UPCATET Agriculture Chemistry Sample Paper-7

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 standardization experiment requires 35 mL of 0.15 M sodium thiosulfate ($Na_2S_2O_3$) to be diluted to exactly 500 mL. What is the molarity of the diluted solution?

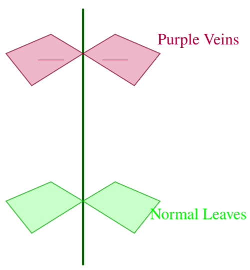
(A) 0.0105 M

(B) 0.0210 M

(C) 0.0420 M

(D) 0.0840 M

Q2. A soil diagnostic test reveals deficiency symptoms of stunted growth and purple discoloration of leaf veins and petioles in a vegetable crop. Which nutrient deficiency is most likely responsible for these distinctive symptoms?



(A) Magnesium (Mg)

(B) Phosphorus (P)

(C) Sulfur (S)

(D) Boron (B)

Q3. In an analytical determination, 0.5 grams of calcium oxide (CaO, molecular weight = 56) is completely dissolved in 100 mL of distilled water and allowed to form a saturated solution. What is the molarity of the calcium hydroxide solution formed?

(A) 0.0893 M

(B) 0.1786 M

(C) 0.2679 M

(D) 0.3571 M

Q4. A sample of the organic compound hexane (C_6H_{14}) undergoes complete combustion in the presence of excess oxygen. How many moles of water molecules are produced from the combustion of 1 mole of hexane?

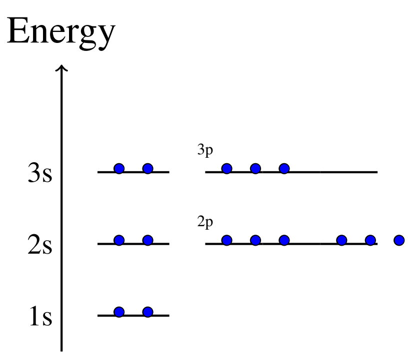
(A) 5 moles

(B) 6 moles

(C) 7 moles

(D) 8 moles

Q5. The orbital energy level diagram below illustrates electron filling in a neutral silicon atom. How many unpaired electrons are present in the valence shell of silicon?



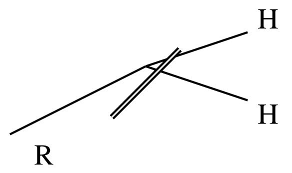
(A) 1 unpaired electron

(B) 2 unpaired electrons

(C) 3 unpaired electrons

(D) 4 unpaired electrons

Q6. An organic chemist observes that a particular compound exhibits the functional group arrangement shown below. This compound contains a double bond between two carbon atoms, each bearing a hydrogen atom on opposite sides of the bond. What is the geometric isomerism designation for this compound?



(A) Cis configuration

(B) Trans configuration

(C) Ortho configuration

(D) Meta configuration

Q7. In a low-pH acidic soil environment, a heavy metal cation becomes highly soluble and toxic. When soil pH is raised to neutral, this metal forms an insoluble hydroxide precipitate. Which metallic element exhibits this characteristic pH-dependent solubility behavior?

(A) Potassium

(B) Calcium

(C) Iron

(D) Chlorine

Q8. A laboratory experiment requires preparation of a standard 0.5 M solution of hydrochloric acid. If the original concentrated acid has a molarity of 12 M, what volume of the concentrated acid must be used to prepare 250 mL of the diluted solution?

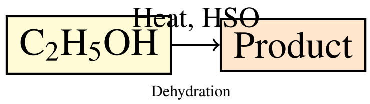
(A) 5.2 mL

(B) 10.4 mL

(C) 15.6 mL

(D) 20.8 mL

Q9. The structural transformation diagram shows the conversion of a simple alcohol to a highly unsaturated hydrocarbon through a multi-step dehydration sequence. What is the primary product formed when ethanol undergoes dehydration at elevated temperature?



(A) Ethane (C_2H_6)

(B) Ethene (C_2H_4)

(C) Acetaldehyde (CH_3CHO)

(D) Diethyl ether ($C_2H_5 - O - C_2H_5$)

Q10. The quantitative elemental composition of an organic compound is determined through combustion analysis. A 0.80 gram sample burns completely to produce 0.80 grams of carbon dioxide. What is the mass percentage of carbon in the original compound?

(A) 12.5 percent

(B) 18.2 percent

(C) 27.3 percent

(D) 36.5 percent

Q11. According to IUPAC nomenclature rules, a straight-chain hydrocarbon containing eight carbon atoms with a single double bond between the third and fourth carbons is named:

(A) 3-octene

(B) 3-octyne

(C) oct-3-ene

(D) oct-4-ene

Q12. A magnesium nutrient deficiency in crop plants causes interveinal chlorosis in older leaves that persists as the deficiency worsens. Which statement best explains why magnesium deficiency symptoms appear first on older leaves?

(A) Magnesium is immobile and gets trapped in root tissues

(B) Magnesium is highly mobile and gets translocated to new growth tissues

(C) Magnesium accumulates preferentially in stem tissues

(D) Magnesium is completely absent from the phloem transport system

Q13. The ground state electron configuration of manganese (atomic number 25) is approximately what?

(A) $[Ar]3d^6 4s^1$

(B) $[Ar]3d^7 4s^1$

(C) $[Ar]3d^5 4s^2$

(D) $[Ar]3d^4 4s^2$

Q14. Which soil exchangeable base cation has the highest charge density and greatest binding affinity for the negatively charged clay exchange sites?

(A) Sodium (Na^+)

(B) Potassium (K^+)

(C) Calcium (Ca^{2+})

(D) Magnesium (Mg^{2+})

Q15. A titration curve diagram shows the relationship between acid-base concentration and pH during a neutralization reaction. Which indicator is appropriate for a titration where the equivalence point occurs at a pH of approximately 3.0?

(A) Phenolphthalein

(B) Methyl orange

(C) Bromothymol blue

(D) Methyl red

Q16. The structural relationship between the ionization potential (IP) and electron affinity (EA) values for elements follows a periodic trend. Which statement correctly characterizes this trend across Period 3?

Na Mg Al Si P S Cl

$\longrightarrow$ Increasing IP

$\longrightarrow$ Increasing EA

(A) IP increases; EA decreases

(B) IP increases; EA increases with exceptions

(C) IP decreases; EA increases

(D) IP remains constant; EA increases

Q17. The molecular formula of acetic acid is CH_3COOH. How many sigma (σ) covalent bonds are present in one molecule?

(A) 6 sigma bonds

(B) 7 sigma bonds

(C) 8 sigma bonds

(D) 9 sigma bonds

Q18. Agricultural soil that has undergone intensive weathering in tropical climates typically contains high concentrations of which primary clay mineral?

(A) Montmorillonite

(B) Illite

(C) Kaolinite

(D) Vermiculite

Q19. For a weak organic acid and strong base titration, if the starting acid concentration is 0.1 M and 25 mL of this acid requires 50 mL of 0.1 M NaOH to reach equivalence, what conclusion can be made about the acid?

(A) The acid is monoprotic

(B) The acid is diprotic

(C) The acid is triprotic

(D) The acid is polyprotic

Q20. Which soil condition most critically restricts the availability of molybdenum to crop plants?

(A) Neutral pH of 7.0

(B) Acidic pH below 5.0

(C) Calcareous pH above 8.0

(D) Waterlogged anaerobic conditions

Q21. When a sample of pure methane gas (CH_4) undergoes a free radical substitution reaction with chlorine gas (Cl_2) under ultraviolet light, what is the primary mono-substituted product?

(A) Dichloromethane

(B) Chloromethane

(C) Trichloromethane

(D) Carbon tetrachloride

Q22. The relationship between orbital angular momentum and orbital geometry is defined by which quantum number?

(A) n (principal quantum number)

(B) l (azimuthal quantum number)

(C) m_l (magnetic quantum number)

(D) m_s (spin quantum number)

Q23. An agricultural soil sample displays a pH reading of 5.0 on a calibrated digital pH meter. Which term most accurately describes this soil classification?

(A) Strongly acidic

(B) Moderately acidic

(C) Slightly acidic

(D) Neutral

Q24. In highly calcareous soils with pH above 8.0, which micronutrient becomes severely deficient due to precipitation of insoluble hydroxides and carbonates?

(A) Zinc and Iron

(B) Copper and Boron

(C) Manganese and Molybdenum

(D) Nickel and Cobalt

Q25. When pure acetic acid (CH_3COOH) is completely neutralized by sodium hydroxide (NaOH), what is the chemical formula of the salt product formed?

(A) CH_3COONa

(B) $NaCH_3CO$

(C) CH_3Na

(D) Na_2CO_3

Detailed Solutions

Q1.

Solution

Concept:
Solution dilution is a fundamental chemical laboratory operation governed by the conservation of solute mass. When solvent is added to a concentrated solution, the absolute number of moles of dissolved solute remains constant while the total solution volume increases. This inverse geometric relationship between solution concentration and solution volume is mathematically quantified using the linear equation $M_1V_1 = M_2V_2$, which allows for the exact calculation of the final molarity when a known volume of concentrated solution is diluted to a specified target final volume.
Solution:

(a) Extract and identify the initial and final parameters from the problem description: initial concentration $M_1 = 0.15$ M, initial aliquot volume $V_1 = 35$ mL, and final total dilution volume $V_2 = 500$ mL.

(b) Set up the standard linear dilution equation $M_1V_1 = M_2V_2$ to express the conservation of sodium thiosulfate moles during the laboratory procedure.

(c) Substitute the known parameters into the formula, yielding the algebraic expression $0.15 \times 35 = M_2 \times 500$.

(d) Rearrange the equation to isolate the unknown variable, which gives $M_2 = \frac{5.25}{500}$.

(e) Execute the final arithmetic division to determine that the final concentration of the diluted solution is exactly 0.0105 M.

Final Answer: The molarity of the diluted solution is 0.0105 M.

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept:
Phosphorus is an essential macronutrient for plant biochemical processes, functioning as a primary structural element in nucleic acids and mediating energy transfer via adenosine triphosphate molecules. In vascular plants, phosphorus exhibits high mobility within the phloem transport system, which allows the plant to actively translocate and redistribute available phosphate ions from mature, fully expanded older leaves toward rapidly developing apical meristems and reproductive organs during periods of environmental soil deficiency. This systemic nutrient mobilization triggers an overproduction and accumulation of protective anthocyanin pigments within the source tissues, manifesting visually as a distinct dark purple coloration along leaf veins.
Solution:

(a) Analyze the physiological symptom profile, noting that a combination of overall stunted vegetative growth and purple discoloration of leaf veins and petioles uniquely points to an underlying phosphorus deficiency.

(b) Recognize that phosphorus is classified as a highly phloem-mobile nutrient, allowing it to be easily exported out of mature leaf structures.

(c) Understand that sugar accumulation from disrupted triose-phosphate transport biochemically upregulates the phenylpropanoid metabolic pathway in older leaves.

(d) Identify that this metabolic upregulation results in the rapid synthesis and accumulation of water-soluble anthocyanin pigments, creating the characteristic dark purple hue.

(e) Deduce that because young developing leaves act as strong metabolic sinks, they successfully draw phosphorus away from older source leaves, causing the older leaves to express these severe deficiency symptoms first.

Final Answer: The nutrient deficiency responsible for these symptoms is Phosphorus (P).

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:
The dissolution of solid calcium oxide in water involves a two-step chemical process: an initial highly exothermic hydration reaction followed by the dissociation of the resulting hydroxide compound. Solid calcium oxide reacts stoichiometrically with water molecules to form calcium hydroxide. The subsequent molarity of the solution is determined by computing the total number of moles of calcium hydroxide generated and dividing that quantity by the final liquid volume of the aqueous solution expressed in liters, assuming complete reaction of the limited alkaline earth metal oxide reactant.

Solution:

(a) Calculate the total number of moles of solid calcium oxide used by dividing the initial mass by its given molecular weight: $\frac{0.5\text{ g}}{56\text{ g/mol}} = 0.00893$ mol.

(b) Write out the balanced stoichiometric equation for the hydration reaction: $CaO + H_2O \rightarrow Ca(OH)_2$.

(c) Apply the 1:1 molar ratio from the reaction stoichiometry to determine that exactly 0.00893 moles of solid calcium hydroxide are produced.

(d) Convert the specified volume of distilled water from milliliters into standard volumetric units of liters: 100 mL = 0.1 L.

(e) Calculate the final solution molarity by dividing total solute moles by the volume in liters: $M = \frac{0.00893\text{ mol}}{0.1\text{ L}} = 0.0893$ M.

Final Answer: The molarity of the calcium hydroxide solution formed is 0.0893 M.

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:
The complete combustion of an organic hydrocarbon molecule is an exothermic oxidation reaction wherein the compound reacts completely with excess molecular oxygen gas. This chemical transformation converts all elemental carbon present in the reactant into carbon dioxide gas, while simultaneously transforming all elemental hydrogen into water vapor molecules. The molar ratio governing the relationship between the consumed hydrocarbon fuel and the generated water molecules is dictated entirely by the conservation of hydrogen atoms, meaning the total number of product water moles is always exactly equal to half the number of hydrogen atoms contained within a single molecule of the starting alkane.

Solution:

(a) Determine the exact chemical formula of the straight-chain alkane fuel, where hexane is represented by the formula C_6H_{14}.

(b) Count the total number of individual hydrogen atoms present within a single molecule of hexane, which is equal to fourteen.

(c) Set up the balanced chemical equation representing the complete combustion process: $C_6H_{14} + 9.5O_2 \rightarrow 6CO_2 + 7H_2O$.

(d) Recognize that each generated molecule of water requires exactly two input hydrogen atoms from the organic alkane structure.

(e) Divide the total number of hexane hydrogen atoms by two to calculate the final stoichiometric coefficient of water: $\frac{14}{2} = 7$ moles.

Final Answer: The number of moles of water molecules produced is 7 moles.

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:
The electronic architecture of a ground-state atom is governed by quantum mechanical principles, including the Aufbau principle, the Pauli exclusion principle, and Hund's rule of maximum multiplicity. Hund's rule dictates that when filling a set of degenerate orbitals belonging to the same subshell, electrons must occupy individual orbitals singly with parallel spins before they begin to pair up in the same spatial orbital. The valence shell configuration represents the outermost electron shell of the element, and the presence of unpaired electrons within these valence states dictates the chemical valency, magnetic properties, and covalent bonding geometry of the atom.
Solution:

(a) Note that a neutral silicon atom has an atomic number of 14, meaning it possesses fourteen total electrons to distribute across its energy levels.

(b) Write out the full ground-state electron configuration in order of increasing subshell energy: $1s^2 2s^2 2p^6 3s^2 3p^2$.

(c) Identify the outermost principal quantum shell ($n = 3$) as the active valence shell, which contains a total of four valence electrons.

(d) Examine the orbital distribution within the highest energy subshell, observing that the $3s$ subshell is completely filled with two paired electrons.

(e) Apply Hund's rule to the remaining two electrons entering the three degenerate $3p$ orbitals, placing one electron into the $3p_x$ orbital and one into the $3p_y$ orbital, which yields exactly two unpaired valence electrons.

Final Answer: The number of unpaired electrons present in the valence shell of silicon is 2.

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:
Geometric isomerism, also known as cis-trans isomerism, represents a form of stereoisomerism encountered in organic molecules containing rigid structural elements that restrict free carbon-carbon single bond rotation, such as a localized carbon-carbon double bond. Because the pi bond prevents rotation without breaking, substituents attached to the sp2 hybridized carbon atoms are locked into a permanent spatial orientation. When identical or high-priority reference substituents, such as hydrogen atoms, reside on completely opposite sides of the imaginary reference plane drawn along the double bond axis, the molecule is classified as the trans isomer. Conversely, when they reside on the same side, it represents the cis configuration.

Solution:

(a) Analyze the provided chemical skeletal drawing to locate the rigid carbon-carbon double bond that forms the core geometric reference framework.

(b) Identify the specific substituents attached to each of the two sp2 hybridized carbon atoms participating in the double bond.

(c) Observe the spatial arrangement of the two hydrogen atoms, noting that they are attached to opposite ends of the double bond on opposite sides of the internuclear axis.

(d) Verify that this diagonal spatial alignment matches the standard stereochemical definition of a trans structural configuration.

(e) Conclude that since the two identical hydrogen atoms are oriented on opposite sides of the double bond, the correct geometric descriptor is the trans configuration.

Final Answer: The geometric isomerism designation for this compound is the Trans configuration.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

The solubility, chemical speciation, and bioavailability of transition metal cations within agricultural soil environments are profoundly influenced by the ambient soil solution pH. In strongly acidic soil conditions, transition metals like iron exist primarily as highly hydrated, soluble ionic species due to the high concentration of hydronium ions, which shifts chemical equilibria away from mineral precipitation. However, when the soil pH is raised toward neutrality through the addition of agricultural lime, the increasing concentration of hydroxide ions drives a precipitation reaction, forcing the soluble metal cations to form insoluble solid metal hydroxides that precipitate out of the soil solution, rendering the nutrient chemically unavailable to plant roots.

Solution:

(a) Recognize that transition metals exhibit distinct, highly sensitive pH-dependent solubility profiles within complex multi-phase agricultural soil systems.

(b) Identify iron as the key transition metal element that remains highly soluble and potentially phytotoxic in low-pH, strongly acidic soil environments.

(c) Understand that raising the soil pH toward neutrality introduces a high concentration of free hydroxide ions into the soil solution.

(d) Apply solubility product dynamics to see that free iron cations combine with hydroxide ions to precipitate as solid iron hydroxides, such as $Fe(OH)_3$.

(e) Conclude that this specific precipitation behavior, which locks up the metal at a neutral pH, is characteristic of iron.

Final Answer: The metallic element that exhibits this behavior is Iron.

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept:
Solution dilution calculations are anchored by the fundamental physical principle of the conservation of matter, which states that the total number of moles of solute remains invariant during the addition of pure solvent. The relationship between the initial concentrated solution properties and the desired final diluted solution properties is represented by the formula $M_1V_1 = M_2V_2$. By algebraically rearranging this linear relationship, a researcher can isolate and compute the exact volume of concentrated stock reagent needed to achieve a target volume of a lower specified molar concentration.

Solution:

(a) Identify and organize the given values from the lab problem: stock concentration $M_1 = 12$ M, target concentration $M_2 = 0.5$ M, and final target volume $V_2 = 250$ mL.

(b) Set up the standard conservation-of-solute dilution equation, expressing it as $M_1V_1 = M_2V_2$.

(c) Algebraic rearrange the formula to isolate the unknown variable representing the required stock volume: $V_1 = \frac{M_2V_2}{M_1}$.

(d) Substitute the known experimental values into the rearranged equation, giving $V_1 = \frac{0.5\times250}{12}$.

(e) Simplify the numerator to 125 and perform the final division to calculate the precise volume required: $V_1 = 10.42$ mL, which rounds to 10.4 mL.

Final Answer: The volume of concentrated acid that must be used is 10.4 mL.

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
The chemical dehydration of a primary alcohol under strongly acidic conditions at elevated temperatures represents an elimination reaction, specifically classified as an E1 or E2 mechanism depending on reaction conditions. Concentrated sulfuric acid acts simultaneously as a catalyst and a powerful dehydrating agent. The acid protonates the hydroxyl group of the alcohol, converting a poor leaving group into an excellent leaving group (water). Upon heating, a water molecule is eliminated alongside an adjacent beta-hydrogen atom, resulting in the formation of a new carbon-carbon pi bond and transforming the saturated aliphatic alcohol into an unsaturated alkene hydrocarbon.

Solution:

(a) Identify the chemical structure of the starting reactant, noting that ethanol is a short two-carbon primary alcohol with the formula C_2H_5OH.

(b) Recognize that heating the alcohol in the presence of concentrated sulfuric acid triggers an acid-catalyzed elimination reaction sequence.

(c) Understand that the acid catalyst protonates the hydroxyl group to facilitate the loss of a neutral water molecule from the ethyl framework.

(d) Eliminate a hydrogen atom from the adjacent methyl carbon atom, which causes the electronic structure to collapse and form a carbon-carbon double bond.

(e) Deduce that the resulting two-carbon unsaturated gaseous hydrocarbon product is ethene, which has the chemical molecular formula C_2H_4.

Final Answer: The primary product formed when ethanol undergoes dehydration is Ethene (C_2H_4).

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
Quantitative combustion analysis operates on the principle that when an organic sample is burned completely in excess oxygen, all carbon atoms are converted into carbon dioxide gas. By measuring the mass of the generated carbon dioxide, the total mass of carbon contained within the original sample can be precisely calculated using the stoichiometric mass ratio of carbon to carbon dioxide. This ratio is derived directly from their respective molar masses, where carbon has an atomic mass of 12 g/mol and carbon dioxide has a molecular mass of 44 g/mol. The mass percentage is then computed by dividing the isolated carbon mass by the total initial mass of the sample.
Solution:

(a) Record the initial mass values provided in the problem: organic sample mass = 0.80 grams, and generated carbon dioxide mass = 0.80 grams.

(b) Determine the stoichiometric mass fraction of carbon contained within carbon dioxide using their respective molar masses: $\frac{12 \text{ g/mol C}}{44 \text{ g/mol CO}_2}$.

(c) Calculate the absolute mass of elemental carbon by multiplying the generated mass of CO_2 by this mass fraction: $0.80 \text{ g} \times \frac{12}{44} = 0.2182$ grams of C.

(d) Set up the mass percentage ratio by dividing the computed mass of elemental carbon by the initial mass of the organic sample: $\frac{0.2182 \text{ g C}}{0.80 \text{ g sample}}$.

(e) Multiply this fractional quotient by one hundred to express the value as a percentage, yielding a final value of 27.3 percent.

Final Answer: The mass percentage of carbon in the original compound is 27.3 percent.

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
The systematic naming of organic compounds follows authoritative IUPAC nomenclature regulations designed to provide a unique, unambiguous structural identifier for every molecule. For unsaturated hydrocarbons containing a carbon-carbon double bond (alkenes), the parent chain prefix is determined by the total number of carbon atoms in the longest continuous chain. The presence of the double bond is denoted by modifying the suffix to "-ene". Furthermore, numerical locants are inserted directly before the functional suffix to specify the exact carbon atom where the double bond begins, with the chain numbered from the end that grants the double bond the lowest possible position number.

Solution:

(a) Identify the length of the continuous carbon chain, noting that an eight-carbon straight-chain framework corresponds to the IUPAC parent root "oct".

(b) Recognize that the presence of a single carbon-carbon double bond dictates the use of the specific alkene functional suffix "-ene".

(c) Pinpoint the location of the double bond, which is described as being positioned between the third and fourth carbon atoms of the chain.

(d) Apply numbering rules to determine that counting from the closest end assigns the lower numerical locant of 3 to the start of the double bond.

(e) Assemble the complete systematic name by placing the numerical locant directly before the suffix according to modern formatting standards, yielding oct-3-ene.

Final Answer: The straight-chain hydrocarbon is named oct-3-ene.

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept:
The spatial distribution of nutrient deficiency symptoms across a plant's anatomy is fundamentally dictated by the relative mobility of that specific nutrient within the vascular phloem tissue. Magnesium serves as the central coordinating ion in the chlorophyll molecule and is classified as a highly mobile nutrient. When an agricultural crop experiences a shortage of soil-available magnesium, the plant initiates a survival mechanism whereby it breaks down chlorophyll in older, mature leaves. The liberated magnesium ions are then actively loaded into the phloem and translocated upward to sustain active photosynthesis in younger, developing leaves, causing interveinal chlorosis to appear on older foliage first.
Solution:

(a) Recognize that the specific location of initial deficiency symptoms is determined by whether a nutrient can be re-mobilized within the plant's vascular network.

(b) Categorize magnesium as a highly mobile element capable of rapid, active redistribution through the phloem.

(c) Understand that under conditions of soil nutrient scarcity, the plant prioritizes the growth of new leaves and apical meristems over older structures.

(d) Identify that magnesium is actively withdrawn from older leaves and translocated upward toward these developing metabolic sinks.

(e) Conclude that this systematic depletion of magnesium from older leaves causes interveinal chlorosis to manifest in mature lower foliage while newer upper leaves remain green.

Final Answer: Magnesium is highly mobile and gets translocated to new growth tissues.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
The ground-state electron configuration of transition metal elements is determined by systematically filling atomic subshells in order of increasing energy, as described by the Aufbau principle, while satisfying the Pauli exclusion principle and Hund's rule. For first-row transition metals, the noble gas core of argon ($Z = 18$) represents the stable, filled inner electron core. When filling subsequent orbitals, the $4s$ and $3d$ subshells are very close in energy. For manganese ($Z = 25$), electrons fill the orbitals to create a highly stable configuration characterized by a completely filled valence $4s$ subshell and a symmetrically stable, half-filled $3d$ subshell.
Solution:

(a) Note that manganese has an atomic number of 25, indicating that a neutral atom contains twenty-five total electrons to be arranged in subshells.

(b) Account for the first eighteen electrons by assigning them to the filled noble gas core configuration of argon, abbreviated as [Ar].

(c) Determine the number of remaining electrons that need to be distributed among the higher energy valence orbitals: $25 - 18 = 7$ electrons.

(d) Assign two of the remaining electrons to completely fill the lower energy spherical $4s$ valence orbital, writing this component as $4s^2$.

(e) Place the final five electrons into the five degenerate d-orbitals of the $3d$ subshell, resulting in a stable half-filled configuration expressed as $3d^5$.

Final Answer: The ground state electron configuration of manganese is $[\text{Ar}]3d^5 4s^2$.

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept:
The electrostatic binding affinity of exchangeable base cations for the negatively charged exchange sites on clay mineral colloids is governed by Coulomb's law. This affinity is determined by the ion's charge density, which is defined as the net electrostatic charge of the cation divided by its ionic radius. Cations possessing a higher positive valence charge experience a stronger electrostatic attraction to negative clay surfaces than monovalent ions. Furthermore, among ions sharing the same valence charge, a smaller ionic radius concentrates the charge over a smaller surface area, resulting in a higher charge density and a greater binding affinity.

Solution:

(a) Compare the electrostatic valence charges of the four competing soil cations: sodium and potassium are monovalent (+1), while calcium and magnesium are divalent (+2).

(b) Eliminate the monovalent cations because divalent cations possess a higher net positive charge, giving them a stronger baseline electrostatic attraction.

(c) Compare the ionic radii of the remaining divalent cations, noting that magnesium has a smaller ionic radius than calcium due to having fewer electron shells.

(d) Combine the high +2 valence charge with the smaller ionic radius of the magnesium ion to deduce that it exhibits the highest overall charge density.

(e) Conclude that this elevated charge density grants the magnesium cation the greatest relative binding affinity for negatively charged clay exchange complexes.

Final Answer: The soil exchangeable base cation with the highest charge density is Magnesium (Mg^{2+}).

Answer: (D)

Go Back to Question 14

Q15.

Solution

Concept:
An acid-base indicator is a weak organic acid or base that undergoes a distinct structural and color change within a specific, narrow hydrogen ion concentration range, quantified by its indicator dissociation constant. To ensure analytical accuracy in a volumetric titration, the selected indicator must exhibit a visible color transition range that matches the rapid pH change occurring at the titration's equivalence point. When titrating a weak chemical base with a strong mineral acid, the resulting conjugate salt undergoes hydrolysis, causing the equivalence point to occur under acidic conditions well below a neutral pH of 7.0.

Solution:

(a) Examine the specified experimental parameters, noting that the titration reaction reaches its chemical equivalence point at an acidic pH value of approximately 3.0.

(b) Evaluate the operative pH color transition ranges for the standard chemical indicators listed among the multiple-choice options.

(c) Dismiss phenolphthalein and bromothymol blue, as their visual transition zones occur in basic and neutral pH regions, respectively.

(d) Analyze the transition range of methyl orange, noting that it undergoes a distinct visual color change from red to yellow between pH 3.1 and 4.4.

(e) Conclude that because the transition zone of methyl orange matches the acidic equivalence point of 3.0, it is the most appropriate indicator for this experiment.

Final Answer: The indicator appropriate for this titration is Methyl orange.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
Periodic trends across a single horizontal row of the periodic table are driven by changes in effective nuclear charge. As one moves from left to right across Period 3, the number of protons in the nucleus increases sequentially, while the number of inner-shell shielding electrons remains constant. This creates a stronger electrostatic pull on the outer valence electrons. Consequently, the first ionization potential increases because more energy is required to remove an electron from the strongly bound valence shell. Similarly, electron affinity generally becomes more exothermic as atoms release more energy when capturing an electron, though minor exceptions occur due to the stability of filled or half-filled electronic subshells.

Solution:

(a) Observe the horizontal path across Period 3, starting from the alkali metal sodium ($Z = 11$) and ending at the halogen chlorine ($Z = 17$).

(b) Note that the number of nuclear protons increases continuously, creating a stronger positive charge that pulls the valence electron cloud closer to the nucleus.

(c) Connect this increasing effective nuclear charge to ionization potential, deducing that it requires more energy to remove an electron, so ionization potential increases.

(d) Connect the nuclear pull to electron affinity, noting that the stronger attraction for extra electrons generally causes electron affinity to increase.

(e) Account for minor exceptions along the trend, such as the filled 3s subshell of magnesium and the half-filled 3p subshell of phosphorus, which modify the progression.

Final Answer: IP increases; EA increases with exceptions.

Answer: (B)

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Q17.

Solution

Concept:

Covalent bonds are classified as sigma (σ) or pi (π) bonds based on the spatial symmetry of the overlapping atomic orbitals. A single covalent bond consists of a single sigma bond formed by the direct, head-on overlap of atomic orbitals along the internuclear axis. A localized double covalent bond consists of one strong sigma bond combined with one weaker pi bond formed by the lateral overlap of unhybridized p-orbitals. To determine the total number of sigma bonds within a polyatomic organic molecule, one must examine its structural connectivity and count every single bond plus one bond from each double bond present.

Solution:

(a) Draw out the full structural connectivity diagram of the acetic acid molecule, expanding the formula CH_3COOH to show all individual atomic linkages.

(b) Count the single covalent bonds within the terminal methyl group, which contains three separate carbon-hydrogen ($C-H$) single sigma bonds.

(c) Count the single covalent bond connecting the two carbon atoms together, which contributes one carbon-carbon ($C-C$) sigma bond.

(d) Examine the carbonyl group ($C=O$), identifying that this double bond consists of one sigma bond and one pi bond.

(e) Count the remaining single bonds in the carboxyl group: one carbon-oxygen ($C-O$) single sigma bond and one oxygen-hydrogen ($O-H$) single sigma bond.

(f) Sum all the individual sigma bonds together: $3+1+1+1+1=8$ total sigma bonds.

Final Answer: The number of sigma covalent bonds present is 8 sigma bonds.

Answer: (C)

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Q18.

Solution

Concept:
The mineralogical composition of agricultural soils is shaped by the intensity of chemical weathering, which is driven by ambient climatic factors such as high temperatures and abundant rainfall. In humid tropical climates, prolonged leaching removes highly soluble basic cations and silica from primary minerals like micas and feldspars. This advanced weathering removes silica from the mineral lattices, transforming expanding 2:1 layer silicates into stable, non-expanding 1:1 aluminosilicate clay minerals. These highly weathered residues have a low cation exchange capacity and do not shrink or swell when wet.

Solution:

(a) Evaluate the environmental conditions of tropical climates, noting that high temperatures and heavy rainfall accelerate chemical weathering and leaching.

(b) Understand that prolonged leaching removes soluble silica along with exchangeable base cations like calcium and potassium from the soil matrix.

(c) Recognize that the loss of silica causes 2:1 clay minerals to break down and re-crystallize into simpler 1:1 layer structures.

(d) Identify kaolinite as the dominant, thermodynamically stable 1:1 aluminosilicate clay mineral produced by this intense weathering process.

(e) Differentiate kaolinite from less-weathered 2:1 clays like montmorillonite and illite, which typically predominate in regions with milder weathering conditions.

Final Answer: The primary clay mineral contained in this soil is Kaolinite.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept:
The stoichiometry of an acid-base neutralization titration is governed by the conservation of chemical equivalents, where the moles of hydronium ions delivered by the acid must exactly equal the moles of hydroxide ions consumed by the base at the equivalence point. By comparing the total moles of sodium hydroxide titrant used with the initial moles of the organic acid sample, a researcher can determine the exact molar reaction ratio. This stoichiometric ratio directly reveals the proticity of the acid, which indicates the number of ionizable hydrogen atoms available per molecule of the acid.

Solution:

(a) Calculate the total number of moles of organic acid initially present in the sample: $25 \text{ mL} \times 0.1 \text{ M} = 0.0025$ moles of acid.

(b) Calculate the total number of moles of sodium hydroxide base consumed at the titration equivalence point: $50 \text{ mL} \times 0.1 \text{ M} = 0.0050$ moles of NaOH.

(c) Determine the stoichiometric molar ratio by dividing the moles of base by the moles of acid: $\frac{0.0050 \text{ mol base}}{0.0025 \text{ mol acid}} = 2$.

(d) Analyze this 2:1 ratio to deduce that each individual molecule of the organic acid releases exactly two moles of hydronium ions during the neutralization reaction.

(e) Conclude from this chemical behavior that the starting organic acid must be classified structurally as a diprotic acid.

Final Answer: The conclusion that can be made is that the acid is diprotic.

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept:
Molybdenum is an essential metallic micronutrient required by plants for vital enzymatic processes, including nitrogen fixation and nitrate reduction. Unlike most other transition metal micronutrients, such as iron, manganese, and zinc—whose solubilities increase in acidic solutions—the chemical availability of molybdenum decreases as soil pH drops. In strongly acidic soil environments, molybdate anions encounter highly protonated clay surfaces and hydrous oxides of iron and aluminum. This triggers a strong adsorption process that chemisorbs and locks up the molybdate ions, making them insoluble and unavailable for root uptake.

Solution:

(a) Identify molybdenum's active chemical state in soil solutions, where it exists primarily as the divalent molybdate anion (MoO_4^{2-}).

(b) Contrast molybdenum's behavior with other transition metals, noting that its availability decreases rather than increases as soil pH drops.

(c) Recognize that low-pH environments below 5.0 increase the positive charge density on the surfaces of iron and aluminum oxides.

(d) Understand that these protonated surfaces form strong coordination complexes that tightly bind and immobilize the molybdate anions.

(e) Conclude that this adsorption at a low pH creates a severe nutrient deficiency, making an acidic pH below 5.0 the most critical restricting factor.

Final Answer: The soil condition that restricts availability is an Acidic pH below 5.0.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
The halogenation of an alkane under ultraviolet light is a free radical substitution reaction that proceeds through three distinct stages: initiation, propagation, and termination. The ultraviolet radiation provides the activation energy needed to cause homolytic cleavage of the halogen molecule, producing highly reactive halogen radicals. During the propagation phase, a halogen radical abstracts a hydrogen atom from the alkane to form a alkyl radical, which then reacts with another halogen molecule to generate a stable, mono-substituted organohalogen compound along with a new halogen radical that sustains the chain reaction.

Solution:

(a) Identify the starting organic reactant as methane, a symmetrical single-carbon alkane containing four equivalent carbon-hydrogen single bonds.

(b) Recognize that ultraviolet light acts as the initiator, cleaving the covalent bond of molecular chlorine to produce free chlorine radicals ($Cl^\bullet$).

(c) Understand the propagation step where a chlorine radical abstracts a hydrogen atom from methane, producing a methyl radical ($CH_3^\bullet$) and hydrogen chloride.

(d) Follow the subsequent propagation step where the methyl radical reacts with a chlorine molecule to form a stable organohalogen compound.

(e) Deduce that this primary mono-substitution reaction replaces a single hydrogen atom with a chlorine atom, yielding chloromethane (CH_3Cl).

Final Answer: The primary mono-substituted product formed is Chloromethane.

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:
The spatial behavior and energy states of electrons within an atom are mathematically described by four unique quantum numbers that solve the Schrödinger wave equation. The principal quantum number (n) defines the primary electron shell size and energy level. The azimuthal quantum number (l), also called the angular momentum or orbital quantum number, mathematically governs the magnitude of the orbital angular momentum of the electron. This quantum number dictates the geometric shape and symmetry of the orbital subshell, restricting the electron to specific spatial distributions designated as spherical (s), dumbbell (p), cloverleaf (d), or complex (f) geometries.
Solution:

(a) Review the distinct physical roles assigned to each of the four fundamental quantum numbers within the framework of atomic theory.

(b) Recognize that the principal quantum number n is restricted to positive integers and determines the size and base energy of the electron shell.

(c) Focus on the azimuthal quantum number l, which ranges from 0 to $n-1$ and determines the orbital angular momentum of the electron.

(d) Correlate the integer values of l with specific orbital geometries, where $l = 0$ represents an s subshell and $l = 1$ represents a p subshell.

(e) Conclude that since the azimuthal quantum number governs both angular momentum and subshell geometry, it is the correct identifier.

Final Answer: The quantum number that defines this relationship is the Azimuthal quantum number (l).

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:

Soil pH is a logarithmic measurement that quantifies the activity and concentration of free hydronium ions (H_3O^+) present within the aqueous soil solution phase. The standard agronomic classification system categorizes soil acidity into distinct descriptive ranges to guide soil management and crop selection. A neutral soil solution has a pH of 7.0, whereas values descending below 7.0 indicate increasing levels of acidity. Descriptive terms such as slightly, moderately, strongly, or very strongly acidic are assigned to specific, standardized numerical ranges based on the measured intensity of the hydrogen ion concentration.

Solution:

(a) Note the digital pH meter reading of 5.0, confirming that the soil solution contains an elevated concentration of hydronium ions and is acidic.

(b) Recall the standard descriptive classification brackets used by soil scientists to categorize measured soil pH values.

(c) Identify that a pH range between 6.1 and 6.5 is slightly acidic, while a range between 5.6 and 6.0 is categorized as moderately acidic.

(d) Recognize that a measured pH value falling between 5.1 and 5.5 is classified as strongly acidic, and a value between 4.5 and 5.0 is classified as very strongly acidic.

(e) Conclude that according to standard agricultural reference definitions, a pH reading of 5.0 is classified as strongly acidic.

Final Answer: The descriptive term that accurately describes this soil is Strongly acidic.

Answer: (A)

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Q24.

Solution

Concept:
Highly calcareous soils are characterized by an abundance of calcium carbonate ($CaCO_3$), which buffers the soil system to an alkaline pH range between 8.0 and 8.5. This alkaline, carbonate-rich environment alters the chemical equilibria governing the solubility of essential transition metal micronutrients. Under high pH conditions, free metal cations react with the abundant hydroxide and carbonate ions present in the soil solution. This drives precipitation reactions that convert soluble nutrients into highly insoluble solid hydroxides and carbonates, removing them from the soil solution and inducing severe plant deficiencies.

Solution:

(a) Analyze the chemical environment of a calcareous soil, noting that a pH above 8.0 indicates an alkaline solution rich in carbonate ions.

(b) Recall that transition metal micronutrients depend heavily on an acidic or neutral pH to remain dissolved in their ionic forms.

(c) Understand that elevated concentrations of hydroxide ions force soluble metal cations to precipitate out as solid hydroxides.

(d) Identify zinc and iron as two critical transition metal micronutrients that form highly insoluble precipitates under these alkaline conditions.

(e) Conclude that this precipitation removes zinc and iron from the soil solution, making them the primary nutrients that become deficient.

Final Answer: The micronutrients that become severely deficient are Zinc and Iron.

Answer: (A)

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Q25.

Solution

Concept:
The chemical reaction between a carboxylic acid and a strong base represents a classic Arrhenius acid-base neutralization process. During this reaction, the acidic hydrogen atom from the carboxyl group of the organic acid is transferred to the hydroxide ion of the base, yielding a water molecule and leaving behind a dissolved ionic salt compound composed of a metal cation and an organic carboxylate anion.

Solution:

(a) Identify the chemical structure of the reactants involved in the process, where pure acetic acid is represented by CHCOOH and sodium hydroxide is represented by NaOH.

(b) Recognize that acetic acid is a monoprotic acid that selectively donates its single terminal carboxylic hydrogen atom located on the functional group rather than the stable hydrogen atoms bound to the methyl carbon.

(c) Write the balanced molecular equation for the complete neutralization process, which proceeds directly as $CH_3COOH + NaOH \to CH_3COONa + H_2O$ under standard aqueous conditions.

(d) Analyze the resulting products to identify that water is generated alongside the specific organic salt compound known systematically as sodium acetate.

(e) Confirm the chemical formula of sodium acetate by balancing the single negative charge of the acetate structural anion with the single positive charge of the sodium metal cation, yielding CHCOONa.

Final Answer: The chemical formula of the salt product formed is CH_3COONa.

Answer: (A)

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Answer Key

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