UPCATET Agriculture Chemistry Sample Paper-10

Duration: 25 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** 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. A soil chemist measures the chemical potential of potassium ions (K^+) in an equilibrium soil-water suspension system containing mixed-layer illite-smectite clay minerals. If the ionic strength of the bulk solution phase is artificially doubled under static conditions while keeping the exchangeable sodium percentage (ESP) constant, what is the thermodynamic consequence on the Gapon selectivity coefficient (K_G) for the $Ca^{2+} - K^+$ exchange process?

(A) It increases exponentially due to the reduction of the active thickness of the diffuse double layer (DDL).

(B) It decreases linearly because of the preferential steric hindrance of hydrated divalent calcium ions over monovalent potassium ions.

(C) It remains thermodynamically constant because K_G is an intrinsic equilibrium expression accounting for activity ratios, though apparent concentration ratios change.

(D) It approaches zero asymptotically as a direct result of complete outer-sphere complex dissociation.

Q2. A 5.00 g sample of a commercial nitrogenous fertilizer containing mixed ammonium sulfate $(NH_4)_2SO_4$ and urea $CO(NH_2)_2$ is treated with hot concentrated $NaOH$ to liberate NH_3 gas completely into 100.0 mL of 0.500 M H_2SO_4. The unreacted excess acid requires exactly 30.0 mL of 0.250 M $NaOH$ for complete neutralization to a methyl red endpoint. Calculate the precise mass percentage of total elemental Nitrogen (N) present within the fertilizer sample.

(A) 11.55%

(B) 25.90%

(C) 43.40%

(D) 51.80%

Q3. Consider the thermodynamic stability and acidity constants (K_a) of chlorinated organic carboxylic acids commonly derived during the degradation of chlorinated hydrocarbon pesticides in anaerobic soils. Arrange 2-chloropropanoic acid (I), 3-chloropropanoic acid (II), 2,2-dichloropropanoic acid (III), and propanoic acid (IV) in the strict decreasing order of their dissociation tendencies (pKa optimization).

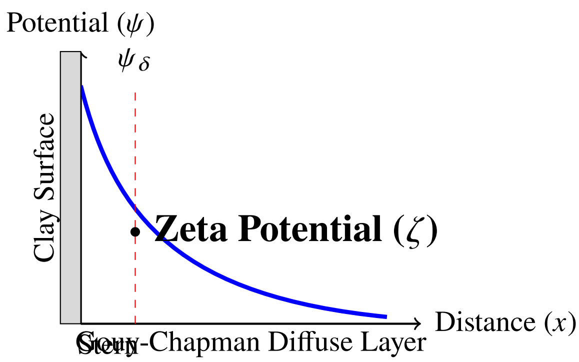
(A) III > I > II > IV

(B) IV > II > I > III

(C) III > II > I > IV

(D) I > III > II > IV

Q4. The schematic profile below maps out the electrostatic potential (ψ) distribution as a function of the distance (x) propagating perpendicularly outwards from a negatively charged montmorillonite clay platelet surface into the bulk soil solution matrix:



If a high concentration of gypsum ($CaSO_4 \cdot 2H_2O$) is added to this alkali soil medium, identify how the geometric contour profile changes under the influence of divalent calcium (Ca^{2+}) ions.

(A) The potential curve stretches further along the x-axis due to electrostatic expansion.

(B) The curve compresses sharply towards the vertical y-axis because the diffuse double layer undergoes compaction.

(C) The Zeta potential (ζ) matches the surface potential exactly, eliminating the Stern plane.

(D) The curve becomes completely linear, obeying a zero-order mathematical decay law.

Q5. Phosphonitrilic polymers or phosphazenes have gained interest as potential slow-release fertilizer carriers when functionalized. Analyze the molecular orbital environment of the hexachlorocyclotriphosphazene molecule ($P_3N_3Cl_6$). What is the true hybridization state of the Phosphorus (P) and Nitrogen (N) atoms within the skeletal framework ring structure?

(A) P is sp^2 hybridized; N is sp^3 hybridized.

(B) Both P and N are uniformly sp^2 hybridized to allow ideal carbon-like aromatic resonance.

(C) P is sp^3 hybridized; N is sp^2 hybridized, where the lone pair on N resides in an sp^2 orbital in the ring plane.

(D) Both P and N exhibit dsp^2 square planar arrangements to host localized d-orbitals.

Q6. During the process of nitrification of ammonium-based fertilizers in well-aerated arable soils, the biochemical sequence proceeds as: $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$. If the soil experiences sudden waterlogging right after the first step due to excessive monsoon flooding, what is the thermodynamic fate of the accumulated toxic intermediate nitrite (NO_2^-) under the newly established anaerobic conditions?

(A) It immediately undergoes rapid chemical oxidation to NO_3^- by dissolved atmospheric nitrogen gases.

(B) It acts as an electron acceptor for facultative anaerobic heterotrophs, undergoing reduction to gaseous N_2O and N_2 via denitrification.

(C) It precipitates with iron as an insoluble complex of iron(III) nitrite.

(D) It permanently isomerizes into stable nitro-alkane matrices within humic acid fractions.

Q7. The total active copper content in a formulation of copper-based fungicide ($CuSO_4 \cdot 3Cu(OH)_2$) is determined by an advanced iodometric titration protocol. A 2.50 g sample of the compound is digested, treated with excess potassium iodide (KI), and the liberated molecular iodine (I_2) requires 20.0 mL of a 0.10 M standardized sodium thiosulfate ($Na_2S_2O_3$) solution to reach the starch-iodide clear endpoint. Determine the milliequivalents of Cu^{2+} reactive centers active in the digested system.

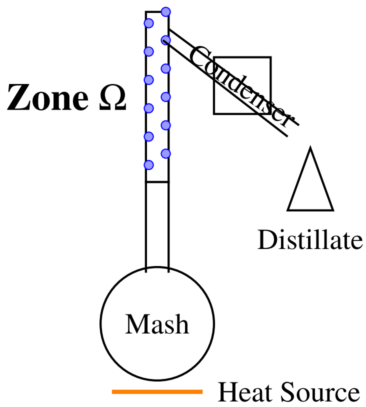
(A) 1.0 meq

(B) 2.0 meq

(C) 4.0 meq

(D) 0.5 meq

Q8. A biochemical laboratory extracts bio-ethanol from fermented sugarcane molasses mash through a fractional distillation column assembly as modeled below:



Identify the precise thermodynamic phenomenon occurring at the bead-packed **Zone** Ω that successfully isolates volatile agricultural bio-alcohols from high-boiling aqueous matrices.

(A) Irreversible exothermic chemical hydration of low-boiling components.

(B) Successive continuous cycles of vapor condensation and liquid revaporization resulting in phase enrichment.

(C) Catalytic cracking of macromolecular pentose fractions into volatile ethene.

(D) Total internal reflection of heat waves stabilizing an azimuthal temperature gradient.

Q9. In strongly acidic red lateritic soils ($pH < 4.8$), major losses of applied soluble orthophosphate fertilizers occur through chemical fixation mechanisms. Which specific mineral surface interactions dominate this fixation network, rendering phosphorus highly unavailable to plant roots?

(A) Isomorphous substitution of P^{5+} for Si^{4+} inside tetrahedral sheets of montmorillonite.

(B) Chemisorption on active binuclear edge sites of gibbsite ($Al(OH)_3$) and goethite ($FeO(OH)$) via ligand exchange.

(C) Electrostatic outer-sphere bridge building with exchangeable sodium ions (Na^+).

(D) Chelation reactions with mobile organic humic polymer core matrices.

Q10. Micronutrient transition metal ions such as Mn, Fe, Co, and Cu act as central structural cofactors in photosynthetic electron transport chains. For a ground-state manganous ion (Mn^{2+}, $Z = 25$) present in plant metabolic structures, calculate the total count of electrons possessing the specific quantum number configuration: $l = 2$ and $m_l = +1$ or -1.

(A) 2

(B) 4

(C) 5

(D) 10

Q11. An agricultural physiologist extracts sap fluid from drought-resistant crop leaves to determine its osmotic threshold characteristics. If the extraction sap shows an observed freezing point depression (ΔT_f) of exactly $-0.558°$C, compute the approximate internal osmotic pressure (Π) exerted by this sap matrix at a standard physiological temperature of 27°C. [Cryoscopic constant of water $K_f = 1.86$ K kg mol^{-1}; assume solution density ideal at 1.0 g mL^{-1}].

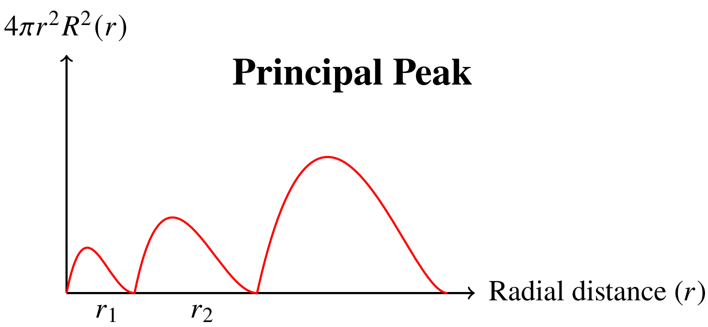
(A) 2.46 atm

(B) 7.39 atm

(C) 1.23 atm

(D) 12.50 atm

Q12. The chart highlighted below represents the radial probability distribution function $4\pi r^2R^2(r)$ evaluated for a crucial outer valence electron orbital of a macro-nutrient element found in alkaline earth soil matrices:



By systematically counting the physical radial nodes mapped within this probability domain, identify the exact electronic subshell designation matching this profile layout.

(A) $2s$ subshell

(B) $3p$ subshell

(C) $4s$ subshell

(D) $3d$ subshell

Q13. The biochemical conversion of agricultural crop residues into fuel-grade biogas involves the volatile fatty acid pathway. When ethanoic acid (CH_3COOH) undergoes a decarboxylation sequence with excess soda-lime ($NaOH + CaO$) at high temperature, which intermediate species directly governs the rate-limiting reaction step?

(A) A highly reactive free methyl radical ($\cdot CH_3$).

(B) A transient pentacoordinate carbon oxo-complex.

(C) A localized carbanion intermediate ($: CH_3^-$).

(D) A carbocation state ($^+CH_3$) stabilized by nearby sodium coordination shells.

Q14. Chelating agents such as Ethylenediaminetetraacetic acid ($EDTA$) are heavily integrated into micronutrient fertilizers to prevent Zinc (Zn) and Iron (Fe) deficiency symptoms. What structural parameter accounts for the exceptional stability of the Zn-EDTA complex across moderate soil pH shifts compared to inorganic salt options ($ZnSO_4$)?

(A) The entropic gain resulting from the creation of multiple five-membered heterocyclic chelate ring structures enclosing the zinc atom.

(B) The low electronegativity constant of the peripheral oxygen atoms.

(C) The spontaneous reduction of zinc from Zn^{2+} to its metallic state within the core cavity.

(D) The physical block of water evaporation driven by the hydrophobic exterior shell of the acetate chains.

Q15. In estimating the chemical character of chemical bonds inside agrochemical crystal matrices, an investigator applies the Mulliken electronegativity scale rules. If the ionization energy (IE) and electron affinity (EA) values of a target element are measured to be 14.0 eV and 3.4 eV respectively, evaluate its matching Pauling electronegativity value reference (X_P).

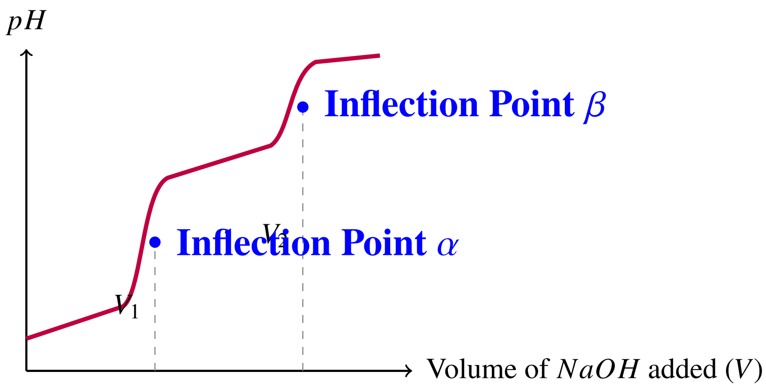
(A) 2.1

(B) 3.1

(C) 4.0

(D) 1.5

Q16. The structural curve trace displayed below charts a high-precision potentiometric neutralization titration monitoring the chemical interaction between an organic polybasic soil extract acid sample and an industrial grade standard $NaOH$ alkali stream:



Based on the distinct appearance of both Inflection Points α and β, identify the nature of the organic acid configuration under tracking.

(A) A fully neutralized monprotic mineral acid mixed with sand impurities.

(B) A weak diprotic acid setup featuring significantly different step dissociation parameters ($K_{a1} \gg K_{a2}$).

(C) A strong tribasic acid whose intermediate steps are perfectly degenerate.

(D) A non-electrolyte polyol showing zero proton transfer traits.

Q17. An agro-industrial process yields pure ethene gas by vaporizing anhydrous ethanol over solid heterogenous catalysts. Which processing condition delivers the highest conversion yield while preventing the alternative creation of diethyl ether ($C_2H_5 - O - C_2H_5$)?

(A) Treatment with excess concentrated H_2SO_4 at a strictly maintained low temperature of 140°C.

(B) Treatment with excess concentrated H_2SO_4 at an elevated temperature regime of 170°C.

(C) Passing alcohol vapors over catalytic alumina (Al_2O_3) beds at 250°C.

(D) Heating with dilute aqueous hydrochloric acid solution under low-pressure reflux.

Q18. When prilled urea fertilizer is applied onto a warm, moist alkaline soil surface ($pH = 8.2$), it undergoes rapid enzymatic hydrolysis driven by widespread microbial urease. What principal environmental hazard is maximized by this specific chemical combination, reducing nitrogen use efficiency (NUE)?

(A) Rapid nitrate leaching into deep groundwater tables via macropores.

(B) Massive gaseous volatilization losses of ammonia ($NH_3 \uparrow$) due to shifted equilibrium dynamics at elevated pH.

(C) Complete structural fixation of nitrogen inside the interlamellar space of kaolinite clays.

(D) Hyper-accumulation of explosive nitrous oxide gas within structural soil aggregates.

Q19. Synthetic potassium chloride (KCl) crystal matrix acts as a fundamental source component in Muriate of Potash (MOP) fertilizers. Using the Born-Landé equation principles, how does the structural lattice energy (U_0) of a crystal respond if the original monovalent ions are replaced by divalent species of identical ionic radii (such as simulating a hypothetical CaS bio-isostere grid formation)?

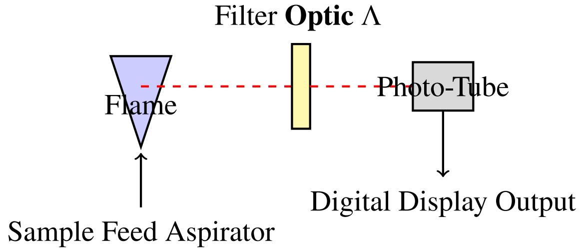
(A) The lattice energy scales up roughly four-fold (4×) due to the product change of ionic charges (z_+z_-).

(B) The lattice energy drops to half because of structural asymmetry.

(C) The lattice energy remains identical because ionic radii values control the denominator matrix exclusively.

(D) The lattice energy scales up exactly sixteen-fold (16×) following an exponential quantum leap.

Q20. An agricultural diagnostics center operates an automated flame photometer system schematic shown below to map potassium (K) and sodium (Na) concentrations from soil saturation extracts:



When an extract containing high exchangeable potassium (K^+) is drawn into the atomizer, identify the precise operational function assigned to the monochromatic filter **Optic** Λ before light hits the detector core.

(A) It absorbs all characteristic purple-violet atomic emission lines to isolate background carbon ash bands.

(B) It isolates the specific emission wavelength at 766 nm while blocking out conflicting background signals from alternative ions.

(C) It refracts continuous white thermal radiation into a broad visible rainbow scale.

(D) It polarizes light waves into a singular plane to measure optical rotation parameters.

Q21. During the determination of total soil hardness ($Ca^{2+} + Mg^{2+}$) using standardized 0.01 M EDTA titrations at $pH = 10$, iron (Fe^{3+}) and aluminum (Al^{3+}) impurities cause severe interference by permanently blocking the Eriochrome Black T (EBT) indicator. Which analytical modification resolves this blocking dilemma without manual physical separation?

(A) Adding potassium cyanide (KCN) or triethanolamine (TEA) to act as a chemical masking agent by forming highly stable complexes with the interfering cations.

(B) Boiling the titration flask with concentrated sulfuric acid until sulfur trioxide fumes appear.

(C) Dropping the operational pH value sharply to 2.0 using concentrated nitric acid additions.

(D) Increasing the amount of indicator twenty-fold to overpower the iron active centers.

Q22. The stability of conjugate bases dictates the chemical behavior of organic soil amendments. Evaluate the relative acid strength of the following structural molecules: Methanoic acid ($HCOOH$), Ethanoic acid (CH_3COOH), Propan-2-ol ($(CH_3)_2CHOH$), and Phenol (C_6H_5OH). Select the option representing the proper decreasing sequence of their proton-donating abilities.

(A) Methanoic acid > Ethanoic acid > Phenol > Propan-2-ol

(B) Ethanoic acid > Methanoic acid > Phenol > Propan-2-ol

(C) Phenol > Methanoic acid > Ethanoic acid > Propan-2-ol

(D) Methanoic acid > Phenol > Ethanoic acid > Propan-2-ol

Q23. According to the Schrödinger wave mechanics model applied to single-electron systems, what does the mathematical square of the spatial wave function (Ψ^2) represent within a given infinitesimal volume element (dV) surrounding a plant nutrient ion core?

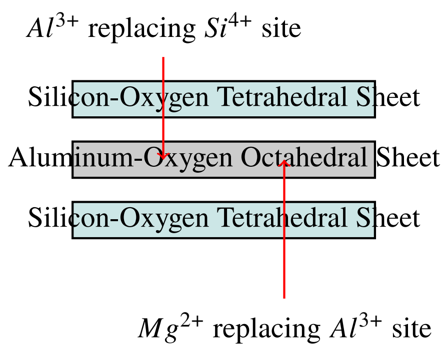
(A) The absolute kinetic velocity trajectory coordinates of that electron.

(B) The exact electrostatic force vectors connecting the electron to the nuclear center.

(C) The radial probability density for finding the electron within that specific coordinate region.

(D) The total quantized energy level threshold belonging to the main principal shell.

Q24. The schematic map structured below captures an ideal cross-sectional layer block of a crystalline silicate clay mineral frequently identified within expansive black cotton soils (Vertisols):



Identify the primary mineral group matching this specific 2:1 expansible layer configuration and the corresponding chemical phenomenon labeled by the red arrows.

(A) Kaolinite group, displaying dynamic physical anion exchange capacity.

(B) Smectite (Montmorillonite) group, displaying internal permanent negative charge generation via isomorphous substitution.

(C) Illite group, displaying permanent positive surface charges through edge modifications.

(D) Gibbsite group, displaying zero lattice substitution characteristics.

Q25. When reclaiming a highly deteriorated sodic soil showing a high electrical conductivity ($EC > 4$ dS m^{-1}) and an exchangeable sodium percentage ($ESP >$ 15%), a soil reclamation officer calculates the Gypsum Requirement (GR). What chemical reaction mechanism describes how gypsum application combined with fresh water flushing removes toxic exchangeable sodium from the clay adsorption complex?

(A) Soluble Ca^{2+} ions displace adsorbed exchangeable Na^{+} ions into the soil solution phase, where they are leached downward out of the root zone as soluble sodium sulfate (Na_2SO_4).

(B) Calcium ions chemically reduce sodium ions into harmless, inert metallic sodium precipitates.

(C) Sulfate anions permanently hydrolyze water molecules to release free hydrogen ions, decreasing soil pH to a neutral value of 7.0.

(D) Gypsum reacts with ambient carbon dioxide gas to build stable sodium carbonate crystals on surface layers.

Detailed Solutions

Q1.

Solution

Concept: The Gapon selectivity coefficient (K_G) describes the ion-exchange equilibrium between monovalent and divalent cations (such as Ca^{2+} and K^+) on soil clay surfaces. Thermodynamically, K_G is formulated using the activities of the ions in solution rather than their concentration values. Therefore, changing the overall ionic strength at a constant exchangeable sodium percentage (ESP) alters active concentration ratios and activity coefficients, but the intrinsic thermodynamic equilibrium constant remains unchanged.

Solution:

1. **Define Gapon Exchange:** The exchange reaction between adsorbed calcium and solution potassium can be written as:

$$\mathrm{Ca_{0.5}\text{-}Clay} + \mathrm{K^+} \rightleftharpoons \mathrm{K\text{-}Clay} + \frac{1}{2}\mathrm{Ca^{2+}}$$

2. **Examine Selectivity Constant Dynamics:** The Gapon selectivity coefficient is given by:

$$K_G = \frac{[\mathrm{K\text{-}Clay}]}{[\mathrm{Ca_{0.5}\text{-}Clay}]} \cdot \frac{\sqrt{a_{\mathrm{Ca^{2+}}}}}{a_{\mathrm{K^+}}}$$

Because K_G is defined in terms of true thermodynamic activities ($a_i = \gamma_i c_i$), any change in bulk solution ionic strength is compensated for by shifts in the activity coefficients (γ_i). Thus, while the apparent concentration-based ratio shifts, the intrinsic thermodynamic equilibrium coefficient (K_G) remains constant under static structural conditions.

Final Answer: $\boxed{\text{It remains thermodynamically constant because } K_G \text{ is an intrinsic equilibrium expression based on activity ratios, although apparent concentration ratios may change.}}$

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

Go Back to Question 1

Q2.

Solution

Concept: This problem utilizes a back-titration strategy to measure the total amount of ammonia (NH_3) evolved from the fertilizer sample. Concentrated NaOH converts all nitrogen components (NH_4^+ and urea) into NH_3 gas. The liberated gas is trapped in a known excess of standard sulfuric acid (H_2SO_4). The unreacted acid is then quantified via neutralization titration with a standard sodium hydroxide solution.

Solution:

1. **Calculate Initial Moles of H_2SO_4 Added:**

$$\text{Initial moles of } H_2SO_4 = 100.0 \text{ mL} \times 0.500 \text{ M} = 50.00 \text{ mmol}$$

$$\text{Initial equivalents of } H^+ = 2 \times 50.00 \text{ mmol} = 100.0 \text{ meq}$$

2. **Calculate Moles of Excess H_2SO_4 (from Back-Titration):** The unreacted acid is neutralized by NaOH:

$$\text{Moles of NaOH} = 30.0 \text{ mL} \times 0.250 \text{ M} = 7.50 \text{ mmol}$$

$$\text{Equivalents of } H^+ \text{ neutralized by NaOH} = 7.50 \text{ meq}$$

3. **Determine Moles of Nitrogen (N) in Sample:** The equivalents of H^+ neutralized by the evolved NH_3 gas are:

$$\text{Equivalents of } NH_3 = 100.0 \text{ meq} - 7.50 \text{ meq} = 92.50 \text{ meq}$$

Since NH_3 accepts one proton, the total amount of elemental nitrogen is:

$$\text{Moles of N} = 92.50 \text{ mmol} = 0.09250 \text{ mol}$$

4. **Calculate Mass and Mass Percentage of Nitrogen:**

$$\text{Mass of N} = 0.09250 \text{ mol} \times 14.01 \text{ g mol}^{-1} = 1.2959 \text{ g}$$

$$\text{Mass percentage of N} = \left(\frac{1.2959 \text{ g}}{5.00 \text{ g}}\right) \times 100\% = 25.918\% \approx 25.90\%$$

Final Answer: $\boxed{25.90\%}$

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

Go Back to Question 2

Q3.

Solution

Concept: The acidity (K_a or pK_a) of carboxylic acids is heavily influenced by the negative inductive effect ($-I$ effect) of electron-withdrawing substituents like chlorine (Cl). Electronegative groups withdraw electron density from the carboxylate group, stabilizing the conjugate base and facilitating proton dissociation. The magnitude of this induction drops sharply as the distance between the substituent and the carboxylic acid head increases.

Solution:

1. **Analyze Inductive Contributions:**

- **2,2-dichloropropanoic acid (III):** Features two highly electronegative Cl atoms located directly on the α-carbon ($C-2$). This exerts the strongest combined $-I$ effect, yielding the highest dissociation tendency.
- **2-chloropropanoic acid (I):** Features a single Cl atom on the α-carbon, which stabilizes the conjugate base moderately.
- **3-chloropropanoic acid (II):** Features one Cl atom on the β-carbon ($C-3$). Due to the increased spatial distance across the carbon chain, its inductive pull is weak.
- **Propanoic acid (IV):** Has no electron-withdrawing halogens; the alkyl chain exhibits an electron-donating ($+I$) effect, making it the weakest acid.

2. **Establish Acid Strength Order:** Combining these trends gives the strict decreasing order of acid dissociation tendencies (K_a values): III > I > II > IV.

Final Answer: $\boxed{\text{III > I > II > IV}}$

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

Go Back to Question 3

Q4.

Solution

Concept: According to the Gouy-Chapman-Stern diffuse double layer (DDL) theory, the electrical potential surrounding a charged clay colloid decays exponentially into the bulk solution. The thickness or extension of this diffuse double layer depends inversely on the concentration and valence of the background electrolyte counter-ions.

Solution:

1. **Evaluate Gypsum Action:** Adding gypsum ($CaSO_4 \cdot 2H_2O$) introduces highly soluble divalent calcium ions (Ca^{2+}) into the bulk matrix.

2. **Assess Double Layer Impact:** Divalent cations neutralize surface charges far more efficiently than monovalent ions (Na^+). This effective charge screening compresses the DDL thickness. Consequently, the electrostatic potential drops to near-zero over a much shorter physical distance, compressing the geometric contour profile sharply toward the vertical y-axis.

Final Answer: The curve compresses sharply toward the y-axis because the diffuse double layer becomes compacted.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: Hexachlorocyclotriphosphazene ($P_3N_3Cl_6$) features an alternating six-membered ring skeleton containing phosphorus and nitrogen atoms. Evaluating the localized steric coordination requirements (using valence shell electron pair repulsion metrics) reveals the hybridization state of each skeletal framework node.

Solution:

1. **Determine Phosphorus (P) Geometry:** Each P atom forms two single σ-bonds with neighboring nitrogen atoms, and two single σ-bonds to peripheral chlorine atoms, along with a π-bond shared within the ring delocalization framework. With a steric number of 4 (four σ-bonds and zero lone pairs), each phosphorus atom is sp^3 hybridized.

2. **Determine Nitrogen (N) Geometry:** Each N atom forms two σ-bonds within the ring framework and holds a lone pair of electrons localized within the plane of the ring structure. Having a steric number of 3 (two σ-bonds and one lone pair), the nitrogen atoms are sp^2 hybridized.

Final Answer: P is sp^3 hybridized, whereas N is sp^2 hybridized, with the lone pair on N occupying an sp^2 orbital in the ring plane.

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Waterlogging drives a soil environment into anoxia because water fills the soil pores and blocks atmospheric oxygen diffusion. Under these anaerobic conditions, facultative and obligate anaerobic microorganisms shift from aerobic respiration to alternative electron acceptors to oxidize organic carbon substrates.

Solution:

1. **Analyze Anaerobic Fate:** The accumulated nitrite intermediate (NO_2^-) cannot be oxidized further to nitrate (NO_3^-) due to the absence of molecular oxygen (O_2).

2. **Identify Biochemical Reduction Path:** Instead, NO_2^- is utilized as an electron acceptor during biological denitrification. Facultative heterotrophs reduce it through gaseous intermediates (NO and N_2O) into stable dinitrogen gas (N_2), which volatilizes out of the soil matrix.

Final Answer: It acts as an electron acceptor for facultative anaerobes, undergoing reduction to gaseous N_2O and N_2 through denitrification.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: In iodometric determinations of copper, Cu^{2+} reactive centers oxidize iodide ions (I^-) to generate free molecular iodine (I_2), while reducing to insoluble copper(I) iodide (CuI). The liberated I_2 is then titrated against a standardized sodium thiosulfate ($Na_2S_2O_3$) solution.

Solution:

1. **Identify Stoichiometric Equivalences:** The sequence of redox reactions is:

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

From these expressions, 1 mol of Cu^{2+} corresponds to 1 mol of $S_2O_3^{2-}$. Thus, the valence factor (n-factor) for the reactive Cu^{2+} centers is exactly 1 in this iodometric context.

2. **Calculate Milliequivalents:**

$$\text{Milliequivalents of } S_2O_3^{2-} = \text{Volume (mL)} \times \text{Molarity (M)} \times n\text{-factor}$$

$$\text{meq of } S_2O_3^{2-} = 20.0 \text{ mL} \times 0.10 \text{ M} \times 1 = 2.0 \text{ meq}$$

By law of chemical equivalence:

$$\text{meq of active } Cu^{2+} = \text{meq of } S_2O_3^{2-} = 2.0 \text{ meq}$$

Final Answer: $\boxed{2.0 \text{ meq}}$

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

Go Back to Question 7

Q8.

Solution

Concept: Fractional distillation segregates components of a miscible liquid mixture based on differences in their boiling points. The fractionating column provides a high surface area where rising vapors encounter cooler surfaces.

Solution:

1. **Examine Micro-Processes in Zone Ω:** As the vapor mixture travels up the packed column, it cools, causing the higher-boiling component (H_2O) to condense preferentially. The heat released during this condensation vaporizes the lower-boiling component (ethanol) from the descending liquid phase.

2. **Identify Vapor Enrichment Mechanism:** This continuous series of vaporizations and condensations up the column enriches the vapor phase in the more volatile component (bio-ethanol), isolating it efficiently before it enters the condenser.

Final Answer: Successive continuous cycles of vapor condensation and liquid revaporization resulting in phase enrichment.

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: Strongly acidic lateritic soils contain elevated levels of hydrous oxides of iron and aluminum. Soluble orthophosphate fertilizers ($H_2PO_4^-$) react quickly with these mineral edge boundaries, converting into highly stable, insoluble forms.

Solution:

1. **Identify the Fixation Pathway:** Phosphate ions have a strong affinity for the hydroxylated edges of minerals like gibbsite ($Al(OH)_3$) and goethite ($FeO(OH)$).

2. **Characterize Surface Adsorption:** The fixation proceeds via ligand exchange, where phosphate anions displace OH^- or H_2O ligands directly from the coordination sphere of surface Al^{3+} or Fe^{3+} ions. This forms stable, binuclear inner-sphere complexes that prevent phosphate release into the soil solution.

Final Answer: Chemisorption on active edge sites of gibbsite ($Al(OH)_3$) and goethite ($FeO(OH)$) through ligand-exchange reactions.

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: The distribution of electrons within an atom or ion is dictated by quantum numbers: principal (n), azimuthal (l), magnetic (m_l), and spin (s). Identifying specific subshells requires matching these quantum parameters to the electronic configuration of the target species.

Solution:

1. **Determine Electron Configuration of Mn^{2+}:** Manganese ($Z = 25$) has a ground-state configuration of:

$$\text{Mn} : 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$$

Ionization to form the divalent Mn^{2+} ion removes the two outermost $4s$ valence electrons:

$$\text{Mn}^{2+} : 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$$

2. **Apply Quantum Number Criteria:**

- The condition $l = 2$ defines a d subshell. In Mn^{2+}, this corresponds exclusively to the $3d$ subshell, which contains 5 electrons.
- A d subshell ($l = 2$) features 5 distinct spatial orbitals corresponding to $m_l = -2, -1, 0, +1, +2$.
- By Hund's rule, the 5 electrons in the $3d$ subshell are distributed singly across these 5 orbitals.
- Therefore, exactly one electron resides in the $m_l = +1$ orbital, and exactly one electron resides in the $m_l = -1$ orbital.

Summing these up yields a total of $1 + 1 = 2$ electrons.

Final Answer: $\boxed{2}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Freezing point depression data can be used to calculate the molality of a solution. For dilute aqueous matrices, molality approximates molarity, allowing the calculation of osmotic pressure (Π) via the van 't Hoff relation.

Solution:

1. **Extract Solution Concentration from ΔT_f:** The cryoscopic depression is expressed as:

$$\Delta T_f = i \cdot K_f \cdot m$$

Given $\Delta T_f = 0.558°\text{C}$ and $K_f = 1.86$ K kg mol^{-1}:

$$\text{Effective Molality } (i \cdot m) = \frac{\Delta T_f}{K_f} = \frac{0.558}{1.86} = 0.300 \text{ mol kg}^{-1}$$

Assuming an ideal aqueous solution density of 1.0 g mL^{-1}, the effective molarity (C) is equal to 0.300 M.

2. **Calculate Osmotic Pressure (Π):** Using the ideal gas relation at a physiological temperature of 27°C (300.15 K):

$$\Pi = C \cdot R \cdot T$$

$$\Pi = 0.300 \text{ mol L}^{-1} \times 0.0821 \text{ L atm mol}^{-1}\text{K}^{-1} \times 300 \text{ K} = 7.389 \text{ atm} \approx 7.39 \text{ atm}$$

Final Answer: $\boxed{7.39 \text{ atm}}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The radial probability distribution curve, $4\pi r^2 R^2(r)$, plots the likelihood of finding an electron at a given distance r from the nucleus. The physical points where this probability function drops to zero (excluding $r = 0$ and $r = \infty$) correspond to radial nodes. The number of radial nodes is given by the formula:

$$\text{Radial Nodes} = n - l - 1$$

Solution:
1. **Count Radial Nodes from the Plot:** The provided distribution trace passes through zero at two intermediate positions (r_1 and r_2) before approaching zero at long distances. This indicates the orbital contains exactly 2 radial nodes.
2. **Test Electronic Subshell Candidates:**

- For a $2s$ subshell: $n = 2, l = 0 \implies 2 - 0 - 1 = 1$ node.
- For a $3p$ subshell: $n = 3, l = 1 \implies 3 - 1 - 1 = 1$ node.
- For a $4s$ subshell: $n = 4, l = 0 \implies 4 - 0 - 1 = 2$ nodes.
- For a $3d$ subshell: $n = 3, l = 2 \implies 3 - 2 - 1 = 0$ nodes.

The $4s$ subshell matches the 2 radial nodes observed in the plot.
Final Answer: $\boxed{4s \text{ subshell}}$

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

Go Back to Question 12

Q13.

Solution

Concept: Thermal decarboxylation of alkanoic acid salts using soda-lime (NaOH+CaO) eliminates the carboxylate group as a carbonate anion. This mechanism involves the heterolytic cleavage of the carbon-carbon bond, generating a highly unstable carbanion intermediate.

Solution:

1. **Analyze the Reaction Mechanism:** Base treatment deprotonates ethanoic acid to form an acetate anion (CH_3COO^-). At high temperatures, this anion undergoes heterolytic cleavage, shifting electron density to release carbon dioxide (CO_2, trapped as CO_3^{2-}):

$$CH_3COO^- \rightarrow : CH_3^- + CO_2$$

2. **Identify the Rate-Limiting Step:** The high-energy methyl carbanion intermediate ($: CH_3^-$) is unstable. Its formation via $C-C$ bond cleavage requires a large activation energy, making it the rate-limiting step of the decarboxylation process. The carbanion then quickly abstracts a proton from water/alkali to form methane (CH_4).

Final Answer: $\boxed{\text{A localized carbanion intermediate } (: CH_3^-).}$

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: The stability of metal-ligand chelates over unchelated coordination complexes is driven primarily by the chelate effect. Polydentate ligands like $EDTA^{4-}$ bind a central metal ion at multiple coordination sites, forming stable, fused ring networks.

Solution:

1. **Analyze the Chelation Process:** When $EDTA^{4-}$ wraps around a hydrated zinc ion (Zn^{2+}), it acts as a hexadentate ligand, forming five separate five-membered heterocyclic chelate rings.
2. **Examine Thermodynamic Factors:** This reaction replaces several coordinated, unidentate water molecules with a single polydentate ligand molecule:

$$[Zn(H_2O)_6]^{2+} + EDTA^{4-} \rightleftharpoons [Zn(EDTA)]^{2-} + 6H_2O$$

This significant increase in molecular disorder generates a large positive entropy change ($\Delta S^\circ > 0$). This entropic stabilization makes the complex highly stable against pH shifts compared to simple inorganic salts.

Final Answer: $\boxed{\text{The entropic gain resulting from the creation of multiple five-membered heterocyclic chelate ring structures enclosing the zinc atom.}}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: The Mulliken electronegativity scale (X_M) is defined as the average of an atom's ionization energy (IE) and its electron affinity (EA). To convert this value to the Pauling scale (X_P), a linear transformation empirical conversion factor is applied.

Solution:

1. **Calculate Mulliken Electronegativity (X_M):** Using the given values ($IE = 14.0$ eV and $EA = 3.4$ eV):

$$X_M = \frac{IE + EA}{2} = \frac{14.0 + 3.4}{2} = \frac{17.4}{2} = 8.7 \text{ eV}$$

2. **Convert to the Pauling Scale (X_P):** The conversion relationship when energies are expressed in electron-volts (eV) is given by:

$$X_P = \frac{X_M}{2.8}$$

$$X_P = \frac{8.7}{2.8} \approx 3.107 \approx 3.1$$

Final Answer: $\boxed{3.1}$

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: Potentiometric acid-base titration curves plot pH as a function of the volume of added titrant. The number of distinct inflection points (pH breaks) corresponds to the number of separate neutralization steps that occur with significantly different equilibrium constants.

Solution:

1. **Analyze Inflection Points:** The provided titration curve clearly exhibits two distinct inflection points (α and β), indicating a two-step neutralization process.

2. **Deduce Molecular Configuration:** This two-stage profile is characteristic of a weak diprotic (dibasic) acid where the first acid dissociation constant is significantly larger than the second ($K_{a1} \gg K_{a2}$). This difference allows the neutralization of the first proton to finish (inflection α) before the neutralization of the second proton begins (inflection β).

Final Answer: $\boxed{\text{A weak diprotic acid exhibiting significantly different dissociation constants } (K_{a1} \gg K_{a2}).}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: The dehydration of ethanol by concentrated sulfuric acid (H_2SO_4) can proceed via competing monomolecular or bimolecular pathways depending on the reaction temperature.

Solution:

1. **Analyze Temperature Dependence:**

- **At** 140°**C:** The reaction follows a bimolecular substitution path (S_N2), where an unprotonated ethanol molecule attacks a protonated ethanol intermediate, preferentially yielding diethyl ether ($C_2H_5 - O - C_2H_5$).
- **At** 170°**C:** The reaction mechanism shifts to an elimination path ($E1/E2$). High thermal energy favors the elimination of a water molecule, generating an ethene double bond ($CH_2 = CH_2$).

2. **Identify Optimal Conditions:** Maintaining an elevated temperature of 170°C in the presence of concentrated acid maximizes the yield of ethene gas while suppressing ether formation.

Final Answer: $\boxed{\text{Treatment with excess concentrated } H_2SO_4 \text{ at an elevated temperature of } 170^\circ\text{C.}}$

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

Go Back to Question 17

Q18.

Solution

Concept: Enzymatic hydrolysis of urea fertilizer by soil urease releases ammonium carbonate, which temporarily increases the local soil pH:

$$CO(NH_2)_2 + 2H_2O \xrightarrow{\text{urease}} (NH_4)_2CO_3 \rightarrow 2NH_4^+ + CO_3^{2-}$$

Solution:

1. **Examine pH-Dependent Equilibrium:** In the soil matrix, ammonium ions exist in a pH-dependent equilibrium with aqueous ammonia gas:

$$NH_4^+ + OH^- \rightleftharpoons NH_3(aq) + H_2O$$

2. **Assess Volatilization Trajectory:** Applying urea to a soil that is already alkaline ($pH = 8.2$) shifts this equilibrium to the right. This converts a large fraction of the hydrolyzed nitrogen into volatile ammonia gas ($NH_3 \uparrow$), which escapes into the atmosphere and reduces nitrogen use efficiency.

Final Answer: $\boxed{\begin{array}{l}\text{Massive gaseous volatilization losses of ammonia } (NH_3 \uparrow) \text{ due to equilibrium} \\ \text{shifts favoring ammonia formation at elevated pH.}\end{array}}$

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

Go Back to Question 18

Q19.

Solution

Concept: The Born-Landé equation determines the structural lattice energy (U_0) of an ionic crystalline solid:

$$U_0 = \frac{N_A M z_+ z_- e^2}{4\pi\varepsilon_0 r_0}\left(1 - \frac{1}{n}\right)$$

This formula shows that for crystals with similar geometries and ionic radii (r_0), the lattice energy scales with the product of the ionic charges (z_+z_-).

Solution:

1. **Evaluate the Baseline Crystal (KCl):** Potassium chloride consists of monovalent ions, where $z_+ = 1$ and $z_- = 1$. The charge product is:

$$(z_+z_-)_{\text{KCl}} = 1 \times 1 = 1$$

2. **Evaluate the Substituted Crystal (CaS):** Replacing these with divalent species (Ca^{2+} and S^{2-}) while maintaining identical ionic radii values sets $z_+ = 2$ and $z_- = 2$. The new charge product is:

$$(z_+z_-)_{\text{CaS}} = 2 \times 2 = 4$$

Because $U_0 \propto (z_+z_-)$, the structural lattice energy increases approximately four-fold (4×).

Final Answer: The lattice energy scales up roughly four-fold (4×) due to the increase in the ionic charge product (z_+z_-).

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: Flame photometry relies on atomic emission spectroscopy. When an elemental sample is aspirated into a flame, the thermal energy excites valence electrons to higher energy states. As these electrons relax back to their ground states, they emit light at wavelengths characteristic of that element.

Solution:

1. **Identify Flame Emission Properties:** Excited potassium ions (K^+) emit light at a characteristic near-infrared/deep-violet wavelength of 766 nm.

2. **Identify Filter Function:** To accurately quantify potassium concentrations without interference from other elements (like sodium at 589 nm), a monochromatic optical filter is placed before the detector. This filter isolates the 766 nm emission line and blocks all other background light.

Final Answer: It isolates the specific emission wavelength at 766 nm while blocking out interfering background signals from other ions.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: During complexometric titrations of calcium and magnesium with EDTA at $pH = 10$, trivalent impurities like Fe^{3+} and Al^{3+} bind irreversibly to the Eriochrome Black T (EBT) indicator. This blocks the indicator, preventing the sharp color change at the titration endpoint.

Solution:

1. **Identify the Masking Mechanism:** To prevent this blocking without physical separation, a masking agent must be added to the sample before titration.

2. **Select a Masking Agent:** Adding triethanolamine (TEA) or potassium cyanide (KCN) introduces ligands that form highly stable, water-soluble coordination complexes with Fe^{3+} and Al^{3+}. These complexes are much more stable than the metal-indicator or metal-EDTA complexes. This effectively masks the impurities, leaving the EBT indicator free to bind Ca^{2+} and Mg^{2+} and change color sharply at the endpoint.

Final Answer: $\boxed{\text{Adding KCN or triethanolamine (TEA) to act as chemical masking agents by forming highly stable complexes with the interfering cations.}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: The acidity of an organic molecule depends on the stability of its conjugate base. Electron-withdrawing substituents stabilize the conjugate base, increasing acidity, while electron-donating groups destabilize it, decreasing acidity.

Solution:

1. **Compare Carboxylic Acids:** Methanoic acid (HCOOH) and ethanoic acid (CH_3COOH) are more acidic than alcohols and phenols because resonance delocalizes the negative charge across two electronegative oxygen atoms in the carboxylate anion. Methanoic acid is stronger than ethanoic acid because the methyl group in ethanoic acid is electron-donating ($+I$), which destabilizes the conjugate base. Thus, HCOOH > CH_3COOH.

2. **Compare Phenol and Alcohol:** Phenol (C_6H_5OH) is more acidic than propan-2-ol ($(CH_3)_2CHOH$) because resonance delocalizes the lone pair on the phenoxide oxygen into the aromatic ring. The conjugate base of propan-2-ol is destabilized by the $+I$ inductive effect of two methyl groups. Thus, $C_6H_5OH > (CH_3)_2CHOH$.

3. **Combine the Trends:** The final decreasing order of proton-donating ability is: Methanoic acid > Ethanoic acid > Phenol > Propan-2-ol.

Final Answer: $\boxed{\text{Methanoic acid > Ethanoic acid > Phenol > Propan-2-ol}}$

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: In the Schrödinger wave mechanics model of the atom, the wave function (Ψ) represents the amplitude of the electron wave, which can have positive or negative values.

Solution:

1. **Interpret Born's Postulate:** According to Max Born's statistical interpretation of quantum mechanics, the wave function amplitude itself has no physical meaning. However, its mathematical square (Ψ^2) is always positive and represents a real physical property.

2. **Define Probability Density:** The quantity Ψ^2 represents the radial probability density of finding an electron at a specific coordinate location. Consequently, the product $\Psi^2 dV$ defines the probability of finding the electron within that infinitesimal volume element (dV) surrounding the nucleus.

Final Answer: The radial probability density for finding the electron within that specific coordinate region.

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept: Expansive black cotton soils (Vertisols) owe their high shrink-swell capacity to dominance by 2:1 expanding silicate clay minerals. These minerals generate a permanent negative surface charge through structural modifications during crystalline formation.

Solution:

1. **Identify Crystalline Sheet Layout:** The diagram shows a 2:1 structural arrangement consisting of one octahedral sheet sandwiched between two tetrahedral sheets. This structure is characteristic of the smectite group, specifically montmorillonite clay.

2. **Examine Isomorphous Substitution:** The red arrows highlight instances where a lower-valence cation replaces a higher-valence cation of similar size within the crystal lattice (e.g., Al^{3+} replacing Si^{4+} in the tetrahedral sheet, or Mg^{2+} replacing Al^{3+} in the octahedral sheet). This process, known as isomorphous substitution, leaves an uncompensated negative charge on the clay surface, giving the mineral a permanent negative charge and a high cation exchange capacity.

Final Answer: Smectite (Montmorillonite) group, displaying internal permanent negative charge generation via isomorphous substitution.

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Reclaiming sodic soils requires replacing toxic exchangeable sodium ions (Na^+) on clay surfaces with divalent calcium ions (Ca^{2+}). This displacement flocculates the clay particles, improving soil structure and permeability.

Solution:

1. **Analyze Cation Exchange Mechanism:** Applying gypsum ($CaSO_4 \cdot 2H_2O$) releases soluble Ca^{2+} ions into the soil solution. Because divalent cations have a higher affinity for clay exchange sites than monovalent cations, Ca^{2+} displaces the adsorbed Na^+ ions:

$$2\text{Na-Clay} + Ca^{2+}_{(aq)} \rightleftharpoons \text{Ca-Clay}_2 + 2Na^+_{(aq)}$$

2. **Identify Leaching Outcome:** The displaced Na^+ ions enter the solution phase, where they react with sulfate anions to form highly soluble sodium sulfate (Na_2SO_4). Flushing the soil with fresh water leaches this soluble salt downward out of the root zone, reducing the exchangeable sodium percentage (ESP) and reclaiming the soil.

Final Answer: Soluble Ca^{2+} ions displace adsorbed exchangeable Na^+ ions into the soil solution phase, where they are leached from the root zone as soluble Na_2SO_4.

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	A	4	B	5	C
6	B	7	B	8	B	9	B	10	A
11	B	12	C	13	C	14	A	15	B
16	B	17	B	18	B	19	A	20	B
21	A	22	A	23	C	24	B	25	A