UPCATET Agriculture Chemistry Sample Paper-3

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 determines that a highly weathered acidic Ultisol exhibits a high level of exchangeable aluminum ions (Al^{3+}). When calculating the theoretical lime requirement using the aluminum saturation index, which of the following expressions precisely represents the hydrolytic behavior of exchangeable aluminum that drives the reserve acidity of the soil solution?

(A) $Al^{3+} + H_2O \rightleftharpoons Al(OH)^{2+} + H^+$

(B) $Al^{3+} + 3OH^- \rightleftharpoons Al(OH)_3$

(C) $2Al^{3+} + 3CO_3^{2-} + 3H_2O \rightleftharpoons 2Al(OH)_3 + 3CO_2$

(D) $Al^{3+} + 4H_2O \rightleftharpoons Al(OH)_4^- + 4H^+$

Q2. During the structural dynamic fixation of potassium (K^+) in expanded 2:1 clay minerals like vermiculite and montmorillonite, the ions are entrapped within a specific geometrical site. Identify the exact structural coordinate site where K^+ loses its hydration shell and becomes permanently fixed.

(A) Octahedral gibbsite sheet cavities

(B) Hexagonal oxygen cavities of the tetrahedral sheet

(C) Isomorphous substitution gaps within the brucite layer

(D) Outer-sphere complex spaces along planar broken edges

Q3. An agronomist applications a heavy dosage of an advanced polyphosphate liquid fertilizer. Before the orthophosphoric form ($H_2PO_4^-$) can be readily absorbed by the root hairs of *Zea mays*, what specific biological agent or catalytic enzyme must mediate the structural cleavage of the pyrophosphate bonds ($P-O-P$) in the rhizosphere?

(A) Pyruvate kinase

(B) Pyrophosphatase / Phosphatase enzymes

(C) Nitrogenase complex

(D) Dehydrogenase systems

Q4. Consider a submerged rice paddy soil condition where the redox potential (E_h) drops sequentially. After the exhaustion of nitrate (NO_3^-) and manganese (Mn^{4+}) as electron acceptors, which specific chemical transformation pathway dominates the rhizosphere, severely affecting the availability of zinc and iron?

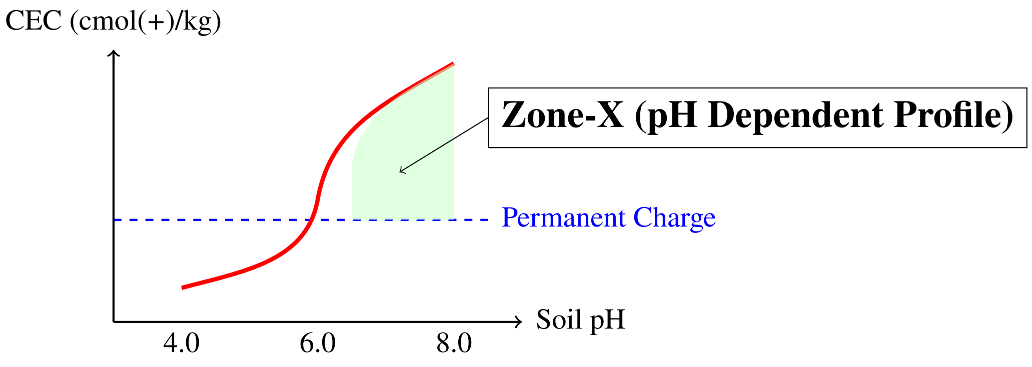
(A) Reduction of SO_4^{2-} to H_2S causing precipitation of metallic sulfides

(B) Oxidation of Fe^{2+} to insoluble Fe^{3+} oxyhydroxides

(C) Dissociation of calcium phosphate into hydroxyapatite crystals

(D) Volatilization of elemental nitrogen through aerobic nitrification

Q5. An advanced soil physics and mineralogical profile mapping system tracks the relative dynamic cation exchange capacity (CEC) variation alongside shifting pH ranges across prominent clay profiles. Identify the specific variable-charge boundary condition marked as **Zone-X** in the interactive schematic profile below where variable charge completely dominates over permanent structural charge:



(A) Isomorphous substitution zone of Kaolinite

(B) Edge-protonation and deprotonation zone of Fe/Al hydrous oxides

(C) Internal interlayer space contraction zone of Illite

(D) Non-expanding crystalline framework zone of Quartz grains

Q6. A biogas slurry sample yields a volatile organic acid mixture. During laboratory dry distillation of anhydrous sodium propionate (C_2H_5COONa) with solid soda lime ($NaOH + CaO$), which specific saturated hydrocarbon is selectively evolved as the principal gaseous product?

(A) Methane (CH_4)

(B) Ethane (C_2H_6)

(C) Propane (C_3H_8)

(D) Butane (C_4H_{10})

Q7. An agrochemical researcher synthesizes a pesticide intermediate via the absolute controlled oxidation of ethyl alcohol (CH_3CH_2OH). If the reaction is conducted using acidified potassium dichromate ($K_2Cr_2O_7/H_2SO_4$) under reflux without distillation of volatile intermediates, what is the terminal major structural organic acid synthesized?

(A) Formic Acid ($HCOOH$)

(B) Acetic Acid (CH_3COOH)

(C) Oxalic Acid ($HOOC\text{-}COOH$)

(D) Propionic Acid (CH_3CH_2COOH)

Q8. The biochemical synthesis of structural cellular matrices within plant tissue involves esterification. When an alcohol reacts with an organic carboxylic acid under a catalytic quantity of concentrated H_2SO_4, what specific structural mechanism determines the origin of the oxygen atom present within the newly formed water (H_2O) molecule?

(A) The $-OH$ group is exclusively lost from the organic carboxylic acid.

(B) The −OH group is exclusively lost from the alcohol moiety.

(C) The oxygen atom is sourced completely from the atmospheric dissolved gases.

(D) The catalyst H_2SO_4 donates its structural oxygen to form water.

Q9. During cold climate storage analysis of vinegar-based agro-preservatives, a pure sample of acetic acid undergoes freezing at 16.6°C forming an ice-like crystalline mass. This pristine chemical phenomenon has earned it which specific chemical nomenclature across industrial analytical standards?

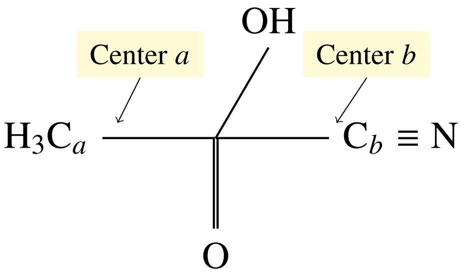
(A) Amorphous ethanoic acid

(B) Glacial acetic acid

(C) Vitriolic organic cream

(D) Perchloric acetic anhydride

Q10. The structural conformation layout of an advanced organic compound molecule involved in plant growth regulation pathway is mapped below. Evaluate the specific spatial hybridization configurations of the carbon centers marked as **C_a** and **C_b** respectively:



(A) $C_a = sp^3$, $C_b = sp$

(B) $C_a = sp^2$, $C_b = sp^3$

(C) $C_a = sp$, $C_b = sp^2$

(D) $C_a = sp^3$, $C_b = sp^2$

Q11. An agro-environmental spectroscopic sensor utilizes the electronic transitions of micro-elements. According to the Bohr-Sommerfeld atomic model and modern quantum mechanical rules, what is the exact maximum number of orbital angular momentum orientations permitted for an electron residing inside a subshell defined by azimuthal quantum number $l = 3$?

(A) 5

(B) 7

(C) 10

(D) 14

Q12. The structural rigidity of specialized silicon-based fertilizers involves high-strength bonding networks. Rank the following primary chemical and intermolecular structural forces in the exact descending order of their average relative bonding dissociation energies: Ionic Bond (I), Covalent Bond (C), Hydrogen Bond (H), London Dispersion Forces (L).

(A) $I > C > H > L$

(B) $C > I > L > H$

(C) $H > I > C > L$

(D) $L > H > C > I$

Q13. When evaluating the modern periodic trends of critical micronutrient elements (such as Cu, Zn, Fe, Mn), which of the following phenomena is principally responsible for the characteristic property where transition elements exhibit variable oxidation states?

(A) Large energy gap between ns and $(n-1)d$ subshells

(B) Exceptionally small energy difference between ns and $(n-1)d$ subshells

(C) High shielding efficacy of inner-shell f-orbital configurations

(D) Complete thermodynamic stabilization of paired p-orbital arrays

Q14. A laboratory high-precision flame photometer analyzes potassium chloride (KCl) salts extracted from soil. In terms of chemical bonding theory, which specific factors maximize the absolute lattice energy ($\Delta H_{\text{lattice}}$) value of an ionic compound?

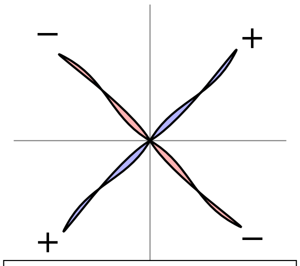
(A) Large ionic radii and small ionic charges

(B) Small ionic radii and highly magnified ionic charges

(C) Minimal difference in electronegativity values between bonding elements

(D) Maximum hydration enthalpy of the gaseous neutral atomic species

Q15. An advanced structural chemistry crystal mapping matrix visualizes the molecular orbital orientation of a coordinated ligand molecule inside a metal-chelate plant fertilizer complex. Identify the specific spatial overlap orbital node layout highlighted as **Configuration-Y** in the structural layout diagram below:



Configuration-Y

(A) p_z atomic orbital symmetry

(B) $d_{x^2-y^2}$ spatial atomic orbital configuration

(C) d_{xy} spatial atomic orbital configuration

(D) σ_{sp^3} hybridized bonding orbital profile

Q16. A standard technical grade solution of sulfuric acid (H_2SO_4) is prepared for structural soil reclamation. If a laboratory technician dissolves 4.9 grams of pure H_2SO_4 into a terminal total volumetric flask capacity of exactly 250 mL of distilled water, what is the exact Normality (N) of the resultant solution?

(A) 0.1 N

(B) 0.2 N

(C) 0.4 N

(D) 0.8 N

Q17. During a complex complexometric/acid-base titration setup to evaluate the calcium carbonate equivalence of irrigation water, an analyst utilizes a weak organic chemical indicator system. If the indicator exhibits a pK_{in} value of 5.0, what is the mathematically defined theoretical pH transitional effective range across which this indicator displays its visual color transition?

(A) pH 3.0 to 7.0

(B) pH 4.0 to 6.0

(C) pH 5.0 to 9.0

(D) pH 1.0 to 14.0

Q18. A standard stock solution containing 1 M sodium hydroxide (NaOH) needs to be precisely titrated against a sample of toxic runoff water. If 50 mL of this 1 M stock solution is diluted to a new final aggregate volume of 500 mL, what volume of this diluted solution is required to neutralize exactly 25 mL of a 0.2 M standard hydrochloric acid (HCl) solution?

(A) 10 mL

(B) 25 mL

(C) 50 mL

(D) 100 mL

Q19. According to the operational fundamental thermal thermodynamic parameters governing solutions, why is the parameter "Molality (m)" highly preferred over "Molarity (M)" when reporting high-precision global agrochemical soil test metrics spanning variable climatic test zones?

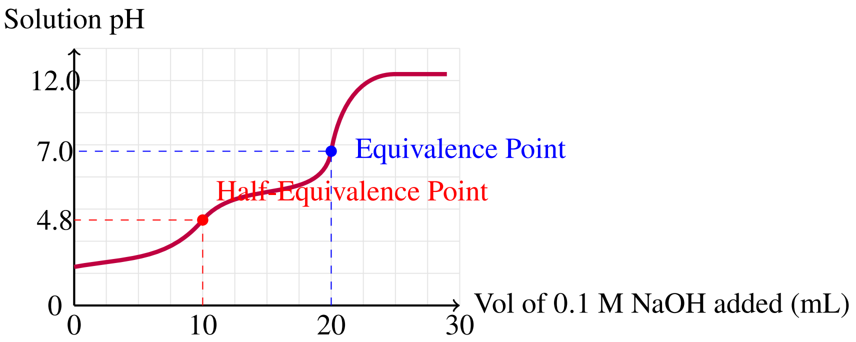
(A) Molality relies directly on density metrics which fluctuate with heavy salt content.

(B) Molality is completely independent of temperature alterations as it is based on solvent mass.

(C) Molarity calculations eliminate the error induced by gas-phase volatile escapes.

(D) Molality scales logarithmically with changing atmospheric barometric pressures.

Q20. An industrial automated titration management device prints a digital visual tracking curve during the neutralization of a weak acid extracted from decomposed organic matter (25 mL sample) titrated against a highly standardized strong base (0.1 M NaOH). Analyze the precise neutralization curve signature shown below to identify the calculated pK_a value of the target organic acid sample:



(A) pK_a = 7.0

(B) pK_a = 12.0

(C) pK_a = 4.8

(D) pK_a = 2.4

Q21. A specialized mineral fertilizer solution composition contains ammonium nitrate (NH_4NO_3). If a researcher requires an aqueous system where the total ionic strength (μ) is exactly equal to its molarity (M), which of the following electrolyte salts must be avoided due to its multi-valent scaling factor?

(A) NaCl

(B) KNO_3

(C) $MgSO_4$

(D) NH_4Cl

Q22. What specific chemical phenomenon accounts for the severe reduction in the solubility of gypsum ($CaSO_4 \cdot 2H_2O$) when it is applied to an alkaline soil formation that already possesses high concentrations of dissolved sodium sulfate (Na_2SO_4)?

(A) Amphoteric complexation effect

(B) Common-ion effect due to excess SO_4^{2-} ions

(C) Chelation effect driven by sodium ions

(D) Coordinate covalent framework dissociation

Q23. The fundamental structural transformation sequence of Nitrogen in soil undergoes specific kinetic stages. Identify the exact intermediate compound generated during the biological conversion stage of ammonium (NH_4^+) to nitrite (NO_2^-) mediated specifically by *Nitrosomonas* bacteria before terminal oxidation by *Nitrobacter*:

(A) Hydroxylamine (NH_2OH)

(B) Nitric acid (HNO_3)

(C) Dinitrogen oxide (N_2O)

(D) Nitrogen dioxide (NO_2)

Q24. During a specific structural laboratory identification assay of organic functional groups present within plant humic substances, an unknown sample displays an instantaneous silver mirror precipitation when combined with ammoniacal silver nitrate solution (Tollens' reagent). This behavior positively validates the existence of which terminal group?

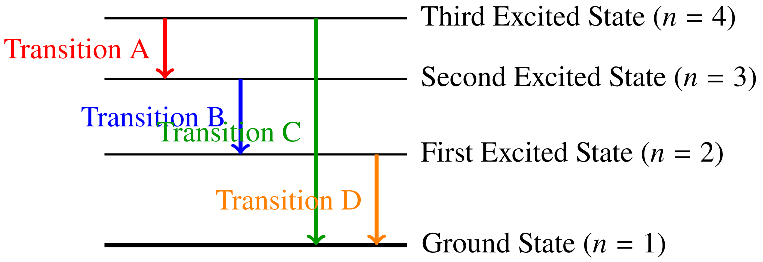
(A) Ketone Group (−CO−)

(B) Ester Linkage (−COOR−)

(C) Aldehyde Group (−CHO)

(D) Phenolic Hydroxyl Group (−OH)

Q25. An automated elemental atomic absorption spectroscopy (AAS) diagnostic chamber scans the operational energy level shells of a target magnesium micronutrient atom. Evaluate the transition schematic map provided below to determine which specific electronic downward jump emits the highest frequency quantum photon energy:



(A) Transition A

(B) Transition B

(C) Transition C

(D) Transition D

Detailed Solutions

Q1.

Solution

Concept: Exchangeable aluminum (Al^{3+}) is a primary driver of reserve acidity in highly weathered soils like Ultisols. When it is displaced into the soil solution, it undergoes a multi-step hydrolytic reaction with water, releasing hydrogen ions (H^+) and lowering the pH of the soil solution.

Solution:

1. **Identify the Stepwise Hydrolysis Process:** In an acidic soil solution, the hexaaquaaluminum ion undergoes a series of dynamic hydrolysis steps. The first step involves a single water molecule:

$$Al^{3+} + H_2O \rightleftharpoons Al(OH)^{2+} + H^+$$

This reaction releases a free hydronium/hydrogen ion directly into the soil solution, contributing significantly to active and reserve acidity.

2. **Evaluate the Alternatives:** * Option (B) represents complete chemical precipitation, not solution equilibrium hydrolysis. * Option (C) represents neutralization via carbonate addition rather than self-hydrolysis. * Option (D) shows the formation of aluminate, which only occurs under highly alkaline conditions.

Final Answer: $\boxed{Al^{3+} + H_2O \rightleftharpoons Al(OH)^{2+} + H^+}$

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

Go Back to Question 1

Q2.

Solution

Concept: Potassium fixation occurs when unhydrated K^+ ions fit perfectly inside the structural openings of specific 2:1 expanding phyllosilicates. The physical size of the dehydrated potassium ion matches the dimensions of these cavities, leading to layer contraction.

Solution:

1. **Identify the Mineral Cavity Geometry:** The sheets of 2:1 clay minerals (like vermiculite and illite) are composed of linked SiO_4 tetrahedra arranged in a ring layout. This arrangement forms a network of **hexagonal oxygen cavities** along the internal surface boundaries.

2. **Analyze Cation Entrapment:** Because of its low hydration energy compared to smaller ions like Mg^{2+} or Ca^{2+}, the K^+ ion readily sheds its surrounding hydration shell. It coordinates directly with the twelve oxygen atoms surrounding the hexagonal cavity, drawing the adjacent sheets together and locking the ion inside the contracted mineral lattice.

Final Answer: $\boxed{\text{Hexagonal oxygen cavities of the tetrahedral sheet}}$

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

Go Back to Question 2

Q3.

Solution

Concept: Polyphosphate fertilizers contain condensed phosphorus networks linked via pyro- or polyphosphate ($P-O-P$) ester chains. Plant roots can only absorb phosphorus as orthophosphate monomers ($H_2PO_4^-$ or HPO_4^{2-}), making structural enzymatic cleavage necessary.

Solution:

1. **Identify the Target Chemical Bond:** The hydrolysis reaction breaks down pyrophosphate molecules into individual orthophosphate units by cleaving the central oxygen bridge:

$$P_2O_7^{4-} + H_2O \rightarrow 2HPO_4^{2-}$$

2. **Determine the Catalytic Enzyme Class:** This reaction is catalyzed by **pyrophosphatase** or general **phosphatase** enzymes. These hydrolase systems are secreted by both soil microorganisms and plant root hairs into the rhizosphere, converting polyphosphates into bioavailable orthophosphate forms.

Final Answer: $\boxed{\text{Pyrophosphatase / Phosphatase enzymes}}$

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

Go Back to Question 3

Q4.

Solution

Concept: As a soil remains submerged, oxygen is depleted, causing the redox potential (E_h) to drop. Anaerobic microorganisms must use alternative electron acceptors in a predictable thermodynamic sequence: $O_2 \rightarrow NO_3^- \rightarrow Mn^{4+} \rightarrow Fe^{3+} \rightarrow SO_4^{2-}$.

Solution:

1. **Trace the Redox Cascade Sequence:** Once nitrate and manganese are exhausted, iron reduction ($Fe^{3+} \rightarrow Fe^{2+}$) takes place. In highly reduced conditions, sulfate-reducing bacteria oxidize organic matter by using sulfate (SO_4^{2-}) as a terminal electron acceptor:

$$SO_4^{2-} + 8H^+ + 8e^- \rightarrow H_2S + 2H_2O + 2OH^-$$

2. **Determine the Impact on Metal Availability:** The generated hydrogen sulfide (H_2S) reacts rapidly with soluble transition metal cations like Zn^{2+} and Fe^{2+}, forming highly insoluble metallic precipitates (ZnS and FeS):

$$Zn^{2+} + S^{2-} \rightarrow ZnS(s)$$

This immobilization dramatically reduces the bioavailability of zinc and iron in the rhizosphere of the paddy field.

Final Answer: $\boxed{\text{Reduction of } SO_4^{2-} \text{ to } H_2S \text{ causing precipitation of metallic sulfides}}$

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

Go Back to Question 4

Q5.

Solution

Concept: Soil cation exchange capacity (CEC) can originate from permanent charge sites or variable (pH-dependent) charge sites. Permanent charge results from isomorphous substitution within clay mineral lattices, whereas variable charge develops from the protonation and deprotonation of surface functional groups at mineral edges and on organic matter surfaces.

Solution:

1. **Analyze the Zone-X Graphical Region:** Zone-X highlights the region at higher pH levels where the CEC curve rises sharply above the permanent charge baseline. This change represents a significant accumulation of pH-dependent negative charge.

2. **Identify the Underlying Mineralogical Mechanism:** As the pH increases, hydroxylated edges of iron/aluminum hydrous oxides (Fe/Al-oxides) and 1:1 minerals lose protons (H^+), transforming neutral or positively charged sites into negatively charged exchange sites:

$$\text{Al-OH} + \text{OH}^- \rightleftharpoons \text{Al-O}^- + H_2O$$

This **edge-protonation and deprotonation zone of Fe/Al hydrous oxides** is responsible for the variable charge characteristics shown in the diagram.

Final Answer: $\boxed{\text{Edge-protonation and deprotonation zone of Fe/Al hydrous oxides}}$

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

Go Back to Question 5

Q6.

Solution

Concept: Thermal dry distillation of a sodium salt of a fatty carboxylic acid with soda lime (NaOH + CaO) is a standard laboratory method for the decarboxylation of organic acids, yielding an alkane containing one less carbon atom than the starting material salt.

Solution:

1. **Formulate the Decarboxylation Equation:** The reaction of sodium propionate with sodium hydroxide can be written as:

$$CH_3CH_2COONa + NaOH \xrightarrow{\Delta,\text{CaO}} CH_3CH_3 + Na_2CO_3$$

2. **Identify the Evolved Gas Species:** The alkyl framework of the reactant is an ethyl group (C_2H_5-). Combining this with a proton from the base generates **ethane (C_2H_6)**. Calcium oxide (CaO) does not participate directly in the stoichiometry but acts to reduce the hygroscopic nature of the solid mixture.

Final Answer: $\boxed{\text{Ethane } (C_2H_6)}$

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

Go Back to Question 6

Q7.

Solution

Concept: Primary aliphatic alcohols undergo a two-stage oxidation when treated with strong oxidizing agents. They are initially converted to aldehydes, which are then further oxidized to carboxylic acids.

Solution:

1. **Trace the Oxidation Stages under Reflux:** Ethyl alcohol (CH_3CH_2OH) is a two-carbon primary alcohol. When treated with acidified potassium dichromate ($K_2Cr_2O_7/H_2SO_4$), it is first oxidized to acetaldehyde (CH_3CHO):

$$CH_3CH_2OH \xrightarrow{[O]} CH_3CHO + H_2O$$

2. **Identify the Final Stable Product:** Because the system is held under reflux conditions without removing the volatile intermediate aldehyde, the acetaldehyde is rapidly oxidized further to form **acetic acid (CH_3COOH)**:

$$CH_3CHO \xrightarrow{[O]} CH_3COOH$$

Final Answer: $\boxed{\text{Acetic Acid } (CH_3COOH)}$

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

Go Back to Question 7

Q8.

Solution

Concept: Fischer esterification links an alcohol and a carboxylic acid to produce an ester and water. Isotopic labeling experiments provide insight into the specific bond-cleavage pathways that form the water byproduct.

Solution:

1. **Examine the Nucleophilic Acyl Substitution Pathway:** The reaction begins with protonation of the carboxylic acid's carbonyl oxygen. The alcohol molecule then attacks the carbonyl carbon to form a tetrahedral intermediate:

$$\text{R-COOH} + \text{R}'\text{-OH} \xrightarrow{H^+} \text{R-COOR}' + H_2O$$

2. **Determine the Origin of the Water Molecule Components:** Proton transfers within the tetrahedral intermediate convert one of the carboxylic acid's original hydroxyl groups into a good leaving group ($-OH_2^+$). Elimination of this leaving group yields water, demonstrating that **the $-OH$ group is exclusively lost from the organic carboxylic acid**, while the alcohol donates only a proton (H^+).

Final Answer: $\boxed{\text{The } -OH \text{ group is exclusively lost from the organic carboxylic acid.}}$

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

Go Back to Question 8

Q9.

Solution

Concept: Pure anhydrous ethanoic acid has a relatively high melting point compared to aqueous solutions. Its physical properties change noticeably at temperatures slightly below typical room temperature.

Solution:

1. **Analyze the Melting Point Properties:** Pure, water-free acetic acid has a melting point of exactly 16.6°C (62°F).

2. **Identify the Standard Nomenclature:** When the ambient laboratory temperature drops below this threshold, the acid solidifies into a well-defined, transparent crystalline solid that resembles water ice. This property has earned anhydrous acetic acid the standard designation **Glacial acetic acid**.

Final Answer: $\boxed{\text{Glacial acetic acid}}$

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

Go Back to Question 9

Q10.

Solution

Concept: The hybridization state of a carbon atom depends on the number of electron domains (sigma bonds and lone pairs) surrounding it. Single bonds are sigma (σ) bonds, a double bond consists of one σ and one pi (π) bond, and a triple bond contains one σ and two π bonds.

Solution:

1. **Evaluate Carbon Center C_a:** The carbon designated as C_a is part of a methyl group (H_3C-). It forms four single σ bonds (three with hydrogen atoms and one with the carbonyl carbon), which corresponds to a tetrahedral geometry and an **sp^3** hybridization state.

2. **Evaluate Carbon Center C_b:** The carbon designated as C_b is part of a nitrile group ($-C \equiv N$). It forms one single σ bond with the adjacent carbon and one triple bond (one σ and two π bonds) with the nitrogen atom. This results in two electron domains, giving it a linear geometry and an **sp** hybridization state.

Final Answer: $\boxed{C_a = sp^3, C_b = sp}$

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

Go Back to Question 10

Q11.

Solution

Concept: The spatial orientation of an electron's orbital is defined by the magnetic quantum number (m_l). The allowed values for m_l are determined by the azimuthal quantum number (l), ranging from $-l$ to $+l$, which gives the total number of orientations within that subshell.

Solution:

1. **Apply the Magnetic Quantum Number Formula:** The total number of allowed spatial orientations for a given subshell is equal to $2l + 1$:

$$\text{Number of Orientations} = 2(3) + 1 = 7$$

2. **Enumerate the Permitted States:** For an f-subshell ($l = 3$), the seven possible magnetic spatial orientations are:

$$m_l = \{-3, -2, -1, 0, +1, +2, +3\}$$

Final Answer: $\boxed{7}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: Chemical structures are held together by a combination of strong intramolecular chemical bonds and weaker intermolecular forces. Comparing these forces requires assessing their average bond dissociation energies.

Solution:

1. **Evaluate Primary Intramolecular Chemical Bonds:** * **Covalent Bonds (C)**: Generally exhibit the highest average bond dissociation energies (typically 200 to 1000 kJ/mol) due to the strong sharing of electron pairs between nuclei, particularly in network solids like silicon structures. * **Ionic Bonds (I)**: Also possess high energies (typically 400 to 4000 kJ/mol for crystal lattices), but are generally outranked by strong network covalent bonds in terms of localized single-bond dissociation stability criteria.

2. **Evaluate Intermolecular Secondary Forces:** * **Hydrogen Bonds (H)**: Represent a relatively strong dipole-dipole attraction (typically 10 to 40 kJ/mol). * **London Dispersion Forces (L)**: Represent weak, transient induced dipole interactions, exhibiting the lowest energy profile (typically 0.1 to 10 kJ/mol).

3. **Establish the Correct Energy Hierarchy:**

$$C > I > H > L$$

Final Answer: $\boxed{C > I > H > L}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: Transition elements (d-block elements) are characterized by their ability to exhibit multiple, variable oxidation states in compounds. This behavior depends on the accessibility of valence electrons from different subshells during chemical bonding.

Solution:

1. **Analyze the Valence Subshell Energy Profiles:** The valence electronic configuration of a d-block element can be written generally as $(n-1)d^{1-10}ns^{1-2}$.

2. **Evaluate Variable Oxidation States:** Because there is an **exceptionally small energy difference between the ns and $(n-1)d$ subshells**, electrons from both subshells can participate in bond formation. As a result, transition metals can lose varying numbers of electrons depending on the chemical nature and electronegativity of the reacting ligand.

Final Answer: $\boxed{\text{Exceptionally small energy difference between } ns \text{ and } (n-1)d \text{ subshells}}$

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

Go Back to Question 13

Q14.

Solution

Concept: Lattice energy ($\Delta H_{\text{lattice}}$) is the energy released when gaseous ions combine to form one mole of an ionic crystal lattice. According to Coulomb's Law, the electrostatic potential energy driving this lattice formation is directly proportional to the product of the ionic charges and inversely proportional to the distance between them:

$$E \propto \frac{q_1 \cdot q_2}{r_0}$$

Solution:

1. **Analyze Charge Parameters (q):** Highly charged ions (such as Mg^{2+} or Al^{3+} compared to Na^+) significantly increase the numerator of the Coulombic expression, maximizing electrostatic attraction.

2. **Analyze Ionic Radius Parameters (r):** Smaller ionic radii allow the centers of the cations and anions to get closer together, minimizing the inter-nuclear separation distance (r_0). This smaller separation increases the total lattice energy of the ionic compound.

Final Answer: $\boxed{\text{Small ionic radii and highly magnified ionic charges}}$

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

Go Back to Question 14

Q15.

Solution

Concept: The spatial configurations of d-orbitals are defined by their angular nodes and orientation relative to the coordinate axes. The five degenerate d-orbitals are divided into two geometric groups: those that lie along the axes ($d_{x^2-y^2}$, d_{z^2}) and those that lie between the axes (d_{xy}, d_{xz}, d_{yz}).

Solution:

1. **Analyze the Lobe Orientation in Configuration-Y:** The four lobes of the orbital are positioned in the xy-plane. Their axes of maximum electron density lie exactly along the bisectors of the coordinate axes, meaning they are oriented **between** the x and y axes.

2. **Identify the Target d-Orbital:** This spatial distribution matches the **d_{xy} atomic orbital configuration**. The $d_{x^2-y^2}$ orbital has a similar four-lobe structure, but its lobes lie directly *along* the x and y axes.

Final Answer: $\boxed{d_{xy} \text{ spatial atomic orbital configuration}}$

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

Go Back to Question 15

Q16.

Solution

Concept: Normality (N) measures the concentration of a solution in equivalents per liter. It is related to molarity (M) by the equation $N = M \times n$, where n represents the number of transferable protons (H^+) or equivalents per mole of solute.

Solution:

1. **Calculate the Molarity (M) of Sulfuric Acid:** The molar mass of H_2SO_4 is 98.08 g/mol. Given 4.9 g of solute:

$$\text{Moles of } H_2SO_4 = \frac{4.9 \text{ g}}{98.08 \text{ g/mol}} \approx 0.050 \text{ moles}$$

The volume of the solution is 250 mL = 0.250 L:

$$M = \frac{0.050 \text{ moles}}{0.250 \text{ L}} = 0.20 \text{ M}$$

2. **Calculate the Normality (N):** Sulfuric acid is a diprotic acid ($n = 2$) because it can release two protons per molecule:

$$N = M \times n = 0.20 \text{ M} \times 2 = 0.4 \text{ N}$$

Final Answer: $\boxed{0.4 \text{ N}}$

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

Go Back to Question 16

Q17.

Solution

Concept: An acid-base indicator is a weak organic acid or base whose conjugate forms display different colors. The human eye can typically perceive a distinct color change when the ratio of the two forms shifts by a factor of 10, which defines the theoretical transition range using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{p}K_{in} \pm 1$$

Solution:

1. **Apply the Indicator Transition Rule:** The effective color transition of an indicator takes place across a range of approximately one pH unit on either side of its acid dissociation constant (pK_{in}):

$$\text{pH Range} = \text{p}K_{in} - 1 \text{ to } \text{p}K_{in} + 1$$

2. **Calculate the Specific Range for pK_{in} = 5.0:**

$$\text{pH}_{\text{lower}} = 5.0 - 1 = 4.0$$

$$\text{pH}_{\text{upper}} = 5.0 + 1 = 6.0$$

The indicator will display its visual color transition between **pH 4.0 and 6.0**.

Final Answer: $\boxed{\text{pH } 4.0 \text{ to } 6.0}$

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

Go Back to Question 17

Q18.

Solution

Concept: To solve neutralization problems involving dilutions, first determine the concentration of the working titrant solution using the dilution equation ($M_1V_1 = M_2V_2$). Then, apply the stoichiometric neutralization relationship ($M_AV_A = M_BV_B$) for the reaction between a strong acid and a strong base.

Solution:

1. **Calculate the Molarity of the Diluted NaOH Solution (M_2):** A 50 mL aliquot of a 1 M stock solution is diluted to a final volume of 500 mL:

$$M_2 = \frac{1 \text{ M} \times 50 \text{ mL}}{500 \text{ mL}} = 0.1 \text{ M}$$

2. **Determine the Neutralization Volume (V_B):** The neutralization reaction between HCl and NaOH has a 1:1 stoichiometric ratio:

$$M_{\text{acid}}V_{\text{acid}} = M_{\text{base}}V_{\text{base}}$$

$$0.2 \text{ M} \times 25 \text{ mL} = 0.1 \text{ M} \times V_B$$

$$V_B = \frac{0.2 \times 25}{0.1} = 50 \text{ mL}$$

Final Answer: $\boxed{50 \text{ mL}}$

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

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Q19.

Solution

Concept: Molarity (M) is defined as moles of solute per liter of solution, while molality (m) is defined as moles of solute per kilogram of solvent. Because liquid volume expands or contracts with temperature, molarity values vary with ambient thermal conditions.

Solution:

1. **Evaluate the Temperature Dependence of Volume:** As temperature changes across different climatic zones, the volume of an aqueous solution shifts, which changes its calculated molarity ($M = \text{mol/L}$).

2. **Compare with Molality:** Molality ($m = \text{mol/kg}$) is calculated using the mass of the solvent. Because mass is invariant with temperature and pressure, **molality remains completely independent of temperature alterations**, making it a more reliable parameter for high-precision analytical comparisons across diverse environmental conditions.

Final Answer: $\boxed{\text{Molality is completely independent of temperature alterations as it is based on solvent mass.}}$

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

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Q20.

Solution

Concept: During the titration of a weak acid with a strong base, the titration curve contains a flat region known as the buffer region. The midpoint of this region is the **half-equivalence point**, where exactly half of the weak acid has been neutralized into its conjugate base ($[HA] = [A^-]$). According to the Henderson-Hasselbalch equation, the pH at this point equals the pK_a of the acid.

Solution:

1. **Locate the Equivalence Point:** The curve shows an inflection point at a titrant volume of 20 mL (pH = 2.4), representing complete neutralization of the organic acid.
2. **Determine the Half-Equivalence Point and pK_a:** The half-equivalence point occurs at exactly half of the equivalence volume:

$$\text{Half-equivalence volume} = \frac{20\text{ mL}}{2} = 10\text{ mL}$$

Reading the pH value on the graph at a titrant volume of 10 mL yields a value of 4.8. At this point:

$$\text{pH} = \text{p}K_a = 4.8$$

Final Answer: $\boxed{\text{p}K_a = 4.8}$

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

Go Back to Question 20

Q21.

Solution

Concept: The ionic strength (μ) of an electrolytic solution depends on both the molar concentration (C_i) and the valence charge (Z_i) of each individual ion present:

$$\mu = \frac{1}{2}\sum C_i Z_i^2$$

Solution:

1. **Analyze 1:1 Electrolytes:** For a univalent salt like NaCl, KNO_3, or NH_4Cl, the ions carry a charge of ±1:

$$\mu = \frac{1}{2}[M(1)^2 + M(-1)^2] = \frac{1}{2}[2M] = M$$

For these salts, ionic strength equals molarity.

2. **Evaluate the Multi-valent Salt ($MgSO_4$):** Magnesium sulfate dissociates into divalent ions (Mg^{2+} and SO_4^{2-}), where $Z = \pm 2$:

$$\mu = \frac{1}{2}[M(2)^2 + M(-2)^2] = \frac{1}{2}[4M + 4M] = 4M$$

Because its divalent ions scale the ionic strength to four times its molarity, **$MgSO_4$** must be avoided to keep ionic strength equal to molarity.

Final Answer: $\boxed{MgSO_4}$

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

Go Back to Question 21

Q22.

Solution

Concept: The common-ion effect describes the reduction in solubility of an ionic precipitate when a soluble compound containing an identical constituent ion is added to the solution equilibrium. This behavior follows Le Chatelier's principle.

Solution:

1. **Examine the Dissolution Equilibrium:** The dissolution of gypsum can be written as:

$$CaSO_4 \cdot 2H_2O(s) \rightleftharpoons Ca^{2+}(aq) + SO_4^{2-}(aq) + 2H_2O(l)$$

2. **Analyze the Effect of Sodium Sulfate Addition:** Sodium sulfate (Na_2SO_4) dissolves completely, introducing a high concentration of sulfate ions (SO_4^{2-}). This excess of a product ion shifts the equilibrium to the left, suppressing gypsum dissolution and reducing its solubility.

Final Answer: $\boxed{\text{Common-ion effect due to excess } SO_4^{2-} \text{ ions}}$

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

Go Back to Question 22

Q23.

Solution

Concept: Biological nitrification converts reduced nitrogen forms into oxidized forms via a sequence of microbial reactions. The first stage converts ammonium (NH_4^+) to nitrite (NO_2^-), a process carried out by chemolithoautotrophic bacteria such as *Nitrosomonas*.

Solution:

1. **Trace the Biochemical Oxidation Pathway:** The oxidation of ammonium by *Nitrosomonas* takes place in two discrete enzymatic steps. First, ammonia monooxygenase converts ammonium to hydroxylamine:

$$NH_4^+ + O_2 + 2H^+ + 2e^- \rightarrow NH_2OH + H_2O$$

2. **Identify the Intermediate Stage:** The resulting highly reactive intermediate, **Hydroxylamine (NH_2OH)**, is subsequently oxidized to nitrite (NO_2^-) by hydroxylamine oxidoreductase before *Nitrobacter* oxidizes it further to nitrate (NO_3^-).

Final Answer: $\boxed{\text{Hydroxylamine } (NH_2OH)}$

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

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Q24.

Solution

Concept: Tollens' reagent (ammoniacal silver nitrate, $[Ag(NH_3)_2]^+$) is a mild oxidizing agent used to distinguish between different carbonyl functional groups. It reacts readily with compounds that are easily oxidized, such as aldehydes.

Solution:

1. **Analyze the Redox Chemical Reaction:** Aldehydes contain a terminal carbonyl group bonded to a hydrogen atom ($-CHO$), making them susceptible to further oxidation into carboxylic acids. Tollens' reagent oxidizes the aldehyde while its silver ions are reduced to metallic silver:

$$\text{R-CHO} + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow \text{R-COO}^- + 2Ag(s) + 4NH_3 + 2H_2O$$

2. **Identify the Precipitate Formation:** The reduced metallic silver deposits on the inner walls of the reaction vessel, forming a reflective silver mirror. Ketones ($-CO-$) and esters ($-COOR-$) lack this terminal hydrogen atom and do not react with Tollens' reagent under standard conditions.

Final Answer: $\boxed{\text{Aldehyde Group } (-CHO)}$

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

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Q25.

Solution

Concept: When an electron transitions from a higher energy level to a lower one, it emits a photon. The energy (ΔE) of the emitted photon is equal to the difference in energy between the two states, and it determines the photon's frequency (ν) according to Planck's equation:

$$\Delta E = h\nu$$

Solution:
1. **Analyze the Energy Level Spacings:** According to atomic models, the energy spacing between adjacent shells decreases significantly as the principal quantum number (n) increases. The largest energy gap occurs between the ground state ($n = 1$) and the first excited state ($n = 2$).
2. **Evaluate the Transition Lines:** * Transition A ($n = 4 \to n = 3$) and Transition B ($n = 3 \to n = 2$) involve small energy gaps. * Transition D ($n = 2 \to n = 1$) covers the large ground-state gap. * Transition C ($n = 4 \to n = 1$) spans from the highest excited state down to the ground state, capturing the largest total energy drop (ΔE). Because Transition C releases the greatest amount of energy, it emits a photon with the highest frequency.

Final Answer: $\boxed{\text{Transition C}}$

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

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Answer Key

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