# Rajasthan JET Chemistry Sample Paper-2

**Duration: 40 Minutes** **Maximum Marks: 160**

## Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

**Q1.** What is the molarity of a solution prepared by dissolving 4.0 g of NaOH in enough water to form 250 mL of solution?

(A) 0.1 M

(B) 0.2 M

(C) 0.4 M

(D) 0.5 M

**Q2.** Which of the following sets of quantum numbers represents the outermost electron of an ungrounded Potassium ($Z = 19$) atom?

(A) $n = 4, l = 0, m_l = 0, m_s = +\frac{1}{2}$

(B) $n = 3, l = 2, m_l = 0, m_s = -\frac{1}{2}$

(C) $n = 4, l = 1, m_l = 0, m_s = +\frac{1}{2}$

(D) $n = 3, l = 1, m_l = 1, m_s = +\frac{1}{2}$

**Q3.** The correct order of increasing first ionization enthalpy for the elements B, C, N, and O is:

(A) B < C < O < N

(B) B < C < N < O

(C) C < B < O < N

(D) O < N < F < B

**Q4.** Which molecule has a see-saw molecular geometry according to VSEPR theory?

(A) $SF_4$

(B) $XeF_4$

(C) $ClF_3$

(D) $BF_3$

**Q5.** In the following redox reaction, identify the oxidizing agent:

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

(A) $C_2O_4^{2-}$

(B) $H^+$

(C) $MnO_4^-$

(D) $Mn^{2+}$

**Q6.** The total number of nodes (radial + angular) present in a $3p$ orbital is:

(A) 1

(B) 2

(C) 3

(D) 0

**Q7.** Which of the following compounds exhibits both ionic and covalent bonding?

(A) $CH_4$

(B) NaCl

(C) $KNO_3$

(D) $H_2O$

**Q8.** An organic compound contains 40% Carbon, 6.67% Hydrogen, and 53.33% Oxygen by mass. What is its empirical formula?

(A) CHO

(B) $CH_2O$

(C) $CHO_2$

(D) $C_2H_4O$

**Q9.** What is the hybridization of the central atom in $I_3^-$ ion?

(A) $sp^3$

(B) $sp^3d$

(C) $sp^3d^2$

(D) $sp^2$

**Q10.** Which of the following pairs is isoelectronic and isostructural?

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

(B) $ClO_3^-$ and $CO_3^{2-}$

(C) $SO_3$ and $SO_3^{2-}$

(D) $ClF_3$ and $BF_3$

**Q11.** What is the oxidation number of Chromium in $K_2Cr_2O_7$?

(A) +3

(B) +5

(C) +6

(D) +7

**Q12.** The formal charge on the central oxygen atom in an ozone ($O_3$) molecule is:

(A) 0

(B) +1

(C) -1

(D) +2

**Q13.** For a first-order reaction, if the rate constant is $k = 4.606 \times 10^{-3}$ $s^{-1}$, how much time will it take for the concentration of the reactant to decrease from 1.0 M to 0.1 M?

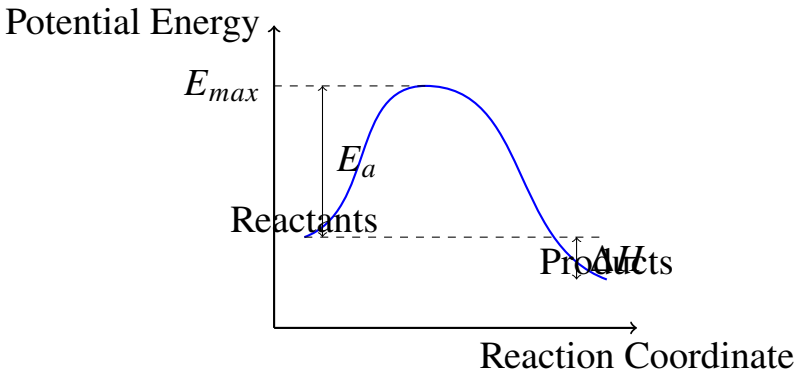
(A) 100 s

(B) 230 s

(C) 500 s

(D) 1000 s

**Q14.** Consider the reaction energy profile diagram below:




Based on this diagram, the reaction is:

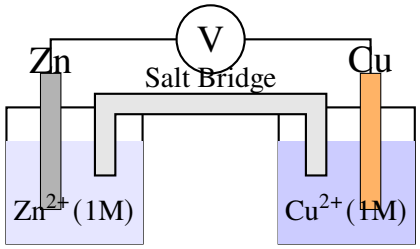
(A) Endothermic with $\Delta H > 0$

(B) Exothermic with $\Delta H < 0$

(C) Endothermic with $\Delta H < 0$

(D) Exothermic with $\Delta H > 0$

**Q15.** What is the cell potential ($E_{cell}$) for the electrochemical cell schematic depicted below at 298 K?



Given: $E^\circ_{Zn^{2+}/Zn} = -0.76$ V and $E^\circ_{Cu^{2+}/Cu} = +0.34$ V.

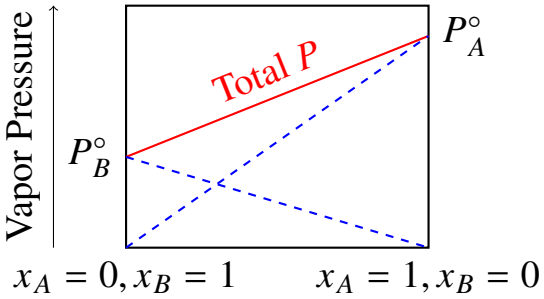
(A) +0.42 V

(B) −1.10 V

(C) +1.10 V

(D) −0.42 V

**Q16.** The vapor pressure diagram of an ideal binary liquid solution of components A and B is shown below.




Which law mathematically models the linear relationships shown in this system?

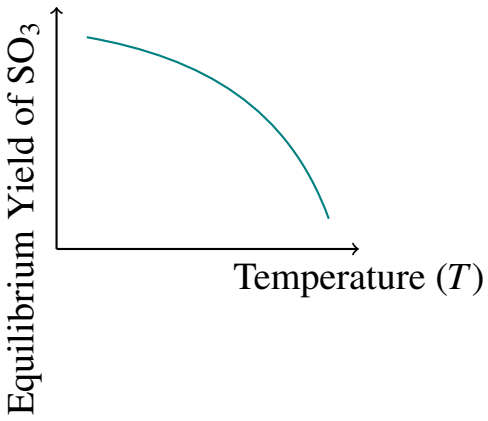
(A) Henry's Law

(B) Raoult's Law

(C) Dalton's Law

(D) Van't Hoff's Law

**Q17.** An equilibrium curve plot for the reversible gas phase reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ is shown below.



Based on the trend that yield decreases as temperature increases, the forward synthesis reaction is:

(A) Endothermic

(B) Exothermic

(C) Isothermal

(D) Irreversible

**Q18.** What is the pH of a buffer solution prepared by mixing equal volumes of 0.2 M acetic acid ($CH_3COOH$) and 0.2 M sodium acetate ($CH_3COONa$)? (Given $K_a$ of acetic acid = $1.8 \times 10^{-5}$ and $\log 1.8 = 0.26$)

(A) 4.74

(B) 5.26

(C) 3.74

(D) 7.00

**Q19.** If the solubility product ($K_{sp}$) of $BaSO_4$ is $1.1 \times 10^{-10}$, its solubility ($s$) in pure water is approximately:

(A) $1.05 \times 10^{-5}$ mol $L^{-1}$

(B) $1.1 \times 10^{-5}$ mol $L^{-1}$

(C) $2.2 \times 10^{-5}$ mol $L^{-1}$

(D) $1.21 \times 10^{-20}$ mol $L^{-1}$

**Q20.** For a spontaneous chemical process at all temperatures, the values of thermodynamic parameters must satisfy:

(A) $\Delta H > 0, \Delta S > 0$

(B) $\Delta H < 0, \Delta S < 0$

(C) $\Delta H < 0, \Delta S > 0$

(D) $\Delta H > 0, \Delta S < 0$

**Q21.** How many Faradays of electricity are required to completely reduce 1 mole of $Al^{3+}$ ions to metallic aluminum?

(A) 1 F

(B) 2 F

(C) 3 F

(D) 4 F

**Q22.** If the rate of a chemical reaction doubles for every 10°C rise in temperature, by what factor does the rate increase when the temperature goes from 30°C to 70°C?

(A) 4

(B) 8

(C) 16

(D) 32

**Q23.** Which of the following colligative properties is most suitable for determining the molecular mass of large biomolecules like proteins?

(A) Relative lowering of vapor pressure

(B) Elevation of boiling point

(C) Depression of freezing point

(D) Osmotic pressure

**Q24.** The unit of rate constant ($k$) for a zero-order chemical reaction is:

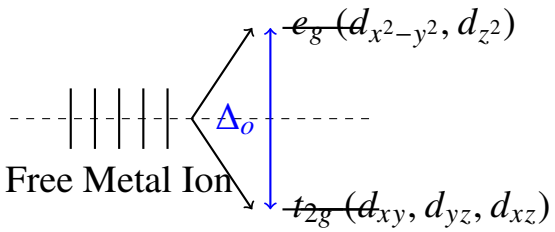
(A) $s^{-1}$

(B) mol $L^{-1}$ $s^{-1}$

(C) L $mol^{-1}$ $s^{-1}$

(D) $L^2$ $mol^{-2}$ $s^{-1}$

**Q25.** The crystal field d-orbital splitting diagram for an octahedral coordination complex environment is presented below.




Which of the following configurations represents a low-spin $d^6$ ion according to this energy split?

(A) $t_{2g}^4 e_g^2$

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

(C) $t_{2g}^5 e_g^1$

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

**Q26.** What is the correct IUPAC name of the complex $[Co(NH_3)_5Cl]Cl_2$?

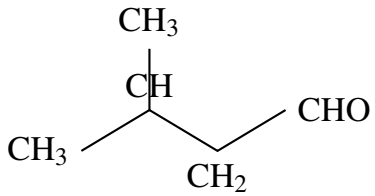
(A) Pentamminechlorocobalt(III) chloride

(B) Chloropentamminecobalt(II) chloride

(C) Pentamminechlorocobalt(II) chloride

(D) Cobaltpentamminechloro chloride

**Q27.** The IUPAC name of the organic molecule structured below is:




(A) 2-Methylbutanal

(B) 3-Methylbutanal

(C) 3-Methylbutan-1-ol

(D) Isopentanal

**Q28.** Which of the following organic reaction intermediates possesses a planar, $sp^2$-hybridized carbon atom?

(A) Carbanion

(B) Carbocation

(C) Carbon free radical

(D) Both Carbocation and Free radical

**Q29.** When Calcium carbide ($CaC_2$) undergoes complete hydrolysis, the hydrocarbon gas evolved is:

(A) Methane

(B) Ethane

(C) Ethene

(D) Ethyne

**Q30.** Which structural component acts as the dominant nucleophile in the addition reactions of aldehydes and ketones?

(A) Hydroxyl group

(B) Carboxylate group

(C) Carbonyl carbon atom

(D) An incoming electron-rich species targeting the carbonyl carbon

**Q31.** The primary reason why aromatic hydrocarbons undergo electrophilic substitution reactions rather than addition reactions is:

(A) High instability of ring structures

(B) Maintenance of ring resonance stabilization energy

(C) Absence of double bonds

(D) Presence of highly reactive single sigma bonds

**Q32.** Identify the major product obtained when propene reacts with HBr in the presence of organic peroxides ($R_2O_2$).

(A) 2-Bromopropane

(B) 1-Bromopropane

(C) 1,2-Dibromopropane

(D) 1-Bromopropan-2-ol

**Q33.** Which of the following organic compounds is most acidic in nature?

(A) Ethanol

(B) Phenol

(C) Water

(D) p-Nitrophenol

**Q34.** The primary structural isomerism exhibited by the pair $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$ is:

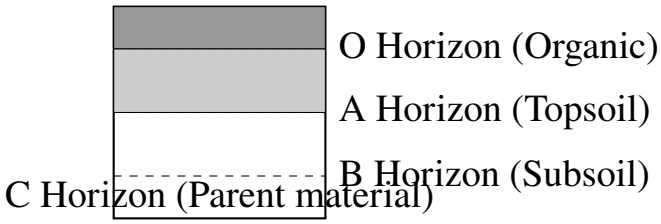
(A) Linkage isomerism

(B) Ionization isomerism

(C) Coordination isomerism

(D) Solvate isomerism

**Q35.** A schematic representation of soil profiles and relative nutrient availability across typical master horizons is shown below.




Which soil horizon typically contains the maximum concentration of humus and microbial activity?

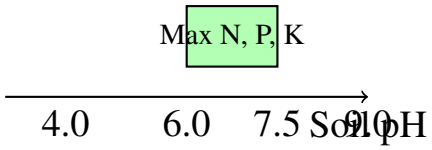
(A) O Horizon

(B) A Horizon

(C) B Horizon

(D) C Horizon

**Q36.** The chart below displays the availability of essential plant macronutrients as a function of soil pH.




What is the optimal pH range for the maximum availability of major plant nutrients (N, P, K) in agricultural soils?

(A) 4.0 – 5.0

(B) 6.0 – 7.5

(C) 8.0 – 9.0

(D) 5.0 – 5.5

**Q37.** Which type of soil colloid exhibits the highest Cation Exchange Capacity (CEC)?

(A) Kaolinite clay

(B) Illite clay

(C) Montmorillonite clay

(D) Organic humus

**Q38.** Which of the following chemical amendments is added to reclaim sodic (alkaline) soils by replacing sodium ions with calcium ions?

(A) Calcium carbonate (Lime)

(B) Calcium sulfate dihydrate (Gypsum)

(C) Sodium chloride

(D) Ammonium sulfate

**Q39.** The fundamental building units forming the crystalline sheets of Kaolinite silicate clay minerals are mixed in a ratio of:

(A) 1:1 (one tetrahedral sheet to one octahedral sheet)

(B) 2:1 (two tetrahedral sheets to one octahedral sheet)

(C) 2:1:1 (chlorite structured layers)

(D) 3:1 ratio arrangements

**Q40.** Which form of nitrogenous fertilizer is highly prone to loss via volatilization as ammonia gas when applied to alkaline soils?

(A) Sodium Nitrate

(B) Urea

(C) Calcium Nitrate

(D) Potassium Nitrate

## Detailed Solutions

# Q1.

## Solution

**Concept:**

Molarity measures the concentration of a solute in a solution and is defined as the number of moles of solute dissolved per liter of solution. The calculation requires converting the solute mass into moles using its molar mass, and converting the solution volume from milliliters to liters.

**Solution:**

(a) Find the molar mass of Sodium Hydroxide (NaOH). The atomic masses are approximately Na = 23 g/mol, O = 16 g/mol, and H = 1 g/mol. Adding these gives $23+16+1 = 40$ g/mol.

(b) Calculate the moles of NaOH present by dividing the given mass by its molar mass: 4.0 g/40 g/mol = 0.1 mole.

(c) Convert the volume of the solution from milliliters to liters by dividing by 1000: 250 mL/1000 = 0.25 L.

(d) Use the molarity formula: Molarity = moles of solute/liters of solution.

(e) Substitute the values: Molarity = 0.1 mole/0.25 L = 0.4 M.

**Final Answer:** 0.4 M

**Answer: (C)**

Go Back to Question 1

## Q2.

### Solution

**Concept:**

Quantum numbers completely describe the energy, orbital shape, orientation, and intrinsic spin of an electron in an atom. For an ungrounded, neutral atom in its ground state, electrons fill atomic orbitals in order of increasing energy according to the Aufbau principle.

**Solution:**

(a) Determine the atomic number of Potassium, which is $Z = 19$. This means a neutral Potassium atom contains exactly 19 electrons.

(b) Write the complete ground-state electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$.

(c) Identify the outermost, highest-energy valence electron, which resides in the $4s$ subshell.

(d) Assign the specific quantum numbers for this $4s^1$ electron. The principal quantum number $n$ is 4 because it occupies the fourth energy shell.

(e) The azimuthal quantum number $l$ is 0 because the electron is in an $s$ orbital. When $l = 0$, the magnetic quantum number $m_l$ must equal 0. The spin quantum number $m_s$ can be either $+\frac{1}{2}$ or $-\frac{1}{2}$, matching option A.

**Final Answer:** n=4, l=0, $m_l = 0, m_s = +\frac{1}{2}$

**Answer: (A)**

Go Back to Question 2

## Q3.

### Solution

**Concept:**

First ionization enthalpy is the energy required to remove the most loosely bound electron from an isolated, gaseous atom in its ground state. While ionization energy generally increases across a period due to increasing nuclear charge, half-filled or fully filled subshells create notable exceptions.

**Solution:**

(a) Look at the positions of the elements Boron ($Z = 5$), Carbon ($Z = 6$), Nitrogen ($Z = 7$), and Oxygen ($Z = 8$) in the second period of the periodic table.

(b) The general periodic trend states that first ionization enthalpy increases from left to right across a period because the atomic radius decreases and the effective nuclear charge increases.

(c) Based purely on the general periodic trend, the expected order would be B < C < N < O.

(d) Analyze the configurations: Nitrogen has a stable, exactly half-filled $2p$ subshell ($2s^2 2p^3$), whereas Oxygen has a $2s^2 2p^4$ configuration.

(e) Removing an electron from Nitrogen breaks a highly stable half-filled state, making it require more energy than removing a paired electron from Oxygen. Thus, Nitrogen has a higher first ionization energy than Oxygen, yielding the order B < C < O < N.

**Final Answer:** B < C < O < N

**Answer: (A)**

Go Back to Question 3

## Q4.

### Solution

**Concept:**

Valence Shell Electron Pair Repulsion (VSEPR) theory predicts the three-dimensional geometry of molecules based on minimizing the electrostatic repulsion between electron pairs surrounding a central atom. The steric number determines the base arrangement, which is then modified by any lone pairs present.

**Solution:**

(a) Examine Sulfur Tetrafluoride ($SF_4$). The central Sulfur atom belongs to group 16 and possesses 6 valence electrons.

(b) Sulfur forms four single covalent bonds with four Fluorine atoms, using 4 of its valence electrons, leaving 2 unbonded electrons.

(c) These 2 remaining valence electrons form exactly 1 lone pair on the Sulfur atom.

(d) Calculate the total steric number of the central atom: Steric Number = 4 bonding pairs + 1 lone pair = 5. A steric number of 5 corresponds to a trigonal bipyramidal electronic geometry.

(e) To minimize strong lone pair-bonding pair repulsions, the lone pair occupies an equatorial position. This spatial layout forces the remaining axial and equatorial bonds into a distorted see-saw molecular geometry.

**Final Answer:** $SF_4$

**Answer: (A)**

Go Back to Question 4

## Q5.

### Solution

**Concept:**

In a redox reaction, the oxidizing agent is the chemical species that gains electrons, undergoes a decrease in its oxidation state, and becomes reduced. By removing electrons from another substance, it facilitates the oxidation of that substance.

**Solution:**

(a) Assign oxidation numbers to all elements involved on both sides of the chemical equation. In the Permanganate ion ($MnO_4^-$), Oxygen has an oxidation state of -2.

(b) Set up the algebraic equation for Manganese: $x + 4(-2) = -1$, which solves to $x = +7$. Thus, Manganese begins with an oxidation state of +7.

(c) In the Oxalate reactant ion ($C_2O_4^{2-}$), Carbon possesses an oxidation state of +3.

(d) Examine the products on the right side of the equation. Manganese is converted into a monoatomic $Mn^{2+}$ ion, which carries an oxidation state of +2.

(e) Because the oxidation state of Manganese drops from +7 to +2, it gains electrons and undergoes reduction. Consequently, the Permanganate ion ($MnO_4^-$) is the oxidizing agent.

**Final Answer:** $MnO_4^-$

**Answer: (C)**

Go Back to Question 5

## Q6.

### Solution

**Concept:**

Nodes are regions in space around an atomic nucleus where the probability density of finding an electron is zero. The total nodes in any orbital are split into two types: spherical radial nodes and planar angular nodes, determined by quantum numbers.

**Solution:**

(a) Identify the principal quantum number $n$ and the azimuthal quantum number $l$ for the given $3p$ orbital. Here, $n = 3$.

(b) For any $p$ subshell orbital, the azimuthal quantum number $l$ is defined as exactly 1.

(c) Calculate the number of angular nodes. The number of angular nodes is always directly equal to the azimuthal quantum number $l$, which means this orbital has 1 angular node.

(d) Calculate the number of radial nodes using the formula: Radial Nodes $= n - l - 1$.

(e) Substitute the values into the formula: Radial Nodes $= 3 - 1 - 1 = 1$.

(f) Sum the radial and angular nodes together to find the total nodes: Total Nodes = Radial Nodes + Angular Nodes $= 1 + 1 = 2$.

**Final Answer:** 2

**Answer: (B)**

Go Back to Question 6

## Q7.

### Solution

**Concept:**

Chemical compounds can contain multiple types of chemical bonds depending on their constituent elements. Ionic bonds form via electron transfer between metals and nonmetals, while covalent bonds form via electron sharing between nonmetal atoms within a polyatomic group.

**Solution:**

(a) Analyze Methane ($CH_4$) and Water ($H_2O$). Both are composed entirely of nonmetal atoms sharing valence electrons, meaning they contain purely covalent bonds.

(b) Analyze Sodium Chloride (NaCl). It consists of a metal cation ($Na^+$) and a nonmetal anion ($Cl^-$) held together entirely by electrostatic attractions, making it purely ionic.

(c) Analyze Potassium Nitrate ($KNO_3$). It is an ionic compound composed of Potassium metal ions ($K^+$) and polyatomic Nitrate anions ($NO_3^-$).

(d) The complete electrostatic attraction operating between the $K^+$ cation and the $NO_3^-$ anion constitutes an ionic bond.

(e) Within the polyatomic Nitrate anion ($NO_3^-$) itself, the central Nitrogen atom shares valence electrons with three Oxygen atoms, forming strong covalent bonds. Therefore, $KNO_3$ possesses both bond types.

**Final Answer:** $KNO_3$

**Answer: (C)**

Go Back to Question 7

## Q8.

### Solution

**Concept:**

An empirical formula expresses the simplest whole-number ratio of the atoms of each element present in a chemical compound. It is calculated by converting mass percentages into relative molar amounts and normalizing them to integers.

**Solution:**

(a) Assume a base sample mass of 100 grams. This converts the mass percentages directly into mass values: 40.0 g of Carbon, 6.67 g of Hydrogen, and 53.33 g of Oxygen.

(b) Divide each element mass value by its respective atomic molar mass to determine the relative number of moles: Moles of C = $40.0/12 = 3.33$, Moles of H = $6.67/1 = 6.67$, and Moles of O = $53.33/16 = 3.33$.

(c) Identify the smallest calculated molar value from this set, which is 3.33.

(d) Divide all the calculated molar quantities by this smallest value to obtain the raw atomic ratios: Ratio for C = $3.33/3.33 = 1$, Ratio for H = $6.67/3.33 = 2$, and Ratio for O = $3.33/3.33 = 1$.

(e) Combine these whole numbers to write out the resulting empirical formula, which is $CH_2O$.

**Final Answer:** $CH_2O$

**Answer: (B)**

Go Back to Question 8

## Q9.

### Solution

**Concept:**

Orbital hybridization explains molecular geometries by mixing atomic orbitals to form identical hybrid orbitals. The hybridization state of a central atom can be deduced from its steric number, which sums the attached single atoms and lone pairs.

**Solution:**

(a) Identify the central atom in the triiodide anion ($I_3^-$), which is the central Iodine atom bonded to two outer Iodine atoms.

(b) Iodine belongs to group 17 and naturally possesses 7 valence electrons. The negative charge of the anion adds 1 extra electron, bringing the total valence pool to 8 electrons.

(c) The central Iodine atom forms two single sigma covalent bonds with the two terminal Iodine atoms, utilizing 2 of its valence electrons.

(d) Subtract the bonding electrons from the total valence pool: $8 - 2 = 6$ remaining unbonded electrons.

(e) Group these 6 remaining valence electrons into pairs: $6/2 = 3$ lone pairs on the central Iodine atom.

(f) Sum the total steric number: Steric Number = 2 sigma bonds + 3 lone pairs = 5. A steric number of 5 requires mixing five atomic orbitals ($ones, threep, oned$), resulting in $sp^3d$ hybridization.

**Final Answer:** $sp^3d$

**Answer: (B)**

Go Back to Question 9

## Q10.

### Solution

**Concept:**

Isoelectronic species share the exact same number of total valence electrons, while isostructural species share the same three-dimensional molecular geometry and shape. If two species have identical central atoms, outer atoms, and valence counts, they share both features.

**Solution:**

(a) Count the total valence electrons for the Carbonate anion ($CO_3^{2-}$): Carbon contributes 4, three Oxygens contribute $3 \times 6 = 18$, and the -2 charge adds 2, totaling $4 + 18 + 2 = 24$ valence electrons.

(b) Count the total valence electrons for the Nitrate anion ($NO_3^-$): Nitrogen contributes 5, three Oxygens contribute $3 \times 6 = 18$, and the -1 charge adds 1, totaling $5 + 18 + 1 = 24$ valence electrons.

(c) Because both anions contain exactly 24 valence electrons, they form an isoelectronic pair.

(d) Determine the geometric structure of both ions using VSEPR theory. The central Carbon and Nitrogen atoms are both surrounded by 3 bonding groups with zero lone pairs.

(e) This corresponds to a steric number of 3, meaning both central atoms exhibit $sp^2$ hybridization and assume an identical trigonal planar geometry, confirming they are isostructural.

**Final Answer:** $CO_3^{2-} and NO_3^-$

**Answer: (A)**

Go Back to Question 10

## Q11.

### Solution

**Concept:**

The oxidation number is a theoretical charge assigned to an atom within a chemical entity according to a set of conventional rules. These rules dictate that the net sum of all individual oxidation numbers must equal the overall net charge of that specific polyatomic molecule or ion.

**Solution:**

(a) Examine the neutral compound Potassium Dichromate ($K_2Cr_2O_7$). Because the entire molecular structure is uncharged, the sum of all individual oxidation numbers equals 0.

(b) Apply standard conventional values: Potassium as an alkali metal in Group 1 always possesses an oxidation state of +1, while Oxygen typically maintains an oxidation state of -2.

(c) Let the unknown oxidation state of a single Chromium atom be represented by the variable $x$.

(d) Set up a balanced linear algebraic equation accounting for all constituent atoms: $2(+1) + 2(x) + 7(-2) = 0$.

(e) Simplify the equation step by step: $2 + 2x - 14 = 0$, which reduces further to $2x - 12 = 0$.

(f) Isolate the variable to solve for the target value: $2x = 12$, which yields $x = +6$.

**Final Answer:** +6

**Answer: (C)**

Go Back to Question 11

## Q12.

### Solution

**Concept:**

Formal charge represents the hypothetical electrical charge assigned to a bonded atom, assuming that all chemical bonds are shared completely equally. It serves as an essential tool in Lewis structure evaluation to identify the most stable arrangement of valence electrons.

**Solution:**

(a) Draw the valid resonance Lewis structure for the Ozone ($O_3$) molecule, which contains a central Oxygen atom bound to two terminal Oxygen atoms.

(b) The central Oxygen atom forms a single covalent bond with one terminal Oxygen atom and a double covalent bond with the other terminal Oxygen atom.

(c) Count the valence configuration of the central Oxygen atom: it is surrounded by a total of 3 bonding pairs and exactly 1 unshared lone pair.

(d) Recall the standard formal charge formula: $\text{Formal Charge} = \text{Valence Electrons} - \text{Non-bonding Electrons} - \frac{1}{2}(\text{Bonding Electrons})$.

(e) Substitute the values for isolated Oxygen (6 valence electrons): $\text{Formal Charge} = 6 - 2 - \frac{1}{2}(6)$.

(f) Compute the final arithmetic values: $6 - 2 - 3 = +1$.

**Final Answer:** $+1$

**Answer: (B)**

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## Q13.

### Solution

**Concept:**

First-order chemical reactions possess a reaction rate that depends directly on the instantaneous concentration of a single reactant. The integrated rate equation mathematically links the elapsed time, the constant reaction coefficient, and the initial and final quantities.

**Solution:**

(a) State the standard integrated rate law equation for a first-order reaction: $k = \frac{2.303}{t} \log\left(\frac{[A]_0}{[A]_t}\right)$.

(b) Rearrange the formula algebraically to isolate the time variable: $t = \frac{2.303}{k} \log\left(\frac{[A]_0}{[A]_t}\right)$.

(c) Identify the values given in the problem: $k = 4.606 \times 10^{-3}\ s^{-1}$, initial concentration $[A]_0 = 1.0$ M, and final remaining concentration $[A]_t = 0.1$ M.

(d) Substitute these values directly into the expression: $t = \frac{2.303}{4.606 \times 10^{-3}} \log\left(\frac{1.0}{0.1}\right)$.

(e) Simplify the fraction and the logarithm component: $\frac{2.303}{4.606 \times 10^{-3}} = \frac{1}{2 \times 10^{-3}} = 500$, and $\log(10) = 1$.

(f) Complete the final multiplication step to find the total time: $500 \times 1 = 500$ s.

**Final Answer:** 500 s

**Answer: (C)**

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## Q14.

### Solution

**Concept:**

Reaction energy profile diagrams trace the potential energy changes that occur as reactants transition through high-energy activated complexes to form products. The relative enthalpy change ($\Delta H$) of the reaction equals the energy difference between products and reactants.

**Solution:**

(a) Examine the provided potential energy profile diagram along the vertical axis. Identify the horizontal line corresponding to the baseline energy of the starting reactants.

(b) Locate the horizontal line at the end of the curve that marks the final potential energy level of the generated products.

(c) Notice that the final energy level of the products lies lower than the initial energy level of the starting reactants.

(d) Recall the thermodynamic definition of enthalpy change for a chemical process: $\Delta H = E_{\text{products}} - E_{\text{reactants}}$.

(e) Because the product energy value is lower than the reactant energy value, subtracting them yields a negative result: $\Delta H < 0$.

(f) A process that releases energy, characterized by a negative enthalpy change, is defined as an exothermic reaction.

**Final Answer:** Exothermic with $\Delta H < 0$

**Answer: (B)**

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## Q15.

### Solution

**Concept:**

The standard electromotive force of a galvanic cell represents the maximum potential difference between two half-cells under standard state conditions. It is calculated by taking the standard reduction potential of the cathode and subtracting that of the anode.

**Solution:**

(a) Analyze the provided cell diagram to identify the anode and cathode components. Zinc undergoes oxidation at the anode, while Copper undergoes reduction at the cathode.

(b) Retrieve the standard reduction potentials provided: $E^\circ_{Zn^{2+}/Zn} = -0.76$ V and $E^\circ_{Cu^{2+}/Cu} = +0.34$ V.

(c) State the fundamental electrochemical equation for standard cell potential: $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$.

(d) Substitute the reduction potentials directly into this equation: $E^\circ_{cell} = (+0.34\text{ V}) - (-0.76\text{ Vspaces})$.

(e) Resolve the double negative mathematically to perform the addition: $E^\circ_{cell} = 0.34 + 0.76 = +1.10$ V.

(f) Because the concentrations are both standard 1 M, the cell potential equals the standard cell potential.

**Final Answer:** +1.10 V

**Answer: (C)**

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## Q16.

### Solution

**Concept:**

Liquid solutions that adhere strictly to predictable thermodynamic mixtures across all concentrations are categorized as ideal solutions. The linear relationship of individual partial vapor pressures to their liquid mole fractions is described by Raoult's Law.

**Solution:**

(a) Observe the provided vapor pressure graph. The horizontal axis represents the changing mole fractions ($x_A, x_B$) of a binary liquid mixture.

(b) The vertical axis tracks the vapor pressure, showing linear dashed lines for the partial pressures and a solid red line for the total pressure.

(c) Recall that Raoult's Law states that the partial vapor pressure of any volatile component in a solution is directly proportional to its mole fraction.

(d) Express this rule mathematically for both components: $P_A = x_A P_A^\circ$ and $P_B = x_B P_B^\circ$.

(e) Note that Dalton's Law sums these partial pressures, but the underlying linear relationship shown for each component stems directly from Raoult's Law.

**Final Answer:** Raoult's Law

**Answer: (B)**

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## Q17.

### Solution

**Concept:**

Le Chatelier's principle states that if a chemical system at equilibrium experiences a change in temperature, pressure, or concentration, the equilibrium position shifts to counteract the imposed perturbation. Temperature shifts depend directly on reaction enthalpy.

**Solution:**

(a) Examine the provided equilibrium graph. The curve shows that as the temperature increases along the x-axis, the equilibrium yield of $SO_3$ drops.

(b) A lower equilibrium yield indicates that increasing temperature shifts the equilibrium position backward toward the reactants.

(c) According to Le Chatelier's principle, adding thermal energy shifts a system in the direction that absorbs heat (the endothermic direction).

(d) Because adding heat drives this reaction backward, the reverse reaction must be the endothermic pathway.

(e) Conclude that the forward reaction must release heat, which means the synthesis of $SO_3$ is an exothermic process.

**Final Answer:** Exothermic

**Answer: (B)**

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## Q18.

### Solution

**Concept:**

An acidic buffer solution consists of a weak acid and its conjugate base salt. The pH of such a system can be quantitatively calculated using the Henderson-Hasselbalch equation, which relates pH, $pK_a$, and the concentrations of the components.

**Solution:**

(a) State the Henderson-Hasselbalch equation for an acidic buffer solution: $\text{pH} = pK_a + \log\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right)$.

(b) Calculate the value of $pK_a$ from the given acid dissociation constant: $pK_a = -\log(K_a) = -\log(1.8 \times 10^{-5})$.

(c) Expand the logarithm: $pK_a = 5 - \log(1.8) = 5 - 0.26 = 4.74$.

(d) Determine the final concentrations of the buffer components. Equal volumes of 0.2 M acetic acid and 0.2 M sodium acetate are mixed.

(e) Because the mixing volumes are identical, both components are diluted equally, maintaining an exact 1:1 concentration ratio: $[\text{Salt}] = [\text{Acid}] = 0.1$ M.

(f) Substitute these equal values into the log term: $\log(0.1/0.1) = \log(1) = 0$. Thus, $\text{pH} = pK_a = 4.74$.

**Final Answer:** 4.74

**Answer: (A)**

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## Q19.

### Solution

**Concept:**

The solubility product constant ($K_{sp}$) is a type of equilibrium constant that applies to saturated solutions of sparingly soluble ionic salts. It represents the product of the dissolved ion concentrations, each raised to the power of their stoichiometric coefficients.

**Solution:**

(a) Write out the complete, balanced heterogenous equilibrium equation for the dissolution of Barium Sulfate: $BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$.

(b) Let the molar solubility of the dissolving salt in pure water be represented by the variable $s$ (expressed in units of mol $L^{-1}$).

(c) Express the equilibrium concentrations of the individual ions in terms of solubility: $[Ba^{2+}] = s$ and $[SO_4^{2-}] = s$.

(d) Write the mathematical expression for the solubility product: $K_{sp} = [Ba^{2+}][SO_4^{2-}] = (s)(s) = s^2$.

(e) Substitute the given numerical value of $K_{sp}$ into the equation: $1.1 \times 10^{-10} = s^2$.

(f) Take the square root of both sides to solve for the solubility: $s = \sqrt{1.1 \times 10^{-10}} \approx 1.05 \times 10^{-5}$ mol $L^{-1}$.

**Final Answer:** $1.05 \times 10^{-5}$ mol $L^{-1}$

**Answer: (A)**

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## Q20.

### Solution

**Concept:**

The criteria for thermodynamic spontaneity is governed by the Gibbs free energy change ($\Delta G$). The fundamental Gibbs-Helmholtz equation, $\Delta G = \Delta H - T\Delta S$, shows how enthalpy, entropy, and absolute temperature interact to determine if a process can occur naturally.

**Solution:**

(a) State the criteria for absolute spontaneity: a chemical reaction is thermodynamically spontaneous if and only if the change in Gibbs free energy is strictly negative ($\Delta G < 0$).

(b) Examine the terms of the fundamental equation: $\Delta G = \Delta H - T\Delta S$, where $T$ represents the absolute temperature measured on the Kelvin scale (always $T > 0$).

(c) For $\Delta G$ to remain negative regardless of how large or small the value of $T$ becomes, look at the signs of $\Delta H$ and $\Delta S$.

(d) If the enthalpy change is negative ($\Delta H < 0$), the first term favors spontaneity by releasing energy.

(e) If the entropy change is positive ($\Delta S > 0$), the term $-T\Delta S$ remains negative at all temperatures.

(f) Combining a negative $\Delta H$ with a positive $\Delta S$ guarantees that $\Delta G$ stays negative under all temperature conditions.

**Final Answer:** $\Delta H < 0, \Delta S > 0$

**Answer: (C)**

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## Q21.

### Solution

**Concept:**

Faraday's laws of electrolysis state that the mass of a substance altered at an electrode during an electrochemical reaction is directly proportional to the quantity of electric charge transferred. One Faraday represents the total electric charge carried by exactly one mole of electrons.

**Solution:**

(a) Write the balanced half-reaction representing the complete reduction of a trivalent aluminum ion to its elemental metallic form.

(b) The reduction half-reaction equation is given by: $Al^{3+}(aq) + 3e^- \rightarrow Al(s)$.

(c) Examine the stoichiometric coefficients established in this balanced half-reaction to determine the electron-to-ion ratio.

(d) The reaction shows that exactly 3 moles of valence electrons are required to completely reduce 1 mole of dissolved $Al^{3+}$ ions.

(e) Recall the fundamental conversion factor linking electron moles to electrical units: 1 mole of electrons equals 1 Faraday (1 F) of electricity.

(f) Multiply the stoichiometric electron quantity by this baseline unit value: 3 moles of electrons = 3 F.

**Final Answer:** 3 F

**Answer: (C)**

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## Q22.

### Solution

**Concept:**

The temperature coefficient of a chemical reaction measures the rate of change of the kinetic velocity constant when the system temperature rises by ten degrees. This exponential relationship describes how thermal energy increases the fraction of molecular collisions exceeding the threshold activation barrier.

**Solution:**

(a) Identify the base temperature change stated in the problem: the reaction velocity doubles for every 10°C elevation.

(b) Calculate the total absolute temperature change experienced by the system: $\Delta T = 70°C - 30°C = 40°C$.

(c) Determine how many complete ten-degree intervals are contained within this total calculated temperature difference: $n = 40/10 = 4$.

(d) Express the total reaction rate modification factor as an exponential function using the temperature coefficient: Factor $= 2^n$.

(e) Substitute the calculated number of intervals into the exponential expression: Factor $= 2^4$.

(f) Calculate the final arithmetic product: $2 \times 2 \times 2 \times 2 = 16$.

**Final Answer:** 16

**Answer: (C)**

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## Q23.

### Solution

**Concept:**

Colligative properties are solutions characteristics that depend strictly on the total ratio of solute particles present rather than the chemical identity of the solute. Macromolecules require specific measurement techniques because their large mass produces highly dilute molar solutions.

**Solution:**

(a) High-molecular-weight polymers like proteins exhibit low molar concentrations even when dissolved at significant mass-to-volume ratios.

(b) Standard methods like boiling point elevation or freezing point depression yield tiny, unmeasurable temperature shifts for these dilute systems.

(c) Vapor pressure measurements face similar practical limitations because the relative lowering effect is almost imperceptible.

(d) Osmotic pressure measurements generate a significant, easily read hydrostatic head at room temperature for the same low molarity solutions.

(e) The operational equation $\Pi = CRT$ demonstrates that osmotic pressure is highly sensitive and functions without risking thermal degradation of delicate biomolecules.

**Final Answer:** Osmotic pressure

**Answer: (D)**

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## Q24.

### Solution

**Concept:**

The kinetic rate law of a chemical process relates the overall velocity of a reaction to the concentrations of its remaining reactants. The dimensional units assigned to a rate constant vary predictably depending on the reaction order to maintain mathematical consistency.

**Solution:**

(a) State the general rate law expression for a zero-order chemical reaction pathway: Rate = $k[\mathrm{A}]^0$.

(b) Simplify the expression by evaluating the zero-exponent term: any concentration value raised to the power of zero equals 1, yielding Rate = $k$.

(c) This mathematical equality indicates that the dimensional units of the rate constant must match the units of the reaction rate. Reaction rate is defined as the change in solute concentration per unit time: Units = Concentration/Time.

(d) Express concentration in standard volumetric molarity units (mol $\mathrm{L}^{-1}$) and time in international standard seconds (s).

(e) Combine these terms to obtain the final dimensional units for the constant: mol $\mathrm{L}^{-1}$ $\mathrm{s}^{-1}$.

**Final Answer:** mol $\mathrm{L}^{-1}$ $\mathrm{s}^{-1}$

**Answer: (B)**

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## Q25.

### Solution

**Concept:**

Crystal Field Theory describes how the proximity of surrounding ligand lone pairs splits the energy degeneracy of metal d-orbitals. In a strong-field octahedral environment, the splitting energy exceeds the spin-pairing energy, forcing electrons to pair up in lower orbitals.

**Solution:**

(a) Observe the provided TikZ diagram illustrating the splitting of d-orbitals into a lower $t_{2g}$ triplet and an upper $e_g$ doublet.

(b) Identify the electron count of the metal center, which is a $d^6$ coordination ion containing 6 valence d-electrons.

(c) Analyze the low-spin condition: the crystal field splitting energy ($\Delta_o$) is greater than the electrostatic pairing energy.

(d) Because the energy penalty to cross the gap is high, electrons fill the lower energy level completely before placing any particles above.

(e) Distribute the 6 electrons into the lower $t_{2g}$ orbitals: each of the three orbitals receives 2 paired electrons, filling the subshell.

(f) This distribution leaves zero electrons in the upper higher-energy $e_g$ subshell, resulting in the electronic configuration $t_{2g}^6 e_g^0$.

**Final Answer:** $t_{2g}^6 e_g^0$

**Answer: (B)**

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## Q26.

### Solution

**Concept:**

The IUPAC nomenclature system for coordination compounds follows standardized rules for sequencing and naming ligands and metals. Anionic ligands are modified to end in "o", neutral ligands retain their names with exceptions, and the metal oxidation state is indicated with Roman numerals.

**Solution:**

(a) Identify the component parts of the coordination complex formula: $[Co(NH_3)_5Cl]Cl_2$. The complex cation is inside the brackets, followed by counter-anions.

(b) Name the ligands present within the coordination sphere in alphabetical order: five Ammine ($NH_3$) molecules and one Chloro ($Cl^-$) ion.

(c) Combine the ligand names using numerical prefixes: "pentammine" precedes "chloro", yielding the combined ligand string "pentamminechloro".

(d) Determine the oxidation state of the central Cobalt atom: $x + 5(0) + 1(-1) + 2(-1) = 0$, which solves to $x = +3$.

(e) Assemble the cation name by appending the metal name and its oxidation state in parentheses: "pentamminechlorocobalt(III)".

(f) Append the outer sphere counter-anion name as a separate word at the end to complete the full name: "chloride".

**Final Answer:** Pentamminechlorocobalt(III) chloride

**Answer: (A)**

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## Q27.

### Solution

**Concept:**

IUPAC systematic organic nomenclature names molecules based on their longest continuous carbon chain containing the principal functional group. Numbering begins from the end closest to the high-priority functional group to give its carbon the lowest possible locant.

**Solution:**

(a) Examine the provided TikZ chemical structure to identify the principal functional group. The terminal group is an aldehyde (-CHO).

(b) Find the longest continuous carbon chain starting directly from the aldehyde carbon: the main backbone contains 4 carbon atoms.

(c) Number the main chain starting with the aldehyde carbon as position 1, moving leftward through the rest of the molecule.

(d) Identify any side-chain substituents: a single methyl group ($-CH_3$) is attached to the third carbon of the main chain.

(e) Combine these structural pieces: a 4-carbon aldehyde base is named "butanal", and adding the substituent yields "3-methylbutanal".

**Final Answer:** 3-Methylbutanal

**Answer: (B)**

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## Q28.

### Solution

**Concept:**

The geometry and electronic hybridization of organic reaction intermediates depend on the number of valence electrons surrounding the central carbon atom. Planar structures maximize orbital overlap and minimize electrostatic repulsion by arranging three bonding domains at 120-degree angles.

**Solution:**

(a) Analyze the electronic structure of a trivalent carbocation: the central carbon forms 3 sigma bonds and carries a positive charge, leaving it with 6 valence electrons.

(b) Calculate its steric number: 3 bonding domains + 0 lone pairs = 3. This requires $sp^2$ hybridization and a trigonal planar geometry with an empty p-orbital.

(c) Analyze a carbon free radical: it forms 3 sigma bonds and holds 1 unpaired electron. This system remains mostly planar or rapidly inverts, showing effective $sp^2$ character.

(d) Analyze a carbanion: it forms 3 sigma bonds and holds 1 lone pair, totaling 8 valence electrons.

(e) Calculate the carbanion steric number: 3 bonds + 1 lone pair = 4, which results in $sp^3$ hybridization and a pyramidal geometry.

(f) Conclude that both carbocations and carbon radicals can exhibit planar, $sp^2$-hybridized structures.

**Final Answer:** Both Carbocation and Free radical

**Answer: (D)**

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## Q29.

### Solution

**Concept:**

Hydrolysis reactions involve breaking chemical bonds in a reactant molecule by reacting with water. Treating metal carbides with water yields a metal hydroxide alongside a characteristic hydrocarbon gas determined by the structure of the starting carbide.

**Solution:**

(a) Identify the chemical composition of Calcium Carbide ($CaC_2$). It is an ionic compound composed of Calcium cations ($Ca^{2+}$) and Acetylide anions ($C_2^{2-}$).

(b) Write out the balanced chemical equation for its reaction with water: $CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$.

(c) Examine the structural formula of the evolved hydrocarbon gas product, $C_2H_2$.

(d) This molecule contains a carbon-carbon triple bond (H-C ≡ C-H), which classifies it as an alkyne.

(e) Recall the systematic IUPAC name for this two-carbon alkyne, which is ethyne (commonly known as acetylene).

**Final Answer:** Ethyne

**Answer: (D)**

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## Q30.

### Solution

**Concept:**

The carbonyl group (C=O) in aldehydes and ketones contains a highly polarized double bond due to the difference in electronegativity between carbon and oxygen. This polarization creates an electron-deficient electrophilic center that is susceptible to nucleophilic attack.

**Solution:**

(a) Analyze the electronic distribution of the carbonyl functional group. Oxygen is highly electronegative and pulls pi-electron density toward itself.

(b) This unequal sharing creates a partial negative charge ($\delta-$) on the oxygen atom and a corresponding partial positive charge ($\delta+$) on the carbonyl carbon.

(c) Because the carbonyl carbon is electron-deficient, it acts as an electrophile within the molecular structure.

(d) Chemical addition reactions are initiated by an external nucleophile—an electron-rich species seeking a positive center.

(e) The incoming nucleophile targets and attacks the electrophilic carbonyl carbon atom, making the nucleophile the driving reactive component.

**Final Answer:** An incoming electron-rich species targeting the carbonyl carbon

**Answer: (D)**

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## Q31.

### Solution

**Concept:**

Aromatic hydrocarbons like benzene possess a specialized planar, cyclic conjugated ring geometry that provides profound thermodynamic stability known as resonance stabilization energy. Chemical transformations that disrupt this continuous delocalized $\pi$-electron cloud are highly unfavorable.

**Solution:**

(a) Analyze the chemical behavior of benzene. The ring contains alternating single and double bonds, but all carbon-carbon bonds are equivalent due to resonance.

(b) If an aromatic ring undergoes a classical electrophilic addition reaction, two new $\sigma$ bonds form at the expense of a localized $\pi$ bond.

(c) This addition completely breaks the continuous cyclic conjugation, destroying the aromatic character and sacrificing the resonance stabilization energy.

(d) Electrophilic substitution reactions replace a hydrogen atom on the ring with an incoming electrophile while preserving the structural integrity of the ring.

(e) Because the final product retains its delocalized $\pi$ framework, the system maintains its original aromatic resonance stabilization energy.

**Final Answer:** Maintenance of ring resonance stabilization energy

**Answer: (B)**

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## Q32.

### Solution

**Concept:**

The addition of hydrogen halides to unsymmetrical alkenes follows different regiochemical pathways depending on the reaction conditions. In the presence of organic peroxides, the reaction proceeds via a free-radical mechanism rather than an ionic carbocation intermediate.

**Solution:**

(a) Identify the reactants: propene ($CH_3CH{=}CH_2$) is an unsymmetrical alkene reacting with Hydrogen Bromide (HBr).

(b) Note the specific reaction conditions: the transformation is conducted in the presence of organic peroxides ($R_2O_2$).

(c) Peroxides initiate a free-radical chain reaction where a bromine radical attacks the alkene first, generating the most stable radical intermediate.

(d) The bromine radical adds to the terminal carbon to yield a secondary radical rather than a less stable primary radical.

(e) This pathway reverses the standard regioselectivity, operating via Anti-Markovnikov addition where the halogen attaches to the carbon with more hydrogens.

(f) The secondary radical abstracts a hydrogen atom from HBr to complete the reaction, yielding 1-bromopropane as the major product.

**Final Answer:** 1-Bromopropane

**Answer: (B)**

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## Q33.

### Solution

**Concept:**

The relative acidity of organic hydroxy compounds is directly determined by the structural stability of the conjugate base phenoxide or alkoxide anion formed upon deprotonation. Electron-withdrawing substituents stabilize the negative charge via resonance and inductive effects.

**Solution:**

(a) Compare the structural components of the given choices: ethanol, phenol, water, and para-nitrophenol.

(b) Phenol is significantly more acidic than aliphatic alcohols and water because its conjugate base, the phenoxide ion, is stabilized by resonance.

(c) The negative charge on the phenoxide oxygen atom is delocalized into the aromatic $\pi$-system via ortho and para positions.

(d) Examine the structure of p-nitrophenol, which contains a highly electron-withdrawing nitro group (-$NO_2$) at the para position.

(e) The nitro group exerts powerful negative inductive (-I) and negative resonance (-M) effects, pulling electron density away from the ring.

(f) This additional electron withdrawal strongly stabilizes the phenoxide charge, making p-nitrophenol the most acidic compound in the group.

**Final Answer:** p-Nitrophenol

**Answer: (D)**

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## Q34.

### Solution

**Concept:**

Structural isomerism in coordination complexes arises when compounds share identical empirical formulas but differ in the arrangement of chemical bonds. Ionization isomerism occurs when ligands inside the coordination sphere exchange places with counter-ions in the outer sphere.

**Solution:**

(a) Examine the formulas of the two coordination compounds provided: $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$.

(b) Identify the contents of the inner coordination sphere within the brackets and the counter-ions residing in the outer sphere.

(c) The first complex contains a coordinated sulfate ligand inside the sphere, while a bromide ion acts as the counter-anion.

(d) The second complex contains a coordinated bromide ligand inside the sphere, while a sulfate ion serves as the counter-anion.

(e) When dissolved in aqueous solution, these structural isomers dissolve to yield entirely different chemical ions.

(f) Because these compounds differ solely by which counter-ion is internalized as a ligand, they are classified as ionization isomers.

**Final Answer:** Ionization isomerism

**Answer: (B)**

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## Q35.

### Solution

**Concept:**

A soil profile consists of distinct vertical layers called master horizons, each defined by unique physical, chemical, and biological properties. The distribution of organic matter, minerals, and microbial communities varies predictably from the surface downward.

**Solution:**

(a) Analyze the soil horizon layers described in the provided diagram: the O, A, B, and C master horizons.

(b) The O horizon consists primarily of fresh or partially decomposed organic litter, such as fallen leaves and plant debris.

(c) The A horizon, commonly designated as topsoil, is a mineral layer enriched with fully decomposed, stabilized organic matter known as humus.

(d) Humus gives the A horizon its dark coloration and creates an optimal environment with high moisture retention and nutrient availability.

(e) This concentration of organic carbon makes the A horizon the primary zone for microbial activity and plant root proliferation.

**Final Answer:** A Horizon

**Answer: (B)**

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## Q36.

### Solution

**Concept:**

Soil pH is a master variable that regulates the solubility, chemical speciation, and biological availability of essential plant nutrients. Extreme acidity or alkalinity triggers chemical fixation reactions that lock nutrients into insoluble forms.

**Solution:**

(a) Review the provided chart illustrating nutrient availability as a function of the soil pH scale.

(b) In strongly acidic soils (pH < 5.5), phosphorus reacts with iron and aluminum ions to form highly insoluble precipitates.

(c) In alkaline soils (pH > 7.5), calcium ions bind tightly with phosphorus, significantly reducing its solubility and availability to root systems.

(d) Microorganisms responsible for nitrogen mineralization and tracking organic matter decomposition thrive best near neutral conditions.

(e) The chart highlights a green region between 6.0 and 7.5 where chemical fixation is minimized and primary macronutrients are highly soluble.

**Final Answer:** 6.0 – 7.5

**Answer: (B)**

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## Q37.

### Solution

**Concept:**

Cation Exchange Capacity (CEC) measures the total capacity of a soil colloid to hold and exchange positively charged chemical ions. This capacity is determined by the total surface area and the density of negative surface charges.

**Solution:**

(a) Evaluate the structural characteristics of the soil colloids: kaolinite, illite, montmorillonite, and organic humus.

(b) Kaolinite is a 1:1 silicate clay with a low surface area and minimal charge, resulting in a low CEC (3 to 15 $cmol_c\ kg^{-1}$).

(c) Montmorillonite is a 2:1 expanding crystalline clay with extensive internal surface area, yielding a higher CEC (80 to 150 $cmol_c\ kg^{-1}$).

(d) Organic humus is a non-crystalline, highly amorphous colloid packed with carboxylic acid and phenolic hydroxyl functional groups.

(e) Deprotonation of these functional groups creates a massive density of pH-dependent negative charges across an immense surface area.

(f) Consequently, organic humus exhibits an exceptionally high CEC (150 to 300 $cmol_c\ kg^{-1}$), outperforming all mineral clays.

**Final Answer:** Organic humus

**Answer: (D)**

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## Q38.

### Solution

**Concept:**

Sodic soils contain excessive concentrations of exchangeable sodium ions ($Na^+$), which cause soil aggregates to disperse, destroying soil structure and reducing permeability. Chemical remediation requires replacing these sodium ions with divalent calcium ions.

**Solution:**

(a) To reclaim a sodic soil, an amendment must provide a soluble source of calcium ($Ca^{2+}$) without raising the soil pH further.

(b) Calcium carbonate (lime) is highly insoluble in alkaline pH conditions, making it ineffective for treating sodic soils.

(c) Calcium sulfate dihydrate (gypsum, $CaSO_4 \cdot 2H_2O$) is moderately soluble across a wide pH range and provides abundant divalent calcium ions.

(d) The released $Ca^{2+}$ ions displace exchangeable $Na^+$ ions from the soil colloid surfaces due to their higher charge density.

(e) The displaced sodium ions react with sulfate to form highly soluble sodium sulfate ($Na_2SO_4$), which can then be leached out with irrigation water.

**Final Answer:** Calcium sulfate dihydrate (Gypsum)

**Answer: (B)**

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## Q39.

### Solution

**Concept:**

Phyllosilicates are layered clay minerals constructed from shared silicon-oxygen tetrahedral sheets and aluminum-hydroxyl octahedral sheets. The structural classification depends on the stacking ratio and arrangement of these fundamental crystalline sheets.

**Solution:**

(a) Analyze the mineral structure of Kaolinite, a prominent non-expanding aluminosilicate clay mineral found widely in highly weathered soils.

(b) The basic structural unit of kaolinite consists of exactly one silica tetrahedral sheet chemically bonded to one aluminum octahedral sheet.

(c) This specific repeating arrangement defines a 1:1 type layer silicate crystal structure.

(d) The individual 1:1 layers are held tightly together by strong hydrogen bonds forming between adjacent sheets.

(e) Because of this tight hydrogen bonding network, the crystal lattice cannot expand, preventing water or ions from entering the interlayer space.

**Final Answer:** 1:1 (one tetrahedral sheet to one octahedral sheet)

**Answer: (A)**

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## Q40.

### Solution

**Concept:**

Ammonia volatilization is a chemical loss mechanism where ammonium ions are converted into volatile ammonia gas ($NH_3$). This process occurs rapidly when ammonium-producing or amide-based fertilizers are applied to soils with elevated pH.

**Solution:**

(a) Examine the chemical nature of urea, $CO(NH_2)_2$. When applied to soil, urea undergoes rapid enzymatic hydrolysis mediated by the widespread urease enzyme.

(b) The hydrolysis reaction consumes protons and generates ammonium carbonate: $CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO_3$.

(c) The accumulation of ammonium carbonate causes a localized, sharp spike in the soil solution pH.

(d) In an alkaline environment with a high concentration of hydroxyl ions ($OH^-$), dissolved ammonium ions ($NH_4^+$) convert into volatile ammonia gas.

(e) The chemical equilibrium shifts: $NH_4^+ + OH^- \rightleftharpoons NH_3(g) + H_2O$, leading to significant nitrogen loss to the atmosphere.

**Final Answer:** Urea

**Answer: (B)**

Go Back to Question 40

# Answer Key

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