. In a face-centered cubic (fcc) unit cell description, identical spherical atoms are situated at all eight corners of the cube as well as at the centers of all six faces. The structural constraints require the face-diagonal atoms to be in direct physical contact with one another. Consequently, the closest distance of approach between any two adjacent atomic centers corresponds mathematically to exactly half the length of the face diagonal of the unit cell.

**Solution:**

(a) For a face-centered cubic (fcc) crystal lattice, the length of the face diagonal of the cubic unit cell is given by the expression $a\sqrt{2}$, where $a$ represents the cell edge length.

(b) The geometry of the face shows that four atomic radii ($4r$) span the entire length of this face diagonal, yielding the fundamental relationship: $4r = a\sqrt{2}$.

(c) The closest distance of approach between two adjacent atomic spheres in the crystal lattice is equal to the distance between their centers, which corresponds to two atomic radii ($d = 2r$).

(d) Rearranging the fundamental contact equation gives the closest distance of approach as: $d = 2r = \frac{a\sqrt{2}}{2} = \frac{a}{\sqrt{2}}$.

(e) The problem states that the edge length $a$ is equal to 400 pm. Substituting this value into our relationship yields: $d = \frac{400}{\sqrt{2}} = 200\sqrt{2}$ pm. Using the value $\sqrt{2} \approx 1.414$, the calculation gives $200 \times 1.414 = 282.8$ pm.

**Final Answer:** The closest distance of approach is 282.8 pm.

**Answer: (B)**

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## Q10.

### Solution

**Concept:**
Surface chemistry deals with the phenomenon of adsorption, where fluid molecules accumulate on the surface of a solid or liquid substrate. The Freundlich adsorption isotherm is an empirical relationship that models how the amount of gas adsorbed per unit mass of a solid adsorbent varies with the equilibrium pressure of the gas at a constant temperature. The mathematical parameters in the equation reflect the nature of the surface active sites and define how adsorption capacity changes under different pressure conditions.

**Solution:**

(a) The Freundlich adsorption equation is expressed as $\frac{x}{m} = kp^{1/n}$, where $x$ is the mass of gas adsorbed, $m$ is the mass of the adsorbent, $p$ is the pressure, and $k$ and $n$ are empirical constants.

(b) The mathematical exponent $1/n$ typically takes values between 0 and 1 under normal operating pressures. This range reflects the energetic heterogeneity of the adsorbent's surface sites.

(c) At very low pressures, the extent of adsorption is directly proportional to pressure, meaning $1/n = 1$, and the equation simplifies to $\frac{x}{m} = kp$.

(d) At very high pressures, the adsorption surfaces become completely saturated, making the extent of adsorption independent of pressure. Under these conditions, $1/n = 0$, and the equation simplifies to $\frac{x}{m} = k$.

(e) Therefore, under standard experimental conditions, the value of $1/n$ varies between 0 and 1, indicating that adsorption capacity does not scale linearly at intermediate pressures.

**Final Answer:** The value of the exponent 1/n is between 0 and 1.

**Answer: (C)**

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# Q11.

## Solution

**Concept:**
The electronic configuration of transition elements determines their chemical behavior, especially their ability to exhibit variable oxidation states. Elements in the $3d$-transition series can utilize both their outer $4s$ electrons and their inner, unshared $3d$ electrons for chemical bonding because the energy difference between these two subshells is remarkably small. The number of stable and variable oxidation states peaks near the middle of the transition series, where elements possess the maximum number of unpaired $3d$ electrons alongside their paired or unpaired $4s$ valence electrons.

**Solution:**

(a) Transition metals show variable oxidation states because the energy levels of the $3d$ and $4s$ orbitals are exceptionally close, allowing electrons from both subshells to participate in bond formation.

(b) The maximum number of variable oxidation states is exhibited by the element that has the largest combined number of valence electrons available before the $3d$ orbitals begin to pair up tightly.

(c) Analyzing the configuration $3d^5 4s^2$, which belongs to Manganese ($Z = 25$), reveals five unpaired electrons in the $3d$ subshell and two electrons in the $4s$ subshell.

(d) Manganese can progressively lose or share electrons ranging from its $4s$ shell up to all seven valence electrons, yielding stable oxidation states from +2, +3, +4, +5, +6, up to +7.

(e) Other configurations like $3d^3 4s^2$ (Vanadium), $3d^5 4s^1$ (Chromium), and $3d^7 4s^2$ (Cobalt) have fewer total configurations or undergo $3d$ electron pairing, which reduces their range of accessible variable oxidation states.

**Final Answer:** The configuration is $3d^5 4s^2$.

**Answer: (C)**

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# Q12.

## Solution

**Concept:**
Environmental chemistry distinguishes between different types of smog based on their chemical composition, primary pollutants, and the atmospheric conditions under which they develop. Classical smog, historically known as London smog, is chemically reducing in nature. It occurs predominantly in regions with cool, damp, and humid climates where coal combustion releases significant amounts of sulfur oxides and carbonaceous particulate matter into the lower atmosphere, creating a dense, toxic winter haze.

**Solution:**

(a) Classical smog or London smog is categorized as a reducing smog because it contains a high concentration of reducing gases, unlike photochemical smog which contains oxidizing agents like ozone.

(b) The primary components necessary to initiate classical smog are sulfur dioxide gas ($SO_2$) and solid or liquid particulate matter, such as soot, fly ash, and moisture droplets.

(c) This atmospheric phenomenon typically develops during the cold winter months in highly industrialized or urban regions where the widespread combustion of sulfur-rich fossil fuels releases heavy pollutants.

(d) When sulfur dioxide gas mixes with high atmospheric humidity, it deposits onto floating particulate surfaces, forming tiny aerosols of sulfurous and sulfuric acid that severely lower visibility and harm respiratory health.

(e) Other options, like nitrogen oxides, ozone, and volatile organic compounds, are characteristic secondary and primary drivers of photochemical smog, which requires warm temperatures and intense solar UV radiation to form.

**Final Answer:** The pollutants are sulfur dioxide ($SO_2$) and particulate matter.

**Answer: (B)**

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## Q13.

### Solution

**Concept:**
The colligative properties of solutions depend exclusively on the total number of solute particles dissolved in a given volume of solvent, rather than the chemical identity of those particles. According to Raoult's Law, the relative lowering of vapor pressure for a dilute solution containing a non-volatile, non-electrolyte solute is exactly equal to the mole fraction of the dissolved solute. This fundamental law allows the direct calculation of the reduction in a solvent's vapor pressure when a clean solute is introduced.

**Solution:**

(a) Raoult's Law state that the relative lowering of vapor pressure is equal to the solute mole fraction: $\frac{P^\circ - P_s}{P^\circ} = X_{\text{solute}}$, where $P^\circ$ is the pure vapor pressure and $P_s$ is the solution vapor pressure.

(b) The vapor pressure lowering itself is defined as $\Delta P = P^\circ - P_s$. Rearranging our formula gives the relationship: $\Delta P = P^\circ \times X_{\text{solute}}$.

(c) The problem provides the mole fraction of the solvent water ($X_{\text{water}} = 0.95$). Since the total sum of mole fractions in a binary mixture is equal to one, we calculate the solute mole fraction as: $X_{\text{solute}} = 1 - 0.95 = 0.05$.

(d) The vapor pressure of pure liquid water ($P^\circ$) at 298 K is given as 23.8 mmHg. Substituting these quantitative values into the equation yields: $\Delta P = 23.8 \times 0.05$.

(e) Calculating this numerical product gives $\Delta P = 1.19$ mmHg, which represents the exact vapor pressure lowering caused by adding the non-volatile solute.

**Final Answer:** The vapor pressure lowering is 1.19 mmHg.

**Answer: (A)**

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# Q14.

## Solution

**Concept:**
The spatial distribution of electrons within a hydrogenic atom is mapped using quantum mechanical wave functions known as atomic orbitals. Nodes are specific regions in space surrounding the nucleus where the probability density of finding an electron drops to zero. The total nodes in any given orbital are split into two geometric types: spherical (radial) nodes, which depend on distance from the nucleus, and angular (planar) nodes, which describe directional planes. Both values are determined by the principal and azimuthal quantum numbers.

**Solution:**

(a) The shapes and nodes of any atomic orbital are governed by its principal quantum number ($n$) and its azimuthal quantum number ($l$).

(b) For a $4p$ atomic orbital, the numerical value of the principal quantum number $n$ is equal to 4, and the value of the azimuthal quantum number $l$ for any $p$-subshell is equal to 1.

(c) The number of angular nodes present in an atomic orbital is always equal to the value of the azimuthal quantum number $l$. Therefore, a $4p$ orbital contains exactly 1 angular node.

(d) The number of radial nodes in an orbital is determined using the mathematical formula: Radial Nodes $= n - l - 1$.

(e) Substituting our values into this formula gives: Radial Nodes $= 4 - 1 - 1 = 2$. Thus, a $4p$ orbital possesses 2 radial nodes and 1 angular node.

**Final Answer:** The orbital has 2 radial nodes and 1 angular node.

**Answer: (A)**

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## Q15.

### Solution

**Concept:**

Organometallic compounds, particularly Grignard reagents, serve as highly versatile nucleophilic intermediates in organic synthesis. When an aryl halide reacts with magnesium metal in an anhydrous ether solvent, it forms an arylmagnesium halide reagent. This Grignard reagent contains a highly polarized, nucleophilic carbon-metal bond. It can attack electrophilic carbon centers, such as those in carbon dioxide, making it a reliable method for extending carbon chains and synthesizing carboxylic acids.

**Solution:**

(a) Reacting bromobenzene ($C_6H_5Br$) with magnesium metal in dry ether forms phenylmagnesium bromide ($C_6H_5MgBr$), a classic nucleophilic Grignard reagent.

(b) The phenyl carbon atom in phenylmagnesium bromide carries a partial negative charge, enabling it to act as a powerful nucleophile.

(c) When dry ice (solid $CO_2$) is introduced, the nucleophilic phenyl group attacks the electrophilic carbon atom of the carbon dioxide molecule.

(d) This nucleophilic addition breaks one of the carbon-oxygen pi bonds, forming a stable magnesium carboxylate salt intermediate: $C_6H_5COO^-\text{Mg}^+\text{Br}$.

(e) Subjecting this intermediate to subsequent aqueous acid hydrolysis breaks the oxygen-magnesium bond by protonating the carboxylate anion, yielding benzoic acid ($C_6H_5COOH$) as the final product.

**Final Answer:** The major organic product is Benzoic acid.

**Answer: (B)**

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## Q16.

### Solution

**Concept:**
The chemical properties and periodic trends of Group 15 hydrides change systematically moving down the column. The relative basic strength of these molecular hydrides depends on the availability and density of the lone pair of electrons residing on the central atom. As atomic size increases down the group, the valence shell electron cloud expands over a much larger volume, altering the charge density and the atom's ability to act as a Lewis base toward electron-accepting protons.

**Solution:**

(a) All Group 15 elements form hydrides of the general formula $MH_3$, where each central atom contains three single covalent bonds and one non-bonding lone pair of electrons.

(b) The base strength of these hydrides depends on the electron charge density of the lone pair, which determines how easily the atom can donate electrons to a proton.

(c) Moving down Group 15 from Nitrogen to Antimony ($N \rightarrow P \rightarrow As \rightarrow Sb$), the atomic size of the central atom increases significantly.

(d) Because the atomic volume increases while the lone pair charge remains constant, the electron density of the lone pair becomes increasingly diffused over a larger spatial region.

(e) Nitrogen, being the smallest atom, has the highest electron density and holds its lone pair in a concentrated space, making it the strongest base. Thus, basic strength decreases in the order: $NH_3 > PH_3 > AsH_3 > SbH_3$.

**Final Answer:** The correct descending order is $NH_3 > PH_3 > AsH_3 > SbH_3$.

**Answer: (A)**

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# Q17.

## Solution

**Concept:**

Osmosis is the spontaneous net movement of solvent molecules through a semi-permeable membrane from a region of lower solute concentration to a region of higher solute concentration. This movement can also be described as flowing from a region of higher solvent chemical potential to one of lower solvent chemical potential. When comparing ionic and non-ionic solutions, the total concentration of dissolved particles—quantified by taking the van 't Hoff factor into account—determines the net direction of solvent migration across the membrane.

**Solution:**

(a) The net movement of solvent during osmosis is determined by comparing the total effective particle concentrations, or osmolarities, of the solutions on either side of the semi-permeable membrane.

(b) Side X contains a 0.1 M glucose solution. Since glucose is a non-electrolyte that does not dissociate in water, its van 't Hoff factor ($i$) is 1, giving an effective particle concentration of $0.1 \times 1 = 0.1$ M.

(c) Side Y contains a 0.05 M sodium chloride solution. Because NaCl is a strong electrolyte that dissociates completely into two ions ($Na^+$ and $Cl^-$), its van 't Hoff factor is 2.

(d) The effective particle concentration on Side Y is calculated as $0.05\text{ M} \times 2 = 0.1$ M.

(e) Comparing both sides reveals that the effective particle concentrations are completely identical (0.1 M). Because both solutions exert equal osmotic pressures, there is no net driving force, resulting in no net movement of solvent across the membrane.

**Final Answer:** There will be no net movement of solvent because both solutions exert identical osmotic pressures.

**Answer: (C)**

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# Q18.

## Solution

**Concept:**
Nucleophilic substitution reactions can follow different kinetic pathways, such as $S_N1$ or $S_N2$, depending on the structure of the alkyl halide substrate. The rate-determining step of an $S_N1$ mechanism involves the spontaneous heterolytic cleavage of the carbon-halogen bond to generate an intermediate carbocation. Consequently, the relative rate of an $S_N1$ reaction depends directly on the thermodynamic stability of this carbocation intermediate, which is enhanced by inductive electron donation and hyperconjugation from surrounding alkyl groups.

**Solution:**

(a) The $S_N1$ mechanism progresses through a two-step pathway where the formation of a stable carbocation intermediate serves as the slow, rate-determining step.

(b) The relative stability of carbocations follows the well-established structural order: tertiary $(3^\circ) >$ secondary $(2^\circ) >$ primary $(1^\circ)$.

(c) Analyzing the options, $CH_3CH_2CH_2CH_2Cl$ is a primary alkyl halide, $CH_3CH_2CH(Cl)CH_3$ is secondary, and $(CH_3)_2CHCH_2Cl$ is a branched primary alkyl halide.

(d) The compound tert-butyl chloride, $(CH_3)_3C-Cl$, is a tertiary alkyl halide. Upon loss of its chloride leaving group, it forms the highly stable tert-butyl carbocation, $+C(CH_3)_3$.

(e) This tertiary carbocation is stabilized by nine hyperconjugative hydrogens and the electron-donating inductive effects of three methyl groups, allowing it to react fastest via an $S_N1$ pathway.

**Final Answer:** The compound $(CH_3)_3C-Cl$ reacts fastest.

**Answer: (B)**

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# Q19.

## Solution

**Concept:**
The Valence Shell Electron Pair Repulsion (VSEPR) theory allows the prediction of molecular geometries and hybridization states by analyzing the total number of bonding and non-bonding electron pairs surrounding a central atom. For hypervalent polyatomic anions, the valence electrons of the central atom, the electrons shared by terminal ligands, and the overall negative charge must be accounted for to determine the steric number, which dictates the arrangement of electron pairs in space.

**Solution:**

(a) In the triiodide anion ($I_3^-$), we treat one central Iodine atom as being covalently bonded to two terminal Iodine ligand atoms.

(b) To find the steric number, we count the total valence electrons on the central Iodine atom (7), add the electrons from the two monodentate Iodine ligands (2), and add the 1 electron from the negative charge, giving 10 total electrons.

(c) Dividing these 10 electrons into pairs gives 5 valence electron pairs around the central atom. Since there are two terminal bonds, these consist of 2 bonding pairs and 3 lone pairs.

(d) A steric number of 5 corresponds to an $sp^3d$ hybridization state, which generates a trigonal bipyramidal electron-pair geometry.

(e) To minimize lone pair-lone pair repulsions, VSEPR theory dictates that the 3 lone pairs occupy the equatorial positions. This leaves the 2 bonding pairs in the axial positions directly opposite each other, resulting in a linear molecular geometry.

**Final Answer:** The geometry and hybridisation are Linear and $sp^3d$.

**Answer: (A)**

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## Q20.

### Solution

**Concept:**

Pyrometallurgy relies on chemical principles to extract metals from crude ores using high-temperature furnace treatments. Copper extraction from sulfide ores like copper pyrites generates copper matte, a molten mixture of copper(I) sulfide ($Cu_2S$) and iron(II) sulfide (FeS). To isolate pure copper, iron impurities must be selectively removed. This is achieved by adding an appropriate flux that reacts with the iron oxides to form a low-density, fusible slag that can be easily skimmed off from the molten metal.

**Solution:**

(a) Copper matte consists of a mixture of $Cu_2S$ and remaining FeS impurities. During furnace heating, air oxidation converts iron sulfide into iron(II) oxide (FeO).

(b) Iron(II) oxide (FeO) is a basic oxide that remains mixed with the molten copper matte and must be separated chemically.

(c) Silica ($SiO_2$) is explicitly introduced into the reverberatory furnace to act as an acidic flux.

(d) The acidic silica flux undergoes an acid-base neutralization reaction with the basic iron oxide impurity at high temperatures: $FeO + SiO_2 \rightarrow FeSiO_3$.

(e) This reaction produces iron(II) silicate ($FeSiO_3$), a fusible slag. The slag has a low density and does not mix with the molten copper, allowing it to float to the top where it can be continuously skimmed off.

**Final Answer:** The function of silica is to act as an acidic flux to remove iron oxide (FeO) impurity as a fusible slag.

**Answer: (C)**

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## Q21.

### Solution

**Concept:**
Neutralization reactions between acids and bases follow strict stoichiometric ratios derived from balanced chemical equations. In a typical acid-base titration or calculation, the equivalents of the acidic species must equal the equivalents of the basic species for complete neutralization. Sulfuric acid is a strong diprotic acid, meaning it releases two moles of hydrogen ions per mole of acid. Sodium hydroxide is a strong monacidic base supplying one mole of hydroxide ions per mole of base.

**Solution:**

(a) Write the balanced neutralization chemical equation: $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$.

(b) Calculate the moles of sulfuric acid present in the solution using its volume and molarity: Moles of $H_2SO_4$ = Molarity × Volume (L) = 0.5 M × 0.1 L = 0.05 mol.

(c) Use the stoichiometric coefficients from the chemical equation to find the required moles of sodium hydroxide: Moles of NaOH = 2 × Moles of $H_2SO_4$ = 2 × 0.05 mol = 0.1 mol.

(d) Convert the moles of sodium hydroxide into mass using its given molar mass (40 g/mol): Mass of NaOH = 0.1 mol × 40 g/mol = 4.0 g.

(e) Thus, exactly 4.0 g of sodium hydroxide is required to fully neutralize the sulfuric acid solution.

**Final Answer:** The mass required is 4.0 g.

**Answer: (B)**

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# Q22.

## Solution

**Concept:**
Carbohydrates are classified as reducing or non-reducing sugars based on the structural availability of an active hemiacetal or hemiketal group within their cyclic structures. Reducing sugars have a free anomeric carbon atom that can open into a straight-chain form with a reactive aldehyde or ketone group, which reduces Tollen's or Fehling's reagents and forms osazones with excess phenylhydrazine. Non-reducing sugars have their anomeric carbons locked in a glycosidic linkage, preventing oxidation and osazone formation.

**Solution:**

(a) Glucose, maltose, and lactose contain free anomeric carbons that can easily undergo mutarotation to yield a reactive carbonyl functional group.

(b) Because they have these free reducing groups, glucose, maltose, and lactose readily form characteristic crystalline osazones when treated with excess phenylhydrazine.

(c) Sucrose is a disaccharide composed of an $\alpha$-D-glucose unit linked to a $\beta$-D-fructose unit through their respective anomeric carbon atoms ($C_1$ of glucose and $C_2$ of fructose).

(d) This unique $\alpha, \beta$-1,2-glycosidic linkage locks both reducing groups, preventing the sugar molecule from opening into an open-chain carbonyl form.

(e) Consequently, sucrose acts as a non-reducing sugar, fails to reduce Fehling's solution, and does not form an osazone.

**Final Answer:** The non-reducing sugar is Sucrose.

**Answer: (C)**

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## Q23.

### Solution

**Concept:**
Colloidal systems are categorized based on the structural nature and aggregate properties of the dispersed phase particles. Multimolecular colloids form when a large number of simple, independent atoms or smaller molecules aggregate together through weak van der Waals forces to build stable, larger clusters within the colloidal size range (1 to 1000 pm). Gold sol is a classic example of a lyophobic system where individual metallic gold atoms cluster into larger colloidal aggregates during chemical reduction.

**Solution:**

(a) Gold sol is prepared by chemically reducing gold chloride salts using suitable reducing agents like formaldehyde or tannin in water.

(b) During this chemical reduction, individual metallic gold atoms are liberated in the aqueous medium.

(c) Because individual gold atoms are too small to stay suspended as separate units, a large number of these atoms spontaneously aggregate.

(d) These atoms cluster together through weak van der Waals forces to create stable particles with dimensions falling inside the standard colloidal range.

(e) This aggregation of smaller independent atomic units defines a multimolecular colloid, which is inherently lyophobic due to its low affinity for the liquid dispersion medium.

**Final Answer:** Gold sol is a Multimolecular lyophobic colloid.

**Answer: (C)**

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## Q24.

### Solution

**Concept:**
The first ionization enthalpy represents the energy required to remove the most loosely bound valence electron from an isolated gaseous atom in its ground state. While ionization enthalpy generally increases across a period due to increasing effective nuclear charge and decreasing atomic radius, electronic configuration plays a critical role. Exceptional stabilities associated with completely filled or half-filled electronic subshells can alter the expected periodic trends between adjacent elements.

**Solution:**

(a) Across the second period, the general order of increasing first ionization enthalpy values is expected to follow the atomic number: B < C < N < O.

(b) Boron ($1s^2 2s^2 2p^1$) has a lower value than Carbon ($1s^2 2s^2 2p^2$) because removing its lone $2p$ electron leaves a stable, fully filled $2s^2$ subshell.

(c) Nitrogen ($1s^2 2s^2 2p^3$) has a stable, half-filled $2p$ subshell, which possesses high exchange energy and extra symmetric stability.

(d) Oxygen ($1s^2 2s^2 2p^4$) has a lower ionization energy than Nitrogen because removing one electron from its paired $2p$ orbital relieves electron-electron repulsion and yields a stable, half-filled $2p^3$ subshell.

(e) Therefore, Nitrogen requires more energy to remove an electron than Oxygen, giving the correct increasing sequence: B < C < O < N.

**Final Answer:** The correct sequence is B < C < O < N.

**Answer: (A)**

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# Q25.

## Solution

**Concept:**

Reductive ozonolysis is a fundamental chemical degradation method used to pinpoint the exact positions of carbon-carbon double bonds in unsaturated hydrocarbons. Treating an alkene with ozone forms an ozonide intermediate, which is then cleaved reductively using zinc dust and water. This reaction breaks both the sigma and pi components of the double bonds, converting each unsaturated carbon center into a distinct carbonyl compound.

**Solution:**

(a) To deduce the parent structure, align the carbonyl products by placing their reactive oxygen atoms face-to-face.

(b) The products are methanal ($CH_2 = O$) and 2-oxopropanal ($O = CH - CO - CH_3$).

(c) Structurally connect the carbonyl carbons by removing the oxygen atoms and replacing them with carbon-carbon double bonds ($C = C$).

(d) Connecting the terminal carbon of methanal to the aldehyde carbon of 2-oxopropanal gives the structure: $CH_2 = C(CH_3) - CH = CH_2$.

(e) This structure corresponds to 2-methylbuta-1,3-diene, commonly known as isoprene. Reductive ozonolysis of this diene cleaves its double bonds to yield exactly one mole of methanal and one mole of 2-oxopropanal.

**Final Answer:** The structure of hydrocarbon X is $CH_2 = C(CH_3) - CH = CH_2$.

**Answer: (B)**

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# Q26.

## Solution

**Concept:**

Le Chatelier's principle states that if a dynamic chemical equilibrium is disturbed by changing the prevailing conditions, the position of the equilibrium shifts in a direction that counteracts the applied change. For gaseous systems, changing the total pressure shifts the equilibrium toward the side with fewer or more moles of gas. For temperature changes, the direction of the shift depends on whether the forward chemical pathway is exothermic or endothermic.

**Solution:**

(a) The synthesis of ammonia via Haber's process is represented by the equilibrium: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{Heat}$.

(b) The forward reaction is exothermic, meaning it releases thermal energy ($\Delta H < 0$).

(c) According to Le Chatelier's principle, lowering the external temperature shifts the equilibrium in the direction that generates heat, favoring the exothermic forward reaction and increasing ammonia yield.

(d) Count the total moles of gaseous reactants ($1 + 3 = 4$ moles) and compare them to the gaseous products (2 moles).

(e) Increasing the total pressure shifts the system toward the side with fewer gas molecules to relieve the pressure. This favors the forward reaction, meaning the optimal conditions are low temperature and high pressure.

**Final Answer:** The conditions are low temperature and high total pressure.

**Answer: (C)**

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## Q27.

### Solution

**Concept:**
Crystal Field Theory describes how the five d-orbitals of a central transition metal ion split in energy when surrounded by a spherical or octahedral field of ligands. In an octahedral complex, the d-orbitals split into a lower-energy triplet ($t_{2g}$) and a higher-energy doublet ($e_g$). The electronic configuration of the complex depends on the oxidation state of the metal ion and the field strength of the ligands, which determines whether electrons pair up or occupy higher-energy orbitals.

**Solution:**

(a) In the complex anion $[\text{Fe(CN)}_6]^{3-}$, let the oxidation state of Iron be $x$. Thus, $x+6(-1) = -3$, which gives $x = +3$.

(b) A neutral Iron atom has the electronic configuration $[\text{Ar}]3d^6 4s^2$. Losing three electrons forms the $\text{Fe}^{3+}$ ion, which has a $3d^5$ valence electronic configuration.

(c) Cyanide ($\text{CN}^-$) is a strong-field ligand that produces a large crystal field splitting energy ($\Delta_o > P$).

(d) Because the splitting energy is greater than the pairing energy, the five valence electrons are forced to pair up in the lower-energy $t_{2g}$ orbitals rather than moving up to the higher-energy $e_g$ orbitals.

(e) Distributing the five d-electrons into the lower triplet fills them sequentially with pairing, giving a low-spin configuration of $t_{2g}^5 e_g^0$.

**Final Answer:** The d-electronic configuration is $t_{2g}^5 e_g^0$.

**Answer: (B)**

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## Q28.

### Solution

**Concept:**
Green Chemistry focuses on designing chemical processes and products that reduce or eliminate the use and generation of hazardous substances. Its core principles emphasize maximizing atom economy, utilizing safer alternative solvents, minimizing energy consumption, and replacing toxic reagents with eco-friendly alternatives. Choosing benign oxidizing agents like hydrogen peroxide helps prevent the production of hazardous chlorinated updates or toxic byproducts.
**Solution:**

(a) Traditional industrial methodologies for bleaching paper pulp relied heavily on elemental chlorine gas ($Cl_2$).

(b) Using chlorine gas generates large amounts of highly toxic, bioaccumulative organochlorine side-products and dioxins that contaminate wastewater streams.

(c) Modern green chemistry practices replace chlorine with hydrogen peroxide ($H_2O_2$) as a cleaner, safer bleaching agent for paper pulp.

(d) Hydrogen peroxide acts as an efficient oxidizing agent and breaks down into completely harmless byproducts: water ($H_2O$) and oxygen gas ($O_2$).

(e) This modification eliminates chlorinated environmental toxins, minimizes auxiliary hazards, and serves as a primary example of sustainable green engineering.

**Final Answer:** The green process is bleaching of paper pulp using hydrogen peroxide ($H_2O_2$) instead of chlorine gas.

**Answer: (B)**

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# Q29.

## Solution

**Concept:**

Structural isomerism occurs when chemical compounds share identical molecular formulas but differ in the connectivity and arrangement of their atoms. For acyclic alkene hydrocarbons, structural variations can arise from changes in the arrangement of the carbon skeleton (chain isomerism) or changes in the position of the carbon-carbon double bond along that skeleton (position isomerism). Stereoisomeric arrangements are excluded from this structural count.

**Solution:**

(a) The molecular formula $C_4H_8$ matches the general formula for acyclic mono-alkenes ($C_nH_{2n}$), indicating the presence of one carbon-carbon double bond.

(b) Start with a straight four-carbon chain (n-butane skeleton) and vary the position of the double bond.

(c) Placing the double bond between the first and second carbons yields the first structural isomer: but-1-ene ($CH_2 = CH - CH_2 - CH_3$).

(d) Moving the double bond to the position between the second and third carbons yields the second structural isomer: but-2-ene ($CH_3 - CH = CH - CH_3$).

(e) Next, branch the carbon skeleton into a three-carbon chain with a methyl group at the central position. Placing the double bond here yields the third structural isomer: 2-methylprop-1-ene [$CH_2 = C(CH_3)_2$]. No other acyclic structures can be formed.

**Final Answer:** The total number of structural isomers is 3.

**Answer: (B)**

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## Q30.

### Solution

**Concept:**

The autoionization of liquid water is an endothermic chemical process described by the equilibrium: $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$. The ionic product constant of water ($K_w$) is temperature-dependent and increases as the temperature rises. Pure water always remains chemically neutral because the autoionization process generates equal concentrations of hydrogen ions and hydroxide ions, regardless of changes in temperature or the numerical value of $K_w$.

**Solution:**

(a) The mathematical expression for the ionic product constant of water is: $K_w = [H^+][OH^-]$.

(b) Pure water is chemically neutral at any temperature because stoichiometry dictates that $[H^+] = [OH^-]$.

(c) Substitute this equality into the ionic product expression to solve for the hydrogen ion concentration: $K_w = [H^+]^2$.

(d) The problem states that $K_w = 1.0 \times 10^{-12}$ at the elevated temperature of 333 K. Substituting this value gives: $1.0 \times 10^{-12} = [H^+]^2$.

(e) Taking the square root gives $[H^+] = 1.0 \times 10^{-6}$ mol $L^{-1}$. Calculate the pH value using the definition: $pH = -\log[H^+] = -\log(1.0 \times 10^{-6}) = 6.0$.

**Final Answer:** The calculated pH value is 6.0.

**Answer: (B)**

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## Q31.

### Solution

**Concept:**

The frequency of an emitted photon during an electronic transition in a hydrogen atom depends directly on the energy difference between the initial and final energy levels. According to the Bohr model, the energy change accompanying an electronic transition is quantified by the Rydberg formula. Electronic shells are spaced closer together in terms of energy as the principal quantum number increases. This means transitions ending at the lowest possible ground shell release significantly greater packets of energy than transitions occurring exclusively between higher shells.

**Solution:**

(a) The energy difference for a electronic transition between any two principal quantum shells is mathematically expressed as $\Delta E = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$.

(b) The frequency of the emitted photon is directly proportional to this energy difference because $\Delta E = h\nu$.

(c) Evaluate the relative energy spacing for a drop down to the lowest shell, such as the transition from $n = 2$ to $n = 1$, which yields a fractional value of $1 - \frac{1}{4} = 0.75$.

(d) Evaluate the remaining choices, which occur between higher shells: $n = 4$ to $n = 2$ gives 0.21875, $n = 5$ to $n = 3$ gives 0.0711, and $n = 3$ to $n = 2$ gives 0.1388.

(e) Comparing these values shows that the electronic transition from the first excited state back to the ground state releases the largest quantity of energy, producing a photon with the maximum frequency.

**Final Answer:** The transition is $n = 2 \longrightarrow n = 1$.

**Answer: (A)**

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# Q32.

## Solution

**Concept:**
The Reimer-Tiemann reaction converts phenol into salicylaldehyde when treated with chloroform in an alkaline medium. The mechanism proceeds through an initial alpha-elimination of a hydrogen atom and a chloride ion from chloroform by a strong base. This reaction generates a highly reactive, neutral, electron-deficient divalent carbon species that acts as the active electrophile. This intermediate attacks the electron-rich aromatic ring of the phenoxide ion primarily at the ortho position.

**Solution:**

(a) Hydroxide ions from sodium hydroxide deprotonate chloroform ($CHCl_3$) to form a transient trichloromethyl carbanion intermediate ($^{-}CCl_3$).

(b) This unstable carbanion rapidly eliminates a chloride ion ($Cl^{-}$) from its structure in a spontaneous alpha-elimination pathway.

(c) Removing the chloride ion leaves behind a neutral carbon center surrounded by six valence electrons, known as dichlorocarbene ($: CCl_2$).

(d) Dichlorocarbene acts as a powerful electrophile because it possesses an empty p-orbital that eagerly accepts electron density from the aromatic system.

(e) The phenoxide anion directs the attack of this neutral dichlorocarbene intermediate to the ortho position, leading to subsequent hydrolysis and acidification steps that yield salicylaldehyde.

**Final Answer:** The active electrophilic intermediate is Dichlorocarbene ($: CCl_2$).

**Answer: (B)**

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# Q33.

## Solution

**Concept:**
The overall order of a chemical reaction represents the sum of the concentration exponents in its experimentally determined rate law expression. These partial orders indicate how changes in the concentration of each individual reactant affect the overall rate of the chemical process. The overall reaction order can be an integer, a fraction, or even zero, and it is independent of the stoichiometric coefficients of the balanced chemical equation.

**Solution:**

(a) Examine the provided rate law expression for the chemical reaction: Rate $= k[\mathrm{A}]^{3/2}[\mathrm{B}]^{-1}$.

(b) Identify the partial order of the reaction with respect to reactant A, which is given by its exponent value of $\frac{3}{2}$ or 1.5.

(c) Identify the partial order of the reaction with respect to reactant B, which is given by its exponent value of $-1$.

(d) Add these partial orders together to determine the overall order ($n$) of the reaction: $n = \left(\frac{3}{2}\right) + (-1)$.

(e) Simplifying this algebraic sum yields $1.5 - 1 = 0.5$. This indicates the chemical process follows an overall half-order kinetic pathway.

**Final Answer:** The overall order is 0.5.

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

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# Q34.

## Solution

**Concept:**

Constitutional or structural isomerism occurs when organic molecules share an identical molecular formula but differ in the connectivity of their atoms. A specific type of structural isomerism is observed in compounds containing a polyvalent heteroatom functional group bounded by carbon networks. When different combinations of alkyl or aryl chains attach to either side of this bridging heteroatom, the resulting compounds are classified as positional variants along the core functional unit.

**Solution:**

(a) Metamerism is a unique form of structural isomerism that arises due to the unequal distribution of alkyl carbon chains on opposite sides of a polyvalent functional group.

(b) This phenomenon is commonly exhibited by compound classes containing bridging heteroatoms, such as ethers (−O−), thioethers (−S−), ketones (−CO−), and secondary amines (−NH−).

(c) For example, an ether with the molecular formula $C_4H_{10}O$ can exist as diethyl ether ($CH_3CH_2 - O - CH_2CH_3$).

(d) The same molecular formula can also form methyl propyl ether ($CH_3 - O - CH_2CH_2CH_3$), where the alkyl chains around the oxygen atom are changed.

(e) Because these structures differ only in the arrangement of the carbon chains attached to the bridging oxygen heteroatom, they are classified as metamers.

**Final Answer:** The type of structural isomerism is Metamerism.

**Answer: (B)**

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# Q35.

## Solution

**Concept:**
The lanthanides are a series of fourteen inner transition elements located in the $4f$-block of the periodic table, spanning from cerium to lutetium. These elements share similar physical and chemical properties due to their outermost electronic configurations. The poor shielding ability of $4f$ electrons leads to a steady decrease in atomic and ionic radii across the series, a phenomenon known as the lanthanide contraction. This trend significantly influences the properties of heavier transition metals.

**Solution:**

(a) The common stable oxidation state for all lanthanides is +3, though a few elements can additionally exhibit +2 or +4 states in solution.

(b) Lanthanide contraction causes a steady decrease in ionic radius from $La^{3+}$ to $Lu^{3+}$, which increases covalent character and causes the basicity of their hydroxides to decrease across the series.

(c) This contraction also explains why second and third-row transition elements in the same group, such as Zirconium (Zr) and Hafnium (Hf), have nearly identical atomic radii.

(d) Most lanthanides are naturally occurring, stable, non-radioactive elements, with Promethium (Pm) being the sole exception as a synthetic radioactive element.

(e) Therefore, the statement asserting that all members of the lanthanide series are highly radioactive synthetic elements is incorrect.

**Final Answer:** The incorrect statement is that all members of the lanthanide series are highly radioactive synthetic elements.

**Answer: (C)**

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# Q36.

## Solution

**Concept:**

Mixing a strong monoprotic acid with a strong monobasic base triggers a neutralization reaction that produces a salt and water. The final pH of the resulting solution depends on the relative amounts of hydrogen ions ($H^+$) and hydroxide ions ($OH^-$) initially present. If the acid is added in excess, the unneutralized hydrogen ions will dictate the final hydronium concentration of the mixed solution, accounting for the total combined volume.

**Solution:**

(a) Let the volume of both solutions be $V$ mL. Calculate the initial millimoles of $H^+$ ions from the hydrochloric acid solution: Millimoles of $H^+ = 0.2\text{ M} \times V\text{ mL} = 0.2V$ mmol.

(b) Calculate the initial millimoles of $OH^-$ ions from the sodium hydroxide solution: Millimoles of $OH^- = 0.1\text{ M} \times V\text{ mL} = 0.1V$ mmol.

(c) The chemical neutralization consumes equal amounts of both ions, leaving an excess of unreacted hydrogen ions: Excess $H^+ = 0.2V - 0.1V = 0.1V$ mmol.

(d) Determine the final concentration of hydrogen ions by dividing the excess millimoles by the total volume of the mixture ($2V$ mL): $[H^+] = \frac{0.1V\text{ mmol}}{2V\text{ mL}} = 0.05\text{ M} = 5 \times 10^{-2}$ M.

(e) Compute the final pH of the solution using logarithmic relationships: $\text{pH} = -\log[H^+] = -\log(5 \times 10^{-2}) = 2 - \log 5 = 2 - 0.699 = 1.30$.

**Final Answer:** The final resultant pH value is 1.30.

**Answer: (B)**

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## Q37.

### Solution

**Concept:**
The standard cell potential ($E^\circ_{\text{cell}}$) of a galvanic cell operating under standard state conditions measures the potential difference between its two constituent half-cells. By IUPAC convention, the standard cell potential is calculated by subtracting the standard reduction potential of the anode from the standard reduction potential of the cathode. Oxidation always occurs at the anode, while reduction takes place at the cathode.

**Solution:**

(a) Analyze the provided standard reduction potentials for the two metallic electrodes: $E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.76$ V and $E^\circ_{\text{Cu}^{2+}/\text{Cu}} = +0.34$ V.

(b) The copper electrode has a higher reduction potential, meaning it undergoes reduction more readily and functions as the cathode.

(c) The zinc electrode has a lower reduction potential, meaning it undergoes oxidation more readily and functions as the anode.

(d) Use the standard cell potential equation to find the overall voltage: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$.

(e) Substitute the values into the formula: $E^\circ_{\text{cell}} = (+0.34\text{ V}) - (-0.76\text{ V}) = +0.34\text{ V} + 0.76\text{ V} = +1.10\text{ V}$.

**Final Answer:** The calculated standard cell potential is +1.10 V.

**Answer: (C)**

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# Q38.

## Solution

**Concept:**

Proteins are complex biopolymers composed of individual amino acid residues linked linearly through covalent bonds. The structural architecture of a protein molecule is organized into four distinct hierarchical levels based on its folding and complexity. The lowest level of this hierarchy is determined by genetic code sequences, which dictate the specific, linear sequence of amino acids linked together by amide linkages during protein synthesis.

**Solution:**

(a) The specific linear sequence of amino acid residues in a polypeptide chain forms the foundational blueprint of a protein, known as its primary structure.

(b) This sequence is held together by strong, covalent peptide bonds (amide linkages) formed between the alpha-carboxyl group of one amino acid and the alpha-amino group of the next.

(c) The secondary structure refers to localized, repeating folding patterns like alpha-helices or beta-pleated sheets, which are stabilized primarily by hydrogen bonding.

(d) The tertiary structure describes the overall three-dimensional folding of a single polypeptide chain, driven by hydrophobic interactions, disulfide bridges, and ionic bonds.

(e) The quaternary structure describes the spatial arrangement and interactions of multiple independent polypeptide subunits working together as a functional multi-subunit protein complex.

**Final Answer:** The configuration constitutes its Primary structure.

**Answer: (A)**

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# Q39.

## Solution

**Concept:**
The net molecular dipole moment ($\mu$) of a polyatomic molecule is the vector sum of its individual bond dipole moments. This property depends on both the electronegativity differences between bonded atoms and the overall geometric symmetry of the molecule. Highly symmetric shapes can cause individual bond dipoles to completely cancel one another out, resulting in a net nonpolar molecule despite containing polar bonds.

**Solution:**

(a) Boron trifluoride ($BF_3$) adopts a symmetric trigonal planar geometry, which causes its three polar $B-F$ bond dipoles to completely cancel each other out, resulting in a net dipole moment of zero ($\mu = 0$).

(b) Carbon tetrachloride ($CCl_4$) adopts a symmetric tetrahedral geometry, which causes its four polar $C-Cl$ bond dipoles to cancel out completely, yielding a net dipole moment of zero ($\mu = 0$).

(c) Ammonia ($NH_3$) and nitrogen trifluoride ($NF_3$) both adopt a pyramidal molecular geometry with a lone pair on the central nitrogen atom.

(d) In ammonia, the highly electronegative nitrogen atom pulls electron density away from the hydrogen atoms. This means the three $N-H$ bond dipoles point in the same direction as the lone pair dipole, reinforcing each other.

(e) In $NF_3$, the highly electronegative fluorine atoms pull electron density away from nitrogen. This causes the three $N-F$ bond dipoles to point opposite to the lone pair dipole, partially canceling them out and making the net dipole moment of $NH_3$ significantly higher.

**Final Answer:** The compound with the highest dipole moment is $NH_3$.

**Answer: (C)**

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# Q40.

## Solution

**Concept:**
Electrophilic aromatic substitution reactions of benzene derivatives are governed by the activating or deactivating nature of existing functional groups. The amino group ($-NH_2$) attached to aniline contains a lone pair of electrons that can be delocalized into the ring. This makes it a powerful activating, ortho/para-directing group under typical reaction conditions. However, the presence of strong acids can drastically alter this behavior.

**Solution:**

(a) Nitrating mixtures contain concentrated nitric acid and concentrated sulfuric acid, creating a highly acidic reaction medium.

(b) Under these strongly acidic conditions, the basic lone pair on the amino group ($-NH_2$) of aniline readily accepts a proton.

(c) This protonation converts the activating amino group into a positively charged anilinium ion ($-NH_3^+$).

(d) The positive charge on the nitrogen atom pulls electron density out of the benzene ring through a powerful inductive effect, turning it into a strongly deactivating group.

(e) This strong inductive withdrawal deactivates the ortho and para positions more heavily than the meta position. As a result, the anilinium ion directs incoming electrophiles to the meta position, explaining the formation of 47% $m$-nitroaniline.

**Final Answer:** The formation is due to protonation of aniline to form the highly deactivating anilinium ion.

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

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# Q41.

## Solution

**Concept:**

The coordination complex compound [Co(en)$_2$Cl$_2$]Cl belongs to the structural type [M(AA)$_2$X$_2$]Y, where 'en' is a symmetrical bidentate chelating ligand. Octahedral complexes of this structural category exhibit both stereoisomerism and geometric isomerism based on the spatial positions of identical ligands. Understanding how these ligands arrange themselves around the central metal atom determines whether the resulting isomers display optical activity.

**Solution:**

(a) The complex contains two chloride ligands and two ethylenediamine ligands coordination-bound to a central cobalt core.

(b) This coordination profile generates two unique geometric configurations known as the cis-isomer and the trans-isomer.

(c) In the trans-isomer, the two mono-dentate chloride ligands lie directly opposite to each other, creating a symmetric mirror plane.

(d) Because of this symmetry, the trans-isomer is optically inactive and exists as a single achiral meso structure.

(e) In the cis-isomer, the chloride ligands reside adjacent to each other, which eliminates internal symmetry elements from the molecule.

(f) This asymmetric configuration splits the cis form into two non-superimposable mirror images known as d- and l-enantiomers.

(g) Summing the single trans structure and the pair of optically active cis-enantiomers gives a total of three stereoisomers.

**Final Answer:** The total number of stereoisomers is 3.

**Answer: (B)**

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## Q42.

### Solution

**Concept:**

The solubility product constant ($K_{sp}$) is an equilibrium constant that describes the dissolution of a sparingly soluble salt in an aqueous medium. For a binary salt configuration that releases a specific ratio of cations and anions, equilibrium expressions link molar solubility ($S$) directly to its ionic product value. Calculating this value requires setting up an equilibrium profile based on the stoichiometry of the dissolving salt.

**Solution:**

(a) The sparingly soluble binary salt $AB_2$ dissociates in water according to the equilibrium equation: $AB_2(s) \rightleftharpoons A^{2+}(aq) + 2B^-(aq)$.

(b) If the molar solubility of the salt is represented by $S$, the equilibrium concentration of $A^{2+}$ is $S$ and $B^-$ is $2S$.

(c) Write the mathematical expression for the solubility product: $K_{sp} = [A^{2+}][B^-]^2 = (S)(2S)^2 = 4S^3$.

(d) Substitute the given value of the solubility product into the derived formula: $4.0 \times 10^{-12} = 4S^3$.

(e) Divide both sides of the equation by four to isolate the cubed term: $S^3 = 1.0 \times 10^{-12}$.

(f) Take the cube root of both sides to determine the final value of $S$: $S = \sqrt[3]{1.0 \times 10^{-12}} = 1.0 \times 10^{-4}$ mol L$^{-1}$.

**Final Answer:** The molar solubility is $1.0 \times 10^{-4}$ mol L$^{-1}$.

**Answer: (A)**

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## Q43.

### Solution

**Concept:**
Colloidal systems carry electric charges on their particle surfaces, which stabilizes them by keeping the particles separated. Introducing an electrolyte neutralizes these surface charges, causing the particles to aggregate and precipitate out of solution. The Hardy-Schulze rule states that the coagulation power of an added electrolyte depends on the valency of the ion carrying a charge opposite to that of the colloidal particles.

**Solution:**

(a) Arsenious sulfide ($As_2S_3$) forms a lyophobic colloidal dispersion whose particles carry a net negative surface charge.

(b) To coagulate this negative sol, an electrolyte must supply positively charged ions (cations) to neutralize the system.

(c) According to the Hardy-Schulze rule, the flocculating efficiency of a neutralizing ion increases with its positive valence state.

(d) Examine the available ionic choices: $Na^+$ has a valency of +1, $Mg^{2+}$ has a valency of +2, and $Al^{3+}$ has a valency of +3.

(e) Higher charges are more effective at neutralizing colloidal particles, meaning the trivalent aluminum ion possesses the highest coagulating efficiency.

**Final Answer:** The ion with the maximum flocculating power is $Al^{3+}$.

**Answer: (C)**

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## Q44.

### Solution

**Concept:**
The Valence Shell Electron Pair Repulsion (VSEPR) theory determines the spatial geometries of covalent molecules based on electron distributions around a central atom. Total valence electron pairs organize themselves to minimize electrostatic repulsion, creating an underlying steric framework. The actual molecular shape is then determined by how these electron pairs are shared between bonding domains and non-bonding lone pairs.

**Solution:**

(a) A see-saw molecular shape describes a geometry that originates from an underlying trigonal bipyramidal steric framework.

(b) This steric framework requires the central atom to be surrounded by five distinct valence electron pairs, giving it a total steric number of five.

(c) To adopt a see-saw shape, four of these five electron domains must be occupied by bonding atoms, while the remaining domain holds a non-bonding pair.

(d) According to VSEPR guidelines, the lone pair occupies an equatorial position within the trigonal plane to minimize lone-pair/bond-pair interactions.

(e) This distribution results in a structure with four bond pairs and one lone pair, like the geometry observed in sulfur tetrafluoride ($SF_4$).

**Final Answer:** The count is 4 bond pairs and 1 lone pair.

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

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## Q45.

### Solution

**Concept:**
Stoichiometric calculations use balanced chemical equations to determine the quantitative relationships between reactants and products in a chemical reaction. Thermal decomposition of alkaline earth metal carbonates yields a solid metal oxide and gaseous carbon dioxide. Calculating the mass of gas produced requires converting the initial reactant mass into moles based on its formula weight.

**Solution:**

(a) Write out the balanced stoichiometric chemical equation for the thermal breakdown process: $\text{CaCO}_3(s) \xrightarrow{\Delta} \text{CaO}(s) + \text{CO}_2(g)$.

(b) The equation shows a one-to-one molar relationship: decomposing one mole of calcium carbonate produces exactly one mole of carbon dioxide gas.

(c) Calculate the moles of reactant present in the sample: Moles of $\text{CaCO}_3 = \frac{20\text{ g}}{100\text{ g/mol}} = 0.2$ mol.

(d) Because of the one-to-one stoichiometric ratio, decomposing 0.2 mol of reactant yields exactly 0.2 mol of carbon dioxide gas.

(e) Convert these product moles into mass using the molar mass of carbon dioxide (44 g/mol): Mass $= 0.2\text{ mol} \times 44\text{ g/mol} = 8.8$ g.

**Final Answer:** The total mass of carbon dioxide gas generated is 8.8 g.

**Answer: (B)**

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## Q46.

### Solution

**Concept:**

Alkyl halides undergo nucleophilic substitution ($S_N2$) reactions when treated with strong nucleophilic salts, replacing the halogen atom with a new functional group. Potassium cyanide (KCN) is an ionic compound that releases ambient cyanide ions ($^-C \equiv N$) in solution. Because both the carbon and nitrogen atoms carry lone pairs, the cyanide ion can act as an ambident nucleophile, attacking through either center depending on the reaction conditions.

**Solution:**

(a) In an aqueous-alcoholic solution, potassium cyanide dissociates into free potassium cations and nucleophilic cyanide anions.

(b) The cyanide anion acts as an ambident nucleophile, meaning it can form a covalent bond using either its carbon atom or its nitrogen atom.

(c) Because a carbon-carbon single bond is thermodynamically more stable than a carbon-nitrogen single bond, attack through the carbon atom is favored.

(d) The nucleophilic carbon center attacks ethyl chloride, displacing the chloride leaving group in a single-step substitution reaction.

(e) This substitution extends the carbon chain by one atom, transforming ethyl chloride ($CH_3CH_2Cl$) into propanenitrile ($CH_3CH_2CN$).

**Final Answer:** The major organic product is Propanenitrile.

**Answer: (B)**

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# Q47.

## Solution

**Concept:**

The agricultural efficiency of a nitrogenous fertilizer depends heavily on its total nitrogen content by weight. To find this percentage, divide the combined atomic mass of all nitrogen atoms in a single formula unit by the total molecular weight of the compound. Higher percentages make a fertilizer more valuable for widespread agricultural use.

**Solution:**

(a) Calculate the weight percentage for urea $[CO(NH_2)_2]$, which has a molar mass of 60 g/mol and contains two nitrogen atoms: $\frac{28}{60} \times 100\% = 46.6\%$.

(b) Calculate the value for ammonium nitrate $(NH_4NO_3)$, which has a molar mass of 80 g/mol and contains two nitrogen atoms: $\frac{28}{80} \times 100\% = 35\%$.

(c) Calculate the value for ammonium sulfate $[(NH_4)_2SO_4]$, which has a molar mass of 132 g/mol and contains two nitrogen atoms: $\frac{28}{132} \times 100\% = 21.2\%$.

(d) Calculate the value for calcium nitrate $[Ca(NO_3)_2]$, which has a molar mass of 164 g/mol and contains two nitrogen atoms: $\frac{28}{164} \times 100\% = 17.1\%$.

(e) Comparing these values shows that urea contains the highest percentage of nitrogen by weight among the standard options.

**Final Answer:** The compound is Urea $(NH_2CONH_2)$.

**Answer: (C)**

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## Q48.

### Solution

**Concept:**
The quantum numbers of an electron define its energy level, orbital shape, spatial orientation, and intrinsic spin orientation within an atom. According to the Aufbau principle, electrons fill atomic orbitals in order of increasing energy levels. Determining the quantum numbers of a valence electron requires writing out the ground-state electronic configuration of the atom.

**Solution:**

(a) Sodium contains eleven protons, giving it a ground-state electronic configuration of $1s^2 2s^2 2p^6 3s^1$.

(b) This configuration shows that the single outermost valence electron resides in the $3s$ atomic orbital.

(c) The principal quantum number ($n$) corresponds to the main energy level of this valence shell, which gives a value of $n = 3$.

(d) The azimuthal quantum number ($l$) defines the subshell orbital geometry; for an s-orbital, this value is always $l = 0$.

(e) The magnetic quantum number ($m$) determines spatial orientation and is restricted by the value of $l$; since $l = 0$, $m$ must also equal 0.

(f) The spin quantum number ($s$) represents the orientation of the electron's intrinsic magnetic field, which can be assigned as $+\frac{1}{2}$.

**Final Answer:** The set is $n = 3, l = 0, m = 0, s = +\frac{1}{2}$.

**Answer: (B)**

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## Q49.

### Solution

**Concept:**
The van 't Hoff factor ($i$) measures how solute dissociation or association affects the colligative properties of a solution. For non-interacting covalent solutes that do not break apart in water, this factor remains equal to one. For ionic electrolytes that dissociate completely in dilute solutions, the van 't Hoff factor equals the total number of ions produced per formula unit.
**Solution:**

(a) Potassium Ferricyanide, $[K_3Fe(CN)_6]$, is an ionic coordination compound that dissolves in water to release its constituent ions.

(b) In a dilute aqueous solution, it dissociates according to the equation: $K_3[Fe(CN)_6](aq) \rightarrow 3K^+(aq) + [Fe(CN)_6]^{3-}(aq)$.

(c) This dissociation produces three potassium cations and one complex anion, yielding a total of four ions per formula unit ($i = 4$).

(d) Urea ($NH_2CONH_2$) is an organic molecule held together by covalent bonds that does not dissociate into ions when dissolved in water.

(e) Because it remains as intact molecules in solution, its van 't Hoff factor is equal to one ($i = 1$).

**Final Answer:** The values are 4 and 1.

**Answer: (A)**

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# Q50.

## Solution

**Concept:**
The inert pair effect describes the tendency of the outermost s-orbital electrons in heavy p-block elements to remain unshared in chemical reactions. This resistance happens because the intervening d- and f-orbitals shield nuclear charge poorly, pulling the outer s-electrons closer to the nucleus. As a result, heavy post-transition elements often form stable compounds in an oxidation state two units lower than their maximum group valence.

**Solution:**

(a) Thallium (Tl) is the heaviest member of Group 13, located directly below aluminum and gallium in the periodic table.

(b) The valence shell electronic configuration of Group 13 elements is represented generally by the expression $ns^2np^1$.

(c) Lighter elements in this group, like boron and aluminum, readily share all three valence electrons to exhibit a stable +3 oxidation state.

(d) In thallium, poor shielding from the filled $4f$ and $5d$ subshells allows the nucleus to hold onto the $6s^2$ electron pair more tightly.

(e) This stabilization prevents the $6s^2$ electrons from participating in bonding, making the lower +1 oxidation state exceptionally stable for thallium.

**Final Answer:** The element is Thallium (Tl).

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

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# Answer Key

| Q | Ans | Q | Ans | Q | Ans | Q | Ans | Q | Ans |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | A | 3 | C | 4 | B | 5 | B |
| 6 | B | 7 | C | 8 | C | 9 | B | 10 | C |
| 11 | C | 12 | B | 13 | A | 14 | A | 15 | B |
| 16 | A | 17 | C | 18 | B | 19 | A | 20 | C |
| 21 | B | 22 | C | 23 | C | 24 | A | 25 | B |
| 26 | C | 27 | B | 28 | B | 29 | B | 30 | B |
| 31 | A | 32 | B | 33 | B | 34 | B | 35 | C |
| 36 | B | 37 | C | 38 | A | 39 | C | 40 | B |
| 41 | B | 42 | A | 43 | C | 44 | B | 45 | B |
| 46 | B | 47 | C | 48 | B | 49 | A | 50 | B |