

UPCATET Agriculture Chemistry Sample Paper-4

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 high-affinity potassium-binding site on the edge of wedge-zones in partially weathered illite mineral clays undergoes selective fixation of K^+ ions. If a soil chemist introduces a competing ion with an identical hydrated ionic radius and matching hydration energy parameters, which of the following ionic species will most effectively block the fixation pathways of potassium in these specific interlayer spaces?

- (A) Na^+
- (B) NH_4^+
- (C) Ca^{2+}
- (D) Mg^{2+}

Q2. An agronomist evaluates an alkaline-saline soil system characterized by an Electrical Conductivity (EC) of 6 dS m^{-1} at 25°C , a Soil pH of 8.2, and an Exchangeable Sodium Percentage (ESP) of 8%. According to the US Salinity Laboratory classification system, this specific agronomic soil profile must be categorized as a:

- (A) Saline Soil
- (B) Sodic Soil
- (C) Saline-Sodic Soil

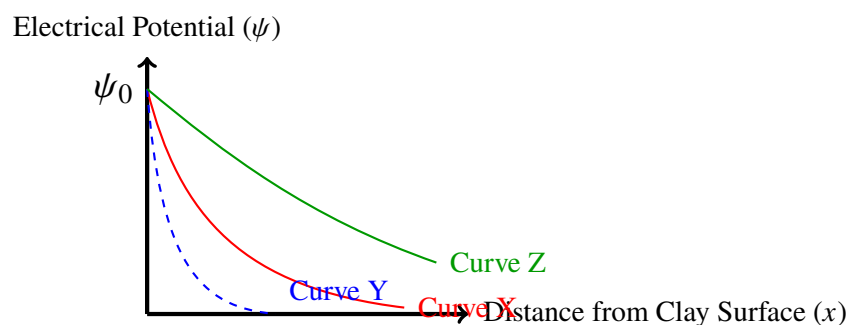


(D) Normal Agricultural Soil

Q3. A researcher tests phosphorus fixation dynamics across a variable pH gradient in an iron-rich Oxisol soil matrix. At a critically low pH value of 3.8, what is the dominant, highly insoluble crystalline orthophosphate mineral phase that precipitates out of the soil solution, permanently fixing applied phosphatic fertilizers?

- (A) Strengite ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$)
- (B) Variscite ($\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$)
- (C) Fluorapatite ($\text{Ca}_5(\text{PO}_4)_3\text{F}$)
- (D) Dicalcium phosphate (CaHPO_4)

Q4. The following electrochemical schematic represents the diffuse double-layer potential distribution (ψ) extending away from a negatively charged silicate clay colloid surface into the bulk agricultural soil solution. Based on the functional decay curves under different management inputs, identify which curve corresponds to a soil treated with high concentrations of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), resulting in rapid flocculation:



- (A) Curve X, because it reflects a highly dispersed sodic state.
- (B) Curve Y, because divalent calcium compresses the diffuse double layer rapidly.
- (C) Curve Z, because monovalent sodium extends the potential zone further.
- (D) None of the curves reflect changes in electrolyte parameters.

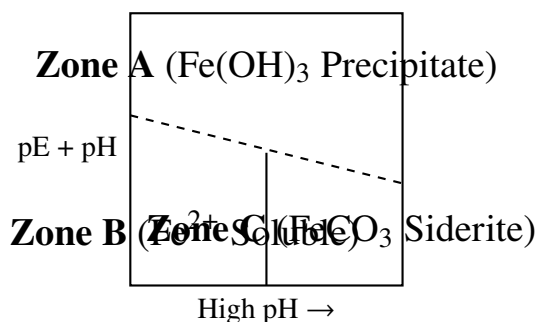


- Q5.** During biological nitrogen fixation inside the root nodules of leguminous agricultural crops, the functional nitrogenase enzyme complex is highly sensitive to denaturing by free molecular oxygen (O_2). What biochemical oxygen-scavenging metalloprotein acts as a physiological buffer to maintain an anaerobic micro-environment while simultaneously delivering oxygen for rhizobial respiration?
- (A) Cytochrome P450
(B) Ferredoxin-NADP+ Reductase
(C) Leghemoglobin
(D) Plastocyanin
- Q6.** A batch of commercial fertilizer is suspected of causing acute plant toxicity and severe chlorosis due to impurities introduced during high-temperature manufacturing processes. Chemical extraction reveals an organic condensation byproduct formed when two urea molecules react with the loss of one ammonia molecule. Identify this toxic compound:
- (A) Guanidine
(B) Biuret
(C) Cyanuric Acid
(D) Melamine
- Q7.** When analyzing the anion exchange capacity (AEC) of highly weathered tropical soils containing substantial proportions of kaolinite, gibbsite, and goethite, how does the magnitude of the AEC behave when the soil solution pH drops well below the Point of Zero Net Charge (PZNC)?
- (A) The AEC decreases because variable-charge hydroxyl groups become deprotonated.
(B) The AEC increases significantly due to the protonation of surface hydroxyl functional groups ($-OH + H^+ \rightarrow -OH_2^+$).
(C) The AEC remains perfectly constant because it is driven entirely by isomorphic substitution.



(D) The AEC drops to zero because permanent negative charges neutralize it.

Q8. The phase equilibrium diagram below illustrates the relative stability and solubility zones of common soil iron minerals as a function of the master variable parameters: Redox Potential ($pE + pH$). Identify the precise zone where highly soluble ferrous iron (Fe^{2+}) becomes completely dominant in the soil solution, leading to critical iron toxicity in waterlogged rice paddy ecosystems:



- (A) Zone A
- (B) Zone B
- (C) Zone C
- (D) Both Zone A and Zone C

Q9. A certain micronutrient acts as a core structural cofactor within the nitrate reductase enzyme framework, governing the physiological reduction step of NO_3^- to NO_2^- within agricultural plant tissue. A deficiency in this element halts nitrogen metabolism completely. Name the element:

- (A) Zinc (Zn)
- (B) Manganese (Mn)
- (C) Molybdenum (Mo)
- (D) Boron (B)

Q10. The pyrolytic thermal cracking of agricultural biomass outputs a complex vapor mixture of lower hydrocarbons. When pure methane (CH_4) gas isolated from this source is subjected to controlled partial oxidation over a silver catalyst at $300^\circ C$, what is the primary oxygenated organic compound synthesized under these exact conditions?

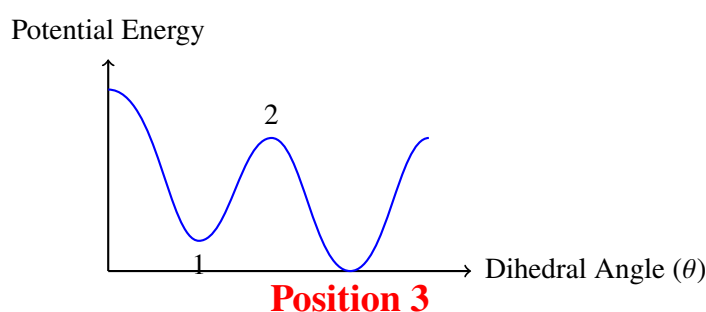


- (A) Formaldehyde (HCHO)
- (B) Methanol (CH₃OH)
- (C) Formic Acid (HCOOH)
- (D) Carbon Dioxide (CO₂)

Q11. An agrochemical laboratory synthesizes an organic pesticide intermediate utilizing a fundamental free-radical substitution reaction of ethane (CH₃CH₃) with chlorine gas (Cl₂) in the presence of ultraviolet light ($h\nu$). Which specific reaction step acts as the primary mechanistic sink that terminates the free radical cascade, forming a butane molecule as an impurity?

- (A) $\text{Cl}^\bullet + \text{CH}_3\text{CH}_3 \rightarrow \text{CH}_3\text{CH}_2^\bullet + \text{HCl}$
- (B) $\text{CH}_3\text{CH}_2^\bullet + \text{Cl}_2 \rightarrow \text{CH}_3\text{CH}_2\text{Cl} + \text{Cl}^\bullet$
- (C) $\text{CH}_3\text{CH}_2^\bullet + \text{CH}_3\text{CH}_2^\bullet \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
- (D) $\text{Cl}^\bullet + \text{Cl}^\bullet \rightarrow \text{Cl}_2$

Q12. The conformational energy profile below traces the rotation about the central C-C bond of a hydrocarbon byproduct isolated during the fermentation of bio-ethanol. Identify the exact structural conformation matching the absolute global energy minimum state point designated as ****Position 3**** on the curve:



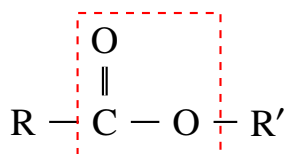
- (A) Fully Eclipsed Conformation
- (B) Gauche Conformation
- (C) Anti-Periplanar (Staggered) Conformation
- (D) Partially Eclipsed Conformation



- Q13.** The conversion of agricultural grain starches into industrial bio-ethanol involves enzymatic hydrolysis followed by fermentation by yeast strains. If the resulting ethanol solution contains a tiny fraction of water forming a low-boiling azeotropic mixture, what is the maximum percentage purity of ethanol that can be reached via standard fractional distillation alone without adding an entrainer?
- (A) 100%
(B) 95.6%
(C) 78.3%
(D) 50.0%
- Q14.** An organic acid exudate isolated from the root zones of certain stress-tolerant crop cultivars undergoes a quantitative test. When this specific monocarboxylic acid is treated with a mixture of concentrated sulfuric acid (H_2SO_4) under mild heating, it undergoes rapid dehydration to evolve a single gas that burns with a characteristic blue flame, leaving no other carbon residue. The organic acid is identified as:
- (A) Acetic Acid
(B) Formic Acid
(C) Oxalic Acid
(D) Propionic Acid
- Q15.** During the storage of wine and fermented fruit juices, an aerobic bacterium accidentally oxidizes the ethanol content into acetic acid, creating a sour defects profile. Mechanistically, this biochemical transformation passes through which unstable, transient intermediate oxidation state before converting completely to the carboxylic acid functional group?
- (A) Dimethyl Ether
(B) Acetone
(C) Acetaldehyde
(D) Formaldehyde



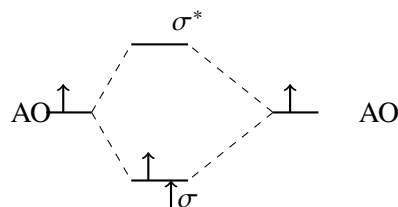
- Q16.** The structural formula layout depicted below represents a key plant growth regulator derivative synthesized from simple organic fractions. Identify the major functional group highlighted within the dotted boundary box region:



- (A) Ether Functional Group
(B) Ester Functional Group
(C) Anhydride Functional Group
(D) Ketone Functional Group
- Q17.** An agricultural analytical spectrometer measures the electronic transition emissions of potassium atoms within a plasma flame. According to the quantum mechanical framework, what is the maximum possible number of electrons that can occupy a single, fully saturated $4f$ subshell orbital array within an excited macro-atom state?
- (A) 2
(B) 6
(C) 10
(D) 14
- Q18.** A crystalline salt formulation used in greenhouse hydroponics relies on a central polyatomic anion with a perfectly symmetrical tetrahedral spatial geometry and an absence of any unshared lone electron pairs on its central atom. Which of the following agrochemical nutrient source anions fits this molecular orbital description?
- (A) NO_3^-
(B) SO_4^{2-}
(C) NH_4^+
(D) NO_2^-



- Q19.** The molecular orbital (MO) energy level alignment diagram mapped below displays the frontier valence electron distributions of a highly reactive diatomic radical intermediate involved in soil redox phenomena. Analyze the diagram layout and identify the calculated net bond order (BO) characteristic of this specific diatomic species configuration:



- (A) Bond Order = 0.5
 (B) Bond Order = 1.0
 (C) Bond Order = 1.5
 (D) Bond Order = 2.0
- Q20.** When moving across Period 3 of the modern periodic table from Sodium (Na) to Chlorine (Cl), the first ionization energy exhibits a general upward trend. However, a distinct, anomalous drop in ionization energy is noted when moving specifically from Phosphorus (P) to Sulfur (S). What is the exact electronic rationale responsible for this anomaly?
- (A) Sulfur has a lower effective nuclear charge than phosphorus.
 (B) Phosphorus possesses a stable, half-filled $3p^3$ subshell which resists electron removal compared to the electron-paired repulsion in sulfur's $3p^4$ state.
 (C) The valence electrons of sulfur enter a brand new $4s$ shell shield layer.
 (D) Phosphorus exhibits greater atomic radius parameters than sulfur.
- Q21.** A soil mineral lattice structure is stabilized by elements possessing highly contrasting electronegativity values, yielding a dominant ionic bonding character. Which pair of elements from the options below represents the greatest electronegativity difference ($\Delta\chi$) on the Pauling scale, forming the most purely ionic bond assembly?

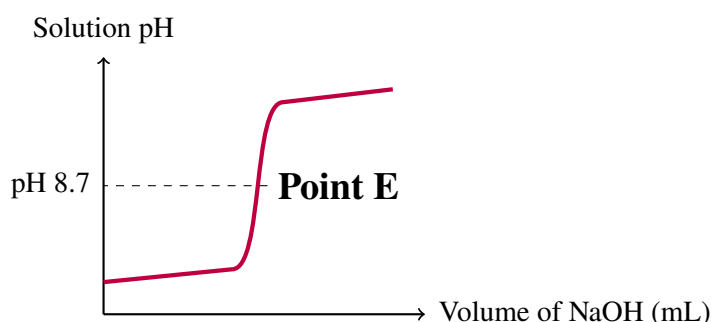


- (A) C – H
- (B) Al – O
- (C) K – F
- (D) Si – O

Q22. A standard reference solution is prepared by dissolving exactly 12.60 grams of pure crystalline oxalic acid dihydrate ($\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, Molecular Weight = $126.07 \text{ g mol}^{-1}$) into enough deionized water to make precisely 500 mL of final solution volumetric standard. What is the exact Normality (N) of this solution when utilized as a primary standard in a standard neutralizing acid-base titration run?

- (A) 0.1 N
- (B) 0.2 N
- (C) 0.4 N
- (D) 0.5 N

Q23. The curve charted below traces the change in solution pH during a high-precision potentiometric titration of a 25.0 mL soil-extract sample stream against a 0.10 M NaOH alkaline titrant flow. Analyze the inflection geometry and select the most accurate indicator candidate whose transition zone perfectly encapsulates the inflection midpoint marked as ****Point E****:



- (A) Methyl Orange (pH range 3.1 - 4.4)
- (B) Bromocresol Green (pH range 3.8 - 5.4)
- (C) Phenolphthalein (pH range 8.2 - 10.0)



(D) Thymol Blue (acid range 1.2 - 2.8)

Q24. An analytical chemist needs to prepare a specific dilute soil amendment rinse. The protocol requires blending 200 mL of a 3.0 M concentrated stock hydrochloric acid (HCl) solution with 300 mL of a separate 1.0 M HCl stock solution. Assuming the fluid volumes are perfectly additive with zero net contraction, the final Molarity (M) of the combined mixture is:

(A) 1.5 M

(B) 1.8 M

(C) 2.0 M

(D) 2.5 M

Q25. A laboratory standardizes an aqueous solution of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) for iodometric determination of copper traces in fungicides. If a solution contains 0.05 moles of solute dissolved in exactly 250 grams of pure water solvent medium, calculate the absolute Molality (m) concentration value of the preparation:

(A) 0.10 m

(B) 0.20 m

(C) 0.25 m

(D) 0.50 m



Detailed Solutions

Q1.

Solution

Concept: Potassium fixation in illite clay minerals occurs selectively at the open edges of interlayer wedge zones. For another cation to compete effectively for these high-affinity binding sites and block the path of K^+ , it must share a very similar hydrated ionic radius, low hydration energy, and coordination geometry.

Solution:

1. **Compare Ionic Properties:** The ammonium ion (NH_4^+) has a crystal ionic radius (1.43 \AA) and a hydration energy profile that are nearly identical to those of the potassium ion (1.33 \AA).
2. **Evaluate the Fixation Mechanism:** Like K^+ , NH_4^+ can easily shed its hydration shell and fit perfectly into the hexagonal oxygen cavities of the interlayer spaces, causing the layers to contract. Because of these identical parameters, NH_4^+ acts as the most direct competing ion, effectively blocking potassium fixation pathways. Divalent ions (Ca^{2+} , Mg^{2+}) or strongly hydrated monovalent ions (Na^+) retain their bulky hydration shells and cannot access these specific wedge zones as effectively.

Final Answer: NH_4^+

Answer: (B)

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Q2.

Solution

Concept: The US Salinity Laboratory (USSL) classifies salt-affected soils based on three master parameters: Electrical Conductivity (EC), Soil pH, and Exchangeable Sodium Percentage (ESP).

Solution:

1. **Review USSL Classification Thresholds:** * **Saline Soil:** $EC > 4 \text{ dS m}^{-1}$, $pH < 8.5$, $ESP < 15\%$ * **Sodic Soil:** $EC < 4 \text{ dS m}^{-1}$, $pH > 8.5$, $ESP > 15\%$ * **Saline-Sodic Soil:** $EC > 4 \text{ dS m}^{-1}$, $pH \leq 8.5$, $ESP > 15\%$
2. **Evaluate the Given Profile Parameters:** The soil sample has an $EC = 6 \text{ dS m}^{-1}$ (which is > 4), a $pH = 8.2$ (which is < 8.5), and an $ESP = 8\%$ (which is $< 15\%$). This specific combination of high soluble salts ($EC > 4$) and low exchangeable sodium ($ESP < 15\%$) classifies the profile precisely as a ****Saline Soil****.

Final Answer: Saline Soil

Answer: (A)

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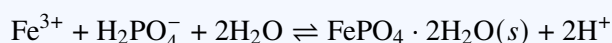
Q3.

Solution

Concept: Phosphorus fixation dynamics are strongly driven by soil pH. In highly weathered, iron-rich acidic soils like Oxisols, soluble orthophosphates react with iron and aluminum oxyhydroxides to form highly insoluble crystalline mineral precipitates.

Solution:

1. **Analyze Mineral Stability at Low pH:** At a critically low pH of 3.8, the concentration of active ferric iron (Fe^{3+}) ions in the soil solution increases significantly.
2. **Identify the Precipitating Phase:** The chemical reaction between soluble orthophosphate (H_2PO_4^-) and active iron species leads to the chemical precipitation of **strengite** ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$):



Variscite ($\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$) precipitates under slightly less acidic conditions, while calcium phosphates like fluorapatite are stable only in alkaline soils.

Final Answer: Strengite ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$)

Answer: (A)

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Q4.

Solution

Concept: The diffuse double layer (DDL) model describes the distribution of electrical potential (ψ) extending away from a negatively charged clay surface. The thickness of the DDL depends on the valence of the counter-ions and the electrolyte concentration of the soil solution.

Solution:

1. **Evaluate the Effect of Gypsum Amendment:** Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) dissolves to release divalent calcium ions (Ca^{2+}) into the soil solution, displacing monovalent sodium ions (Na^+).
2. **Determine the Impact on Curve Geometry:** According to the Gouy-Chapman theory, increasing the ion valence from +1 to +2 drastically reduces the thickness of the diffuse double layer. This change causes the electrical potential to decay rapidly over a much shorter distance from the clay surface, which minimizes inter-particle repulsion and leads to rapid flocculation. In the schematic, **Curve Y** illustrates this compressed double-layer potential profile.

Final Answer: Curve Y, because divalent calcium compresses the diffuse double layer rapidly.

Answer: (B)

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Q5.

Solution

Concept: The nitrogenase enzyme complex, which drives biological nitrogen fixation within rhizobial bacteroids, is irreversibly denatured by exposure to free molecular oxygen (O₂). However, the bacteroids still require oxygen to fuel ATP production via aerobic respiration.

Solution:

1. **Identify the Physiological Oxygen Regulator:** To balance these competing demands, legume root nodules produce a high-affinity oxygen-binding metalloprotein called **leghemoglobin**.
2. **Examine the Transport Mechanism:** Leghemoglobin maintains the free oxygen concentration in the nodule cytoplasm at an extremely low level (a few nanomolar), protecting the nitrogenase complex. Concurrently, it facilitates a steady flux of bound oxygen directly to the bacteroid respiratory chain, supporting cellular respiration without disabling the fixation machinery.

Final Answer: Leghemoglobin

Answer: (C)

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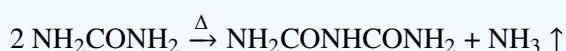
Q6.

Solution

Concept: During industrial fertilizer manufacturing, high temperatures can cause urea molecules to undergo an unwanted condensation reaction. If the concentration of this resulting byproduct exceeds safety limits, it can cause severe phytotoxicity and leaf chlorosis when applied to agricultural crops.

Solution:

1. **Analyze the Condensation Chemistry:** When two molecules of urea (NH₂CONH₂) are heated, they react and eliminate one molecule of ammonia gas (NH₃):



2. **Identify the Resulting Byproduct:** The structure NH₂CONHCONH₂ corresponds precisely to **biuret**. Monitoring biuret levels is an essential quality control step in commercial urea production to prevent crop damage.

Final Answer: Biuret

Answer: (B)

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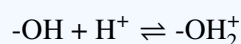
Q7.

Solution

Concept: Highly weathered tropical soils are rich in variable-charge minerals like kaolinite, gibbsite, and goethite. The net surface charge of these minerals depends heavily on the pH of the surrounding soil solution.

Solution:

1. **Analyze Surface Protonation Dynamics:** The surface functional groups of these minerals are primarily hydroxyl (-OH) groups. When the soil solution pH drops well below the Point of Zero Net Charge (PZNC), the high concentration of hydronium ions (H^+) drives surface protonation:



2. **Determine the Effect on Anion Exchange Capacity:** This protonation converts neutral edge surfaces into positively charged sites. These positive charges electrostatically attract and retain nutrient anions (such as SO_4^{2-} and Cl^-), leading to a significant increase in the soil's Anion Exchange Capacity (AEC).

Final Answer:

The AEC increases significantly due to the protonation of surface hydroxyl functional groups ($-OH + H^+ \rightarrow -OH_2^+$).

Answer: (B)

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Q8.

Solution

Concept: The solubility and chemical speciation of iron in soils are controlled by two master variables: pH and Redox Potential (pE). Waterlogged or submerged conditions deplete oxygen, causing a drop in pE that drives the reduction of insoluble ferric iron compounds to soluble ferrous forms.

Solution:

1. **Interpret the Stability Phase Diagram:** * **Zone A** represents highly oxidized, well-aerated conditions where iron precipitates as insoluble ferric hydroxide ($Fe(OH)_3$). * **Zone C** represents moderately reduced conditions at higher pH levels where iron precipitates as siderite ($FeCO_3$). * **Zone B** occupies the lower-left region of the diagram, which corresponds to low pE (highly reducing conditions) and low-to-moderate pH values.

2. **Identify the Toxicity Region:** In **Zone B**, the reduced, highly soluble free ferrous iron (Fe^{2+}) form dominates the soil solution. In flooded rice paddies, this high solubility can lead to excessive iron uptake and physiological iron toxicity ("bronzing").

Final Answer: **Zone B**

Answer: (B)

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Q9.

Solution

Concept: Nitrate reductase is a key plant enzyme that catalyzes the initial rate-limiting step in nitrogen assimilation: reducing nitrate (NO_3^-) to nitrite (NO_2^-) within plant tissues.

Solution:

1. **Identify the Active Coordination Center:** The active site of the nitrate reductase enzyme contains a specialized pterin-based cofactor known as the molybdenum cofactor (Moco).
2. **Determine the Micronutrient Requirement:** **Molybdenum (Mo)** sits at the core of this structural framework, cycling between its Mo(VI) and Mo(IV) oxidation states to transfer electrons directly to the bound nitrate substrate. A deficiency in molybdenum prevents the enzyme from functioning, halting protein synthesis and causing severe nitrogen deficiency symptoms in plants.

Final Answer: Molybdenum (Mo)

Answer: (C)

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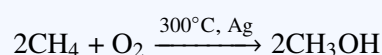
Q10.

Solution

Concept: The controlled partial oxidation of methane can yield different oxygenated organic compounds depending on the choice of catalyst, temperature, and pressure conditions.

Solution:

1. **Analyze the Catalytic Reaction Parameters:** When methane (CH_4) is mixed with oxygen and passed over a metallic silver or copper catalyst tube at elevated temperatures (300°C), it undergoes selective partial oxidation.
2. **Determine the Primary Product:** Under these specific catalytic conditions, methane is oxidized directly to **methanol (CH_3OH)**:



Different catalysts, such as molybdenum trioxide, would instead target the production of formaldehyde (HCHO).

Final Answer: Methanol (CH_3OH)

Answer: (B)

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Q11.

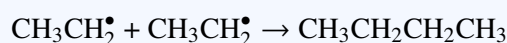
Solution

Concept: Free-radical halogenation of alkanes proceeds via three sequential mechanistic steps: initiation, propagation, and termination. Termination occurs when any two active free radicals collide and combine, neutralizing their unpaired electrons and ending that specific radical chain cascade.

Solution:

1. **Analyze the Elementary Radical Steps:** * Option (A) and Option (B) represent propagation steps, which sustain the radical chain reaction. * Option (C) and Option (D) represent termination steps because active free radicals combine to form stable, neutral covalent molecules.

2. **Identify the Impurity Source:** The question asks for the specific step that generates a butane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$) impurity. This occurs when two ethyl radicals ($\text{CH}_3\text{CH}_2^\bullet$) collide and combine:



This step serves as a mechanistic sink that terminates those specific radical chains while producing butane as a byproduct.

Final Answer: $\text{CH}_3\text{CH}_2^\bullet + \text{CH}_3\text{CH}_2^\bullet \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

Answer: (C)

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Q12.

Solution

Concept: The rotation of a carbon-carbon single bond changes the dihedral angle between attached substituents, creating different spatial arrangements known as conformations. These conformations have varying potential energies due to torsional and steric strain.

Solution:

1. **Analyze the Energy Profile Curve:** The potential energy graph shows minima and maxima across a 360° rotation: * Maxima represent high-strain, unstable eclipsed states where substituents align directly behind one another. * Minima represent more stable staggered states where substituents are spaced further apart.

2. **Identify the Global Minimum State:** **Position 3** sits at the absolute lowest potential energy point on the entire profile curve. This global minimum corresponds to the **anti-periplanar (staggered) conformation**, where the largest bulky groups (such as the terminal methyl fractions) are positioned exactly 180° apart. This orientation minimizes both steric hindrance and torsional strain.

Final Answer: Anti-Periplanar (Staggered) Conformation

Answer: (C)

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Q13.

Solution

Concept: An azeotrope is a liquid mixture of two or more components that boils at a constant temperature and retains the same composition in both the liquid and vapor phases. Because the vapor and liquid compositions are identical, the components cannot be separated further by conventional fractional distillation alone.

Solution:

1. **Analyze the Ethanol-Water Azeotrope:** During the fractional distillation of fermented mashes, ethanol and water form a minimum-boiling azeotropic mixture when the ethanol concentration reaches a high level.

2. **Identify the Separation Limit:** This azeotropic point occurs at a composition of **95.6%** ethanol and 4.4% water by weight (boiling at 78.2°C). Consequently, standard fractional distillation cannot yield a higher concentration of ethanol without using an entrainer (like benzene or cyclohexane) for azeotropic distillation or utilizing molecular sieves.

Final Answer:

Answer: (B)

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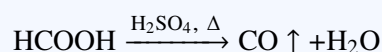
Q14.

Solution

Concept: Simple monocarboxylic and dicarboxylic acids react differently when heated with concentrated sulfuric acid (H₂SO₄), which acts as a strong dehydrating agent.

Solution:

1. **Analyze the Dehydration Mechanism:** Formic acid (HCOOH) is the simplest monocarboxylic acid. When heated with concentrated H₂SO₄, it undergoes clean dehydration, losing a molecule of water:



2. **Identify the Evolved Gas Product:** This reaction produces carbon monoxide (CO) gas, which burns with a characteristic faint blue flame to form carbon dioxide (CO₂). Because formic acid contains only one carbon atom, it yields no carbonaceous char residue. In contrast, oxalic acid (HOOC-COOH) decomposes to release a mixture of both CO and CO₂ gases.

Final Answer:

Answer: (B)

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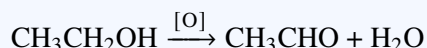
Q15.

Solution

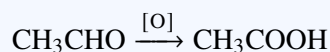
Concept: The oxidation of a primary aliphatic alcohol to a carboxylic acid proceeds via a two-stage oxidation pathway. Each stage changes the oxidation state of the terminal functional carbon center.

Solution:

1. **Trace the Oxidation Sequence:** During fermentation spoilage, aerobic acetic acid bacteria (such as *Acetobacter aceti*) oxidize the ethanol content of wine. In the first step, ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) loses two hydrogen atoms to form a volatile intermediate carbonyl compound:



2. **Identify the Intermediate Phase:** This transient intermediate is **acetaldehyde (CH_3CHO)**. It is subsequently oxidized further by adding an oxygen atom to form the final stable product, acetic acid (CH_3COOH):



Final Answer: Acetaldehyde

Answer: (C)

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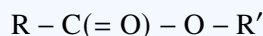
Q16.

Solution

Concept: Organic compounds are categorized into families based on their specific functional groups, which are distinct arrangements of atoms that exhibit characteristic chemical behaviors.

Solution:

1. **Examine the Structure in the Boundary Box:** The highlighted region shows a carbonyl group ($\text{C} = \text{O}$) bonded directly to an oxygen link atom, which is connected to an alkyl or aryl carbon chain skeleton ($-\text{R}'$):



2. **Identify the Matching Functional Group:** This structural arrangement ($-\text{COO}-$) defines an **Ester Functional Group**. An ether lacks the carbonyl group ($\text{R}-\text{O}-\text{R}'$), an anhydride contains two connected carbonyl groups ($\text{R}-\text{CO}-\text{O}-\text{CO}-\text{R}'$), and a ketone lacks the oxygen bridge entirely ($\text{R}-\text{CO}-\text{R}'$).

Final Answer: Ester Functional Group

Answer: (B)

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Q17.

Solution

Concept: The maximum electron capacity of any atomic orbital or subshell array is governed by quantum mechanical rules and the Pauli Exclusion Principle, which states that no two electrons within an atom can share the exact same set of four quantum numbers.

Solution:

1. **Apply the Subshell Capacity Formula:** For any subshell designated by an azimuthal quantum number (l), the maximum number of electrons it can hold is given by the expression $2(2l + 1)$.
2. **Calculate the Value for an f-Subshell ($l = 3$):** Regardless of the principal quantum number shell ($n = 4$), an f -subshell has an azimuthal quantum number of $l = 3$. This yields $2l + 1 = 7$ individual orbitals. Applying the formula:

$$\text{Max Electrons} = 2 \times [2(3) + 1] = 2 \times 7 = 14 \text{ electrons}$$

Final Answer:

Answer: (D)

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Q18.

Solution

Concept: According to Valence Shell Electron Pair Repulsion (VSEPR) theory, a polyatomic ion or molecule adopts a perfectly symmetrical tetrahedral spatial geometry when its central atom has exactly four electron domains (σ -bonds) and zero unshared lone pairs.

Solution:

1. **Evaluate the Sulfate Anion (SO_4^{2-}):** The central sulfur atom has 6 valence electrons. In the sulfate anion (SO_4^{2-}), it forms bonds with four oxygen atoms, sharing all of its valence electrons. This leaves 4 bonding domains and **zero lone pairs** on the sulfur atom, resulting in a perfectly symmetrical tetrahedral geometry with ideal 109.5° bond angles.
2. **Compare with Alternatives:** * NO_3^- has 3 electron domains, giving it a trigonal planar geometry. * NO_2^- has a lone pair on the nitrogen atom, giving it a bent geometry. * While NH_4^+ is also tetrahedral, it is a cation rather than a nutrient anion.

Final Answer:

Answer: (B)

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Q19.

Solution

Concept: In molecular orbital (MO) theory, the net bond order (BO) of a diatomic molecule or radical indicates its structural stability. It is calculated as half the difference between the number of electrons in bonding molecular orbitals (N_b) and the number of electrons in antibonding molecular orbitals (N_a):

$$BO = \frac{N_b - N_a}{2}$$

Solution:

1. **Count Valence Electrons from the Diagram:** * The lower bonding orbital (σ) holds a pair of shared electrons: $N_b = 2$. * The upper antibonding orbital (σ^*) is empty: $N_a = 0$.

2. **Calculate the Bond Order:**

$$BO = \frac{2 - 0}{2} = 1.0$$

A bond order of 1.0 indicates a stable single covalent bond configuration.

Final Answer: Bond Order = 1.0

Answer: (B)

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Q20.

Solution

Concept: First ionization energy generally increases across a period because the effective nuclear charge increases while valence electrons enter the same shell layer. However, electron configuration anomalies can disrupt this general trend.

Solution:

1. **Examine Valence Shell Electron Configurations:** * Phosphorus ($Z = 15$) has the valence configuration $3s^23p^3$. * Sulfur ($Z = 16$) has the valence configuration $3s^23p^4$.

2. **Analyze the Ionization Energy Drop:** The three $3p$ electrons in phosphorus occupy separate orbitals with parallel spins, forming a **stable, half-filled subshell ($3p^3$)** that resists electron removal. In sulfur, the fourth $3p$ electron must pair up in an already occupied orbital. The resulting **electron-electron repulsion** between the two paired electrons in this orbital makes it energetically easier to remove an electron from sulfur, causing a slight drop in its first ionization energy compared to phosphorus.

Final Answer: Phosphorus possesses a stable, half-filled $3p^3$ subshell which resists electron removal compared to the electron-paired repulsion in sulfur's $3p^4$ state.

Answer: (B)

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Q21.

Solution

Concept: The ionic or covalent character of a chemical bond depends on the electronegativity difference ($\Delta\chi$) between the two bonding atoms on the Pauling scale. A larger difference results in a higher percentage of ionic character.

Solution:

1. **Evaluate the Element Positions on the Periodic Table:** * Potassium (K) is an alkali metal located in Group 1, making it highly electropositive with a very low electronegativity ($\chi \approx 0.8$). * Fluorine (F) is a halogen located in Group 17. It is the most electronegative element on the periodic table ($\chi \approx 4.0$).

2. **Determine the Maximum Difference:** The pairing of **K – F** creates the largest electronegativity difference ($\Delta\chi \approx 3.2$) among the choices provided, forming a nearly pure ionic crystal lattice. The other pairs (Al-O, Si-O, C-H) have smaller electronegativity differences and exhibit higher covalent character.

Final Answer:

Answer:

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Q22.

Solution

Concept: Normality (N) measures concentration in equivalents per liter ($N = \text{eq/L}$). For an acid, the equivalent weight equals the molecular weight divided by the number of replaceable hydrogen ions (n -factor) per molecule.

Solution:

1. **Determine the Equivalent Weight of Oxalic Acid Dihydrate:** Oxalic acid ($\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$) is a diprotic acid ($n = 2$). Given its molecular weight of $126.07 \text{ g mol}^{-1}$:

$$\text{Equivalent Weight} = \frac{126.07 \text{ g/mol}}{2} \approx 63.035 \text{ g/eq}$$

2. **Calculate the Number of Equivalents Dissolved:** The solution contains 12.60 grams of solute:

$$\text{Equivalents} = \frac{12.60 \text{ g}}{63.035 \text{ g/eq}} \approx 0.20 \text{ equivalents}$$

3. **Calculate the Normality (N):** The total volume of the solution is $500 \text{ mL} = 0.500 \text{ L}$:

$$N = \frac{0.20 \text{ equivalents}}{0.500 \text{ L}} = 0.4 \text{ N}$$

Final Answer:

Answer:

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Q23.

Solution

Concept: In an acid-base titration, a suitable indicator must have a visual color transition range that matches the steep vertical inflection zone of the titration curve. The pH at the titration midpoint (equivalence point) should fall within this transition range.

Solution:

1. **Analyze the Inflection Midpoint Geometry:** The titration curve shows a sharp vertical inflection region. The midpoint, **Point E**, corresponds to a solution pH of **8.7**.
2. **Select the Matching Indicator:** * Methyl Orange and Bromocresol Green change color in the acidic pH range (3.1 – 5.4). * Thymol Blue's acid range operates at very low pH (1.2 – 2.8). * **Phenolphthalein** has an alkaline transition range between **pH 8.2 and 10.0**. Since the equivalence point pH of 8.7 falls squarely within this range, phenolphthalein is the ideal indicator to accurately identify the endpoint.

Final Answer: Phenolphthalein (pH range 8.2 - 10.0)

Answer: (C)

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Q24.

Solution

Concept: When mixing two solutions of the same solute, the total number of moles of solute in the final mixture equals the sum of the moles from each individual solution. The final molarity (M_f) is calculated by dividing this total number of moles by the combined final volume (V_f).

Solution:

1. Calculate Moles from the First Solution (n_1):

$$V_1 = 200 \text{ mL} = 0.200 \text{ L}, \quad M_1 = 3.0 \text{ M}$$

$$n_1 = M_1 \times V_1 = 3.0 \text{ mol/L} \times 0.200 \text{ L} = 0.60 \text{ moles}$$

2. Calculate Moles from the Second Solution (n_2):

$$V_2 = 300 \text{ mL} = 0.300 \text{ L}, \quad M_2 = 1.0 \text{ M}$$

$$n_2 = M_2 \times V_2 = 1.0 \text{ mol/L} \times 0.300 \text{ L} = 0.30 \text{ moles}$$

3. Calculate the Final Molarity (M_f):

$$\text{Total Moles } (n_f) = 0.60 + 0.30 = 0.90 \text{ moles}$$

$$\text{Total Volume } (V_f) = 0.200 \text{ L} + 0.300 \text{ L} = 0.500 \text{ L}$$

$$M_f = \frac{n_f}{V_f} = \frac{0.90 \text{ moles}}{0.500 \text{ L}} = 1.8 \text{ M}$$

Final Answer:

Answer: (B)

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Q25.

Solution

Concept: Molality (m) measures the concentration of a solution in moles of solute per kilogram (1000 grams) of pure solvent:

$$m = \frac{\text{moles of solute}}{\text{mass of solvent in kg}}$$

Solution:

1. **Convert Solvent Mass to Kilograms:** The solution contains 250 grams of water solvent:

$$\text{Mass in kg} = \frac{250 \text{ g}}{1000 \text{ g/kg}} = 0.250 \text{ kg}$$

2. **Calculate the Molality (m):** The total amount of sodium thiosulfate solute dissolved is 0.05 moles:

$$m = \frac{0.05 \text{ moles}}{0.250 \text{ kg}} = 0.20 \text{ mol/kg} = 0.20 \text{ m}$$

Final Answer:

Answer: (B)

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Answer Key

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

