Rajasthan JET Chemistry Sample Paper-9

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

Instructions

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

Q1. Which of the following sets of quantum numbers is not permissible for an electron in an atom?

(A) n = 3, l = 2, m = -2, s = +1/2

(B) n = 4, l = 0, m = 0, s = -1/2

(C) n = 3, l = 3, m = 1, s = +1/2

(D) n = 2, l = 1, m = 0, s = -1/2

Q2. The correct order of increasing first ionization enthalpy for the elements Na, Mg, Al, and Si is:

(A) Na < Al < Mg < Si

(B) Na < Mg < Al < Si

(C) Al < Na < Mg < Si

(D) Na < Al < Si < Mg

Q3. The geometry and hybridization of the central atom in SF_4 molecule according to VSEPR theory are respectively:

(A) Tetrahedral, sp^3

(B) See-saw, sp^3d

(C) Trigonal bipyramidal, sp^3d

(D) Square planar, d^2sp^3

Q4. In which of the following compounds does nitrogen exhibit its highest oxidation state?

(A) N_2H_4

(B) NH_3

(C) N_3H

(D) HNO_3

Q5. How many grams of $NaOH$ are required to prepare 250 mL of a 0.5 M aqueous solution?

(A) 5.0 g

(B) 10.0 g

(C) 2.0 g

(D) 4.0 g

Q6. An element has the electronic configuration $[Ar]3d^5 4s^1$. Identify its position in the periodic table:

(A) Group 6, Period 4

(B) Group 5, Period 4

(C) Group 6, Period 3

(D) Group 11, Period 4

Q7. Which of the following pairs represents isoelectronic species?

(A) Na^+ and Mg

(B) Al^{3+} and O^{2-}

(C) Ca^{2+} and S

(D) N^{3-} and Cl^-

Q8. The type of bond present in a crystalline copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) specimen comprises:

(A) Electrovalent and covalent bonds only

(B) Covalent and coordinate bonds only

(C) Electrovalent, covalent, and coordinate bonds only

(D) Electrovalent, covalent, coordinate, and hydrogen bonds

Q9. Identify the disproportionation reaction among the following chemical transformations:

(A) $2KClO_3 \rightarrow 2KCl + 3O_2$

(B) $2H_2O_2 \rightarrow 2H_2O + O_2$

(C) $CuO + H_2 \rightarrow Cu + H_2O$

(D) $CaCO_3 \rightarrow CaO + CO_2$

Q10. The number of radial and angular nodes present in a 3p orbital are respectively:

(A) 1, 1

(B) 2, 1

(C) 1, 0

(D) 0, 2

Q11. According to molecular orbital theory, which of the following diatomic species is expected to be paramagnetic and have a bond order equal to 2?

(A) O_2

(B) N_2

(C) C_2

(D) F_2

Q12. Empirical formula of a compound containing 40% carbon, 6.67% hydrogen, and 53.33% oxygen by mass is:

(A) CHO

(B) CH_2O

(C) CHO_2

(D) C_2H_4O

Q13. For a first-order chemical reaction, if the initial concentration of the reactant is doubled, the half-life ($t_{1/2}$) of the reaction will:

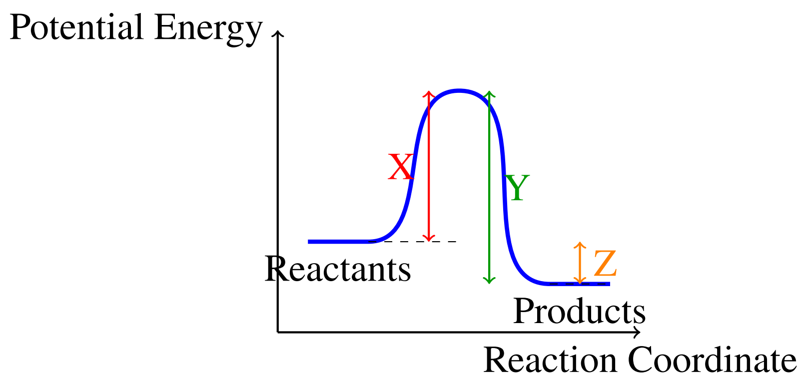
(A) Be doubled

(B) Be halved

(C) Remain unchanged

(D) Increase by four times

Q14. Consider the following potential energy profile for a chemical reaction. What represents the activation energy (E_a) of the forward reaction?



(A) Interval X

(B) Interval Y

(C) Interval Z

(D) Sum of X and Y

Q15. The molar conductivity of a strong electrolyte increases slightly with dilution primarily because:

(A) The total number of ions increases significantly

(B) Interionic attractions decrease, increasing ionic mobility

(C) The degree of ionization increases sharply

(D) Viscosity of the solvent increases drastically

Q16. The relationship between the equilibrium constants K_p and K_c for the gaseous phase reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is correctly expressed as:

(A) $K_p = K_c(RT)^2$

(B) $K_p = K_c(RT)^{-2}$

(C) $K_p = K_c(RT)^{-1}$

(D) $K_p = K_c$

Q17. Which of the following aqueous solutions will exhibit the highest boiling point elevation? (Assume complete dissociation where applicable)

(A) 0.1 M Glucose

(B) 0.1 M $NaCl$

(C) 0.1 M $BaCl_2$

(D) 0.1 M $Al_2(SO_4)_3$

Q18. For a spontaneous thermodynamic process occurring at constant temperature and pressure, which of the following conditions must be satisfied?

(A) $\Delta H < 0$ only

(B) $\Delta S > 0$ only

(C) $\Delta G < 0$

(D) $\Delta G > 0$

Q19. The conjugate base of the Bronsted-Lowry acid $H_2PO_4^-$ is:

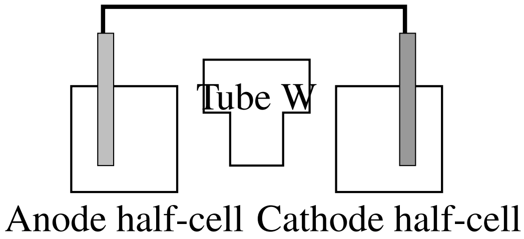
(A) HPO_4^{2-}

(B) PO_4^{3-}

(C) H_3PO_4

(D) HPO_4^-

Q20. Consider the standard electrochemical cell setup represented below. Identify the label corresponding to the salt bridge component.



(A) Anode Half-cell

(B) Tube W

(C) Cathode Half-cell

(D) Connecting Metallic wire

Q21. An aqueous solution of which of the following salts will turn red litmus paper blue?

(A) $NaCl$

(B) NH_4Cl

(C) CH_3COONa

(D) K_2SO_4

Q22. According to Henry's law, the solubility of a gas in a liquid medium is directly proportional to the:

(A) Temperature of the system

(B) Volume of the liquid container

(C) Partial pressure of the gas above the liquid surface

(D) Nature of the solute molecule size

Q23. The rate equation for a chemical process is given as Rate = $k[A]^2[B]^{1/2}$. What is the overall order of this reaction?

(A) 2

(B) 1

(C) 2.5

(D) 1.5

Q24. In an ideal solution binary system, the total vapor pressure over the solution phase is determined using:

(A) Raoult's Law

(B) Dalton's Law of partial volumes

(C) Ostwald's Dilution Law

(D) Van't Hoff Isotherm equation

Q25. According to IUPAC nomenclature rules, what is the systematic name of the coordination compound $[Co(NH_3)_5Cl]Cl_2$?

(A) Pentaamminechlorocobalt(III) chloride

(B) Pentaamminechlorocobalt(II) chloride

(C) Chloropentaamminecobalt(III) chloride

(D) Pentaamminechlorocobaltate(III) chloride

Q26. Which type of structural isomerism is demonstrated by the pair of coordination complexes $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$?

(A) Linkage isomerism

(B) Ionization isomerism

(C) Coordination isomerism

(D) Solvate isomerism

Q27. The hybridisation state and the number of unpaired electrons in the octahedral complex ion $[Fe(CN)_6]^{3-}$ are respectively:

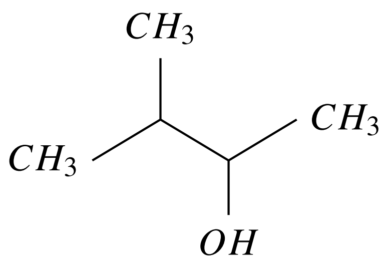
(A) sp^3d^2 and 5

(B) d^2sp^3 and 1

(C) d^2sp^3 and 5

(D) sp^3d^2 and 1

Q28. What is the correct IUPAC name of the organic compound illustrated in the structure below?



(A) 2-Methylbutan-3-ol

(B) 3-Methylbutan-2-ol

(C) Pentan-3-ol

(D) 2-Methylbutan-2-ol

Q29. Which of the following chemical groups acts as a strong deactivating and meta-directing group during electrophilic aromatic substitution reactions?

(A) $-NH_2$

(B) $-OCH_3$

(C) $-NO_2$

(D) $-CH_3$

Q30. When calcium carbide (CaC_2) undergoes controlled hydrolysis with water, the major gaseous organic product generated is:

(A) Methane (CH_4)

(B) Ethane (C_2H_6)

(C) Ethylene (C_2H_4)

(D) Acetylene (C_2H_2)

Q31. The homolytic cleavage of a covalent C–C bond yields which of the following reactive intermediate chemical species?

(A) Carbocations

(B) Carbanions

(C) Free Radicals

(D) Carbenes

Q32. The core structural functional unit present inside all geometric isomers of alkenes that restricts free molecular rotation is a:

(A) Carbon-Carbon single bond (σ)

(B) Carbon-Carbon double bond ($\sigma + \pi$)

(C) Carbon-Hydrogen single bond

(D) Carbon-Carbon triple bond

Q33. Identify the final major product 'Z' obtained in the following organic synthetic reaction sequence:

$$\text{Ethane} \xrightarrow{Cl_2/h\nu} X \xrightarrow{\text{Aqueous } KOH} Y \xrightarrow{\text{Alkaline } KMnO_4} Z$$

(A) Ethanol

(B) Chloroethane

(C) Ethanoic Acid

(D) Ethanal

Q34. The markownikoff addition of HBr to an unsymmetrical alkene like propene is a classic example of:

(A) Electrophilic Addition Reaction

(B) Nucleophilic Substitution Reaction

(C) Free Radical Addition Reaction

(D) Electrophilic Substitution Reaction

Q35. Black soil (Regur soil) found commonly across regions of India is primarily characterized as being exceptionally rich in which clay mineral?

(A) Kaolinite

(B) Illite

(C) Montmorillonite

(D) Gibbsite

Q36. Which of the following chemical elements is classified as an essential macronutrient for plant growth and is absorbed as an anion?

(A) Zinc (Zn)

(B) Phosphorus (P)

(C) Copper (Cu)

(D) Iron (Fe)

Q37. Ammonification is an essential soil microbiology process that describes the transformation of:

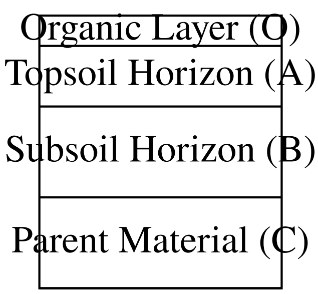
(A) Nitrate nitrogen into atmospheric nitrogen gas

(B) Organic nitrogenous matter into ammonia compounds

(C) Ammonium ions into nitrite ions

(D) Atmospheric nitrogen gas into chemical fertilizers

Q38. Consider the cross-section diagram of a mature soil profile. Which layer indicates the zone of maximum eluviation (leaching out) of clay and iron oxides?



(A) Organic Layer (O)

(B) Topsoil Horizon (A)

(C) Subsoil Horizon (B)

(D) Parent Material (C)

Q39. Which type of chemical fertilizer is categorized as a complex fertilizer containing more than one primary plant nutrient element?

(A) Urea

(B) Ammonium Sulfate

(C) Diammonium Phosphate (DAP)

(D) Single Super Phosphate (SSP)

Q40. Reclamation of highly sodic/alkali soil profiles to restore agricultural fertility is conventionally performed by adding:

(A) Calcium Carbonate (Lime)

(B) Calcium Sulfate Dihydrate (Gypsum)

(C) Sodium Carbonate

(D) Ammonium Chloride

Detailed Solutions

Q1.

Solution

Concept:
The permissible states of an electron in an atom are governed strictly by the four quantum numbers, which define its energy, orbital shape, orientation, and magnetic spin state. The principal quantum number n defines the primary shell, while the azimuthal quantum number l dictates the orbital subshell type and is limited to integer values ranging from 0 up to $n - 1$. The magnetic quantum number m determines the spatial orientation of that orbital and must fall within the range from $-l$ to $+l$, inclusive. Lastly, the spin quantum number s accounts for the intrinsic angular momentum of the electron and can only possess values of $+1/2$ or $-1/2$. Any violation of these mathematical dependencies makes a quantum state physically impossible.

Solution:

(a) For the configuration where $n = 3$ and $l = 3$, we must analyze the dependency between the principal and azimuthal quantum numbers.

(b) The rule states that l can only take values from 0 to $n - 1$. For a shell where $n = 3$, the allowed values for l are strictly 0, 1, or 2, which correspond to the s, p, and d subshells respectively.

(c) Therefore, an azimuthal quantum number of $l = 3$ requires at least a principal shell of $n = 4$ to exist as an f subshell.

(d) Because l cannot be equal to n, this specific set of quantum numbers represents an impossible state for an atomic electron.

(e) The remaining given options all satisfy the boundary rules where $l < n$, m falls within the correct bounds, and s is valid.

Final Answer: The set where the azimuthal quantum number equals the principal quantum number is invalid.

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept:
First ionization enthalpy is the energy required to remove the most loosely bound electron from an isolated gaseous atom in its ground state. Generally, ionization enthalpy increases across a period due to increasing nuclear charge and decreasing atomic size, which pulls outer electrons closer. However, anomalies arise due to exceptionally stable electronic configurations, such as fully filled or half-filled subshells. When an electron is removed from a stable configuration, a higher amount of energy is demanded than what regular periodic trends would otherwise predict for that position.
Solution:

(a) Sodium, magnesium, aluminum, and silicon belong to the third period of the periodic table, where nuclear charge systematically increases from sodium to silicon.

(b) The general trend predicts a steady increase in ionization energy across this period: Na < Mg < Al < Si.

(c) However, magnesium has an electronic configuration of $[Ne]3s^2$, featuring a completely filled outer s subshell which possesses high stability.

(d) Aluminum has a configuration of $[Ne]3s^23p^1$, meaning its outermost electron resides in a higher energy p orbital and experiences shielding by the inner $3s$ electrons.

(e) Consequently, it is easier to remove the $3p$ electron from aluminum than a $3s$ electron from magnesium, making the actual order Na < Al < Mg < Si.

Final Answer: The correct sequence accounts for the anomalous stability of the completely filled subshell of magnesium over aluminum.

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:
The Valence Shell Electron Pair Repulsion (VSEPR) theory predicts the geometric arrangement of molecules based on minimizing steric repulsion between electron pairs around a central atom. To deduce hybridization and shape, one calculates the steric number by summing the total number of sigma bonds and lone pairs residing on the central atom. Steric numbers correspond to specific hybridization states and idealized electronic geometries, which then become distorted when lone pairs exert stronger repulsive forces than bonding pairs.

Solution:

(a) In a sulfur tetrafluoride molecule, sulfur acts as the central atom and belongs to group 16, contributing six valence electrons to the structure.

(b) Sulfur forms four single sigma bonds with four individual fluorine atoms, consuming four of its valence electrons.

(c) The remaining two valence electrons form exactly one non-bonding lone pair on the sulfur atom.

(d) The steric number is the sum of four bonding pairs and one lone pair, yielding five, which corresponds mathematically to sp^3d hybridization.

(e) While the spatial arrangement of these five electron pairs forms a trigonal bipyramid, the lone pair occupies an equatorial position to minimize repulsion, creating a distorted molecular geometry widely known as a see-saw shape.

Final Answer: The molecule exhibits a steric number of five with one lone pair, resulting in a see-saw shape.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:
The oxidation state or oxidation number reflects the hypothetical charge an atom would carry if all its bonds to different elements were completely ionic. Determining oxidation states relies on assigning electrons in a bond to the more electronegative atom based on standard priority rules. Hydrogen is consistently assigned an oxidation state of +1 when bonded to non-metals, while oxygen typically holds a state of −2 in most standard compounds, allowing the unknown oxidation state of a central heteroatom to be calculated algebraically.

Solution:

(a) In hydrazine (N_2H_4), setting the oxidation state of nitrogen to x gives $2x + 4(+1) = 0$, which simplifies to $x = -2$.

(b) In ammonia (NH_3), the algebraic sum yields $x + 3(+1) = 0$, revealing an oxidation state of $x = -3$ for the nitrogen atom.

(c) In hydrazoic acid (N_3H), the calculation becomes $3x + 1(+1) = 0$, which results in a fractional oxidation state where $x = -1/3$.

(d) In nitric acid (HNO_3), nitrogen is bonded to highly electronegative oxygen atoms, and the neutral molecule formula gives $(+1) + x + 3(-2) = 0$.

(e) Solving this linear equation yields $x = +5$, which represents the maximum possible oxidation state for a group 15 element.

Final Answer: Nitrogen reaches its maximum group oxidation state of positive five within nitric acid.

Answer: (D)

Go Back to Question 4

Q5.

Solution

Concept:
Molarity is a foundational concentration term in chemistry defined as the number of moles of solute dissolved per liter of solution. To solve stoichiometry and solution preparation problems, one must relate mass, molar mass, volume, and molarity through systematic unit conversions. The relationship dictates that the total moles of solute equals the molarity multiplied by the solution volume expressed in liters. Once the required moles are found, the physical mass is determined by multiplying the value by the specific molar mass of the compound.

Solution:

(a) The target volume of the aqueous solution is given as 250 mL, which must be converted to liters by dividing by 1000, giving 0.250 L.

(b) Using the fundamental molarity equation, the required moles of sodium hydroxide equal Molarity $\times$ Volume in Liters, which calculates to 0.5 mol/L $\times$ 0.250 L = 0.125 moles.

(c) Next, we calculate the molar mass of sodium hydroxide ($NaOH$) by summing the atomic masses: Na(23) + O(16) + H(1) = 40 g/mol.

(d) To find the final mass required, multiply the calculated moles by the molar mass: Mass = 0.125 moles $\times$ 40 g/mol.

(e) Performing this multiplication yields exactly 5.0 grams of pure sodium hydroxide pellets needed to prepare the solution.

Final Answer: Preparing the specified concentration requires exactly five grams of the solute.

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept:
The position of an element in the periodic table is directly dictated by its ground-state electronic configuration. The highest principal quantum number n containing electrons reveals the period to which the element belongs. The specific block is determined by the subshell that receives the differentiating electron. For d-block elements, where the filling occurs in the $(n-1)d$ subshell, the group number is found by summing the total number of electrons present in both the outer ns orbital and the inner $(n-1)d$ orbital.

Solution:

(a) The given electronic configuration is $[\text{Ar}]3d^5 4s^1$, which represents chromium, an exceptional configuration caused by the stability of a half-filled d-subshell.

(b) The highest principal quantum number in this configuration is $n = 4$ due to the presence of the $4s$ valence orbital, placing the element in Period 4.

(c) Because the differentiating electrons are progressively entering the $3d$ subshell, this element is classified in the d-block of transition metals.

(d) For transition metals, the group number is determined by adding the number of electrons in the $(n-1)d$ and ns subshells.

(e) Adding 5 electrons from the $3d$ subshell and 1 electron from the $4s$ subshell gives a sum of 6, identifying it as Group 6.

Final Answer: The element resides within the fourth period and belongs to the sixth group of the periodic table.

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:
Isoelectronic species are atoms, ions, or molecules that possess the exact same total number of electrons, resulting in highly similar electronic structures. To evaluate whether a given pair of species is isoelectronic, one must determine the neutral atomic number of each element, which equals its proton count. For cations, electrons are subtracted from this atomic number equivalent to the positive charge, while for anions, electrons are added matching the negative charge. Comparing these final calculated values allows for easy identification.

Solution:

(a) Sodium has an atomic number of 11; the Na^+ cation has lost one electron, leaving it with $11 - 1 = 10$ electrons, while neutral magnesium has 12 electrons.

(b) Aluminum has an atomic number of 13; the Al^{3+} cation has lost three electrons, giving it a total of $13 - 3 = 10$ electrons.

(c) Oxygen has an atomic number of 8; the O^{2-} oxide anion has gained two additional electrons, resulting in $8 + 2 = 10$ electrons.

(d) Comparing these values shows that both Al^{3+} and O^{2-} possess exactly 10 electrons, making them an isoelectronic pair matching the neon configuration.

(e) Analyzing the other options reveals unequal electron counts between the paired chemical species.

Final Answer: The aluminum cation and oxide anion each contain ten total electrons, satisfying the definition.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
Solid-state coordination chemical compounds often exhibit complex bonding networks that simultaneously incorporate multiple types of chemical interactions. These interactions can span from strong electrostatic ionic attractions to shared localized covalent bonds, coordinate dative interactions, and weaker intermolecular forces like hydrogen bonding. In hydrated transition metal salts, water molecules can function both as coordinated ligands bonded directly to the metal cation and as structural units held in place within the crystal lattice by hydrogen bonds to the oxoanions.
Solution:

(a) In copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$), the primary lattice interaction is ionic or electrovalent between the $[Cu(H_2O)_4]^{2+}$ complex cation and the SO_4^{2-} anion.

(b) Inside the polyatomic sulfate anion (SO_4^{2-}), the central sulfur atom is bonded to four surrounding oxygen atoms via covalent bonds.

(c) Four of the five water molecules act as neutral ligands, donating their lone electron pairs to the empty orbitals of the central Cu^{2+} ion via coordinate covalent bonds.

(d) The fifth water molecule is not directly coordinated to the metal; instead, it is held in the crystal structure via hydrogen bonds to both the sulfate ions and the coordinated water molecules.

(e) Therefore, this single crystalline material beautifully incorporates electrovalent, covalent, coordinate, and hydrogen bonds within its structure.

Final Answer: The hydrated crystal structure simultaneously contains all four distinct types of chemical bonds.

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept:
A disproportionation reaction is a specialized type of redox process where a single chemical species containing an element in an intermediate oxidation state simultaneously undergoes both oxidation and reduction. To identify such a process, one must track the oxidation number of each element on the reactant side and compare it to its final values on the product side. If the same element splits into two different products where its oxidation state increases in one and decreases in the other, the reaction is a disproportionation.

Solution:

(a) In the decomposition of potassium chlorate ($KClO_3$), chlorine changes from +5 to -1 while oxygen changes from -2 to 0, which represents an intra-molecular redox reaction.

(b) In hydrogen peroxide (H_2O_2), oxygen exists in a unique peroxide oxidation state of -1.

(c) Upon decomposition into water (H_2O), the oxidation state of oxygen decreases from -1 to -2, which is a reduction process.

(d) Simultaneously, when forming oxygen gas (O_2), the oxidation state of oxygen increases from -1 to 0, which is an oxidation process.

(e) Because the same oxygen element undergoes both oxidation and reduction, this decomposition reaction is a classic example of a disproportionation reaction.

Final Answer: Hydrogen peroxide decomposition features oxygen simultaneously increasing and decreasing its oxidation state.

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
The structural probability distribution of an electron within an atomic orbital is characterized by regions where the probability of finding the electron drops to zero, known as nodes. Nodes are categorized into two types: radial nodes, which are spherical shells concentric with the nucleus, and angular nodes, which are planar or conical surfaces. The number of nodes is strictly determined by the principal quantum number n and the azimuthal quantum number l. The total number of nodes in any orbital is given by $n - 1$, where the number of angular nodes equals l, and the remaining nodes are radial nodes calculated as $n - l - 1$.

Solution:

(a) For a $3p$ atomic orbital, we first identify the corresponding quantum numbers from the orbital label, giving $n = 3$.

(b) The letter label p designates the azimuthal quantum number, which means $l = 1$ for this subshell.

(c) The number of angular nodes is directly equal to the value of the azimuthal quantum number l, giving exactly 1 angular node.

(d) To find the number of radial nodes, we apply the standard formula: Radial Nodes $= n - l - 1$.

(e) Substituting our values gives Radial Nodes $= 3 - 1 - 1 = 1$, meaning the $3p$ orbital possesses 1 radial node and 1 angular node.

Final Answer: The orbital contains exactly one radial node and one angular node based on its quantum numbers.

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept:
Molecular Orbital Theory describes the electronic structure of molecules by constructing molecular orbitals over the entire molecule via the linear combination of atomic orbitals. The magnetic behavior and stability of a homonuclear diatomic species are determined by distributing its total valence electrons into bonding and antibonding molecular orbitals according to the Aufbau principle, Hund's rule, and the Pauli exclusion principle. The net stability is measured by the bond order, defined as half the difference between the number of bonding and antibonding electrons, while the presence of any unpaired electrons causes paramagnetism.

Solution:

(a) A neutral oxygen molecule (O_2) possesses a total of 16 electrons distributed throughout its molecular orbitals.

(b) The ground-state molecular orbital electronic configuration for this diatomic system follows the specific energy ordering: $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$.

(c) Counting the total number of electrons in this distribution yields 10 bonding electrons and 6 antibonding electrons.

(d) The corresponding bond order is calculated algebraically using the standard formula: Bond Order $= (10 - 6)/2 = 2$.

(e) Because the two highest occupied molecular orbitals ($\pi^* 2p_x$ and $\pi^* 2p_y$) each contain a single electron with parallel spins, the molecule contains two unpaired electrons and exhibits paramagnetism.

Final Answer: The oxygen molecule contains two unpaired antibonding electrons and exhibits a calculated bond order of two.

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:
The empirical formula of a chemical compound represents the simplest, lowest whole-number atomic ratio of each element present within the substance. Determining this formula from elemental mass percentages requires a systematic sequence of stoichiometric calculations. First, the mass percentages are treated as absolute masses in a hypothetical one-hundred-gram sample. These masses are then converted into respective molar quantities by dividing each value by the element's specific standard atomic mass, and a relative atomic ratio is established by dividing all molar amounts by the smallest calculated value.

Solution:

(a) In a 100 g sample of the compound, the absolute masses of the constituent elements are 40.00 g of Carbon, 6.67 g of Hydrogen, and 53.33 g of Oxygen.

(b) Convert these mass values into moles by dividing each by their respective molar masses: Moles of C $= 40.00/12.01 = 3.33$.

(c) Applying the same calculation for the remaining elements gives: Moles of H $= 6.67/1.008 = 6.62$.

(d) The molar amount for the oxygen component evaluates to: Moles of O $= 53.33/16.00 = 3.33$.

(e) To establish the simplest integer ratio, divide each value by the smallest molar quantity, which is 3.33, yielding an exact ratio of 1 Carbon to 2 Hydrogen to 1 Oxygen.

Final Answer: The simplest relative atomic ratio of the constituent elements reduces to one carbon, two hydrogens, and one oxygen.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
Chemical kinetics defines the half-life of a reaction as the precise time span required for the initial reactant concentration to decrease to exactly half its starting value. The mathematical dependence of half-life on initial concentration varies fundamentally with the overall reaction order. For a generic integrated rate law, the half-life is inversely proportional to the initial concentration raised to the power of the reaction order minus one. Consequently, analyzing how changes in initial concentration affect this time interval provides a reliable method for identifying the underlying kinetic order of a chemical process.

Solution:

(a) The integrated rate law expression for a standard first-order chemical process is given by the equation: $k = (2.303/t) \cdot \log([A_0]/[A])$.

(b) To find the half-life, we substitute the remaining concentration $[A] = [A_0]/2$ into this expression, where t becomes equal to $t_{1/2}$.

(c) Simplifying the logarithmic terms yields the classic isolated half-life relationship: $t_{1/2} = \ln(2)/k = 0.693/k$.

(d) Inspection of this derived equation reveals that the variable representing the initial reactant concentration, $[A_0]$, does not appear anywhere in the final formula.

(e) Because the time required to consume half the reactant depends solely on the constant value of the rate coefficient, doubling the initial concentration has zero mathematical effect on the half-life.

Final Answer: The half-life of a first-order kinetic process remains completely independent of the starting concentration of the reactant.

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept:
A reaction coordinate diagram visually illustrates the continuous energy changes that occur as reactant molecules transform into products during a chemical reaction. The vertical axis monitors the total potential energy of the system, while the horizontal axis tracks the structural progress from left to right. The reactants sit in a stable energy well at the beginning, but they must absorb sufficient kinetic energy through molecular collisions to overcome a localized energy barrier. The minimum additional energy required to scale this barrier and reach the high-energy transition state configuration is defined as the activation energy.

Solution:

(a) The initial baseline state on the potential energy profile represents the total starting energy of the reactant molecules.

(b) As the reaction proceeds forward, the curve ascends to a maximum point that corresponds to the short-lived, unstable transition state configuration.

(c) The net vertical distance measured directly from the reactant energy baseline up to this absolute peak represents the forward activation energy barrier.

(d) In the provided TikZ graphic, the vertical interval labeled as X strictly marks this distance between the reactant level and the peak of the transition state.

(e) The interval Y indicates the reverse activation energy, while interval Z represents the net change in enthalpy for the exothermic reaction.

Final Answer: The vertical distance labeled as X represents the forward activation energy barrier on the potential energy diagram.

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
Molar conductivity measures the efficiency with which a solution conducts electricity per mole of dissolved electrolyte. Strong electrolytes are chemical substances that undergo complete ionization in aqueous solution across all concentration ranges. According to the Debye-Huckel-Onsager theory, even though the total number of ions remains constant upon diluting a strong electrolyte, the physical distance between these ions increases as the solvent volume expands, altering the interionic forces and affecting the overall conductivity.

Solution:

(a) Strong electrolytes exist in a completely dissociated state in solution, meaning dilution cannot create additional ions.

(b) In a concentrated solution, the closely packed ions experience strong electrostatic interionic attractions that hinder their free movement.

(c) Adding more solvent increases the average physical distance separating the cations from the anions within the medium.

(d) This spatial separation dramatically weakens the interionic attractions, effectively reducing both the asymmetric effect and the electrophoretic effect.

(e) With fewer electrostatic restrictions opposing their motion, the individual ions achieve greater mobility through the bulk solution under an applied electric field, causing a slight rise in molar conductivity.

Final Answer: Dilution increases the molar conductivity of a strong electrolyte by reducing interionic forces and increasing ionic mobility.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
For reversible chemical reactions involving gaseous components, the position of chemical equilibrium can be quantitatively expressed using two distinct mathematical constants. The constant K_c evaluates equilibrium positions utilizing molar concentrations, whereas K_p utilizes the partial pressures of the gases. These two values are fundamentally related through the ideal gas law, because the partial pressure of a gas is directly proportional to its molar concentration at a specific absolute temperature, adjusted by the net change in the number of gaseous moles.
Solution:

(a) The general mathematical relationship linking these two constants is expressed by the equation: $K_p = K_c(RT)^{\Delta n_g}$.

(b) The exponent term, Δn_g, is defined as the total moles of gaseous products minus the total moles of gaseous reactants.

(c) For the ammonia synthesis reaction, the chemical equation is given as: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.

(d) Calculating the change in gaseous moles for this reaction yields: $\Delta n_g = 2 - (1 + 3) = 2 - 4 = -2$.

(e) Substituting this negative integer value back into the general formula results in the exact relationship: $K_p = K_c(RT)^{-2}$.

Final Answer: The balanced equation has a net mole change of negative two, yielding the reciprocal squared temperature term.

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:
Boiling point elevation is a colligative property of solutions, meaning its magnitude depends strictly on the total concentration of solute particles present in the solution rather than the chemical identity of those particles. When a non-volatile solute dissolves in a volatile liquid solvent, it lowers the solvent's vapor pressure, requiring a higher temperature to match atmospheric pressure. For electrolytic solutes, the total concentration of active particles is determined by multiplying the nominal molarity by the van 't Hoff factor, which represents the number of ions produced per formula unit upon dissociation.

Solution:

(a) The elevation in boiling point is directly proportional to the product of the solution molarity and its specific van 't Hoff factor (i).

(b) Glucose is a non-electrolyte that does not dissociate in water, meaning its van 't Hoff factor is $i = 1$, yielding a particle concentration of 0.1 M.

(c) Sodium chloride ($NaCl$) dissociates into two ions (Na^+ and Cl^-), giving $i = 2$ and a total particle concentration of 0.2 M.

(d) Barium chloride ($BaCl_2$) yields three total ions in solution (Ba^{2+} and $2Cl^-$), which results in a particle concentration of 0.3 M.

(e) Aluminum sulfate ($Al_2(SO_4)_3$) dissociates completely into five ions ($2Al^{3+}$ and $3SO_4^{2-}$), giving $i = 5$ and the highest particle concentration of 0.5 M.

Final Answer: Aluminum sulfate produces the maximum number of solute particles in solution, causing the largest boiling point elevation.

Answer: (D)

Go Back to Question 17

Q18.

Solution

Concept:
The second law of thermodynamics establishes the absolute criteria for predicting whether a chemical reaction or physical change can occur spontaneously without external intervention. For a system operating under conditions of constant temperature and pressure, these thermodynamic parameters are combined into a single state function known as the Gibbs free energy (G). The change in Gibbs free energy (ΔG) accounts for both the driving force of enthalpy changes and the organizational driving force of entropy changes, acting as the definitive thermodynamic potential for determining process spontaneity.

Solution:

(a) The fundamental thermodynamic relation defining Gibbs free energy changes is expressed by the equation: $\Delta G = \Delta H - T\Delta S$.

(b) A negative value for ΔG indicates that the forward process is thermodynamically favorable and will occur spontaneously.

(c) If ΔG is greater than zero, the process is non-spontaneous in the forward direction but spontaneous in the reverse direction.

(d) When ΔG equals zero, the forward and reverse rates balance perfectly, indicating that the system has reached chemical equilibrium.

(e) Neither a negative enthalpy change ($\Delta H < 0$) nor a positive entropy change ($\Delta S > 0$) can individually guarantee spontaneity on their own; only a net negative Gibbs free energy change ensures a spontaneous process under these conditions.

Final Answer: A net decrease in the total Gibbs free energy of the system is the absolute requirement for spontaneity.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept:
The Bronsted-Lowry acid-base theory defines an acid as a substance capable of donating a hydrogen ion or proton (H^+) to another species, whereas a base is defined as a proton acceptor. When a Bronsted-Lowry acid successfully donates its proton, the remaining chemical fragment retains the ability to re-accept a proton, meaning it acts as a base. This remaining species is termed the conjugate base of the original acid. Every acid and its corresponding conjugate base form a conjugate pair that structurally differs by exactly one single proton.

Solution:

(a) The chemical species given in the question is the dihydrogen phosphate anion, represented by the formula $H_2PO_4^-$.

(b) To function as a Bronsted-Lowry acid, this chemical species must lose exactly one proton (H^+) during an acid-base reaction.

(c) Mathematically removing a single proton involves subtracting one hydrogen atom and subtracting a single positive charge from the formula.

(d) Removing H^+ from $H_2PO_4^-$ leaves behind a chemical structure consisting of one hydrogen, one phosphorus, and four oxygen atoms.

(e) The negative charge decreases from negative one down to negative two, producing the monohydrogen phosphate anion, represented as HPO_4^{2-}.

Final Answer: Removing a single proton from the dihydrogen phosphate ion yields the monohydrogen phosphate conjugate base.

Answer: (D)

Go Back to Question 19

Q20.

Solution

Concept:
A standard galvanic or electrochemical cell generates electrical energy from spontaneous chemical redox reactions by physically separating the oxidation half-reaction from the reduction half-reaction. Anode and cathode components are placed in separate containers filled with matching electrolyte solutions. To maintain electrical neutrality and sustain a continuous flow of electrons through the external circuit, these two isolated half-cells must be connected internally by a specialized device that allows ions to migrate between the compartments without mixing the bulk solutions.

Solution:

(a) In the provided diagram, the standard components of a voltaic cell are arranged with the anode container on the left and the cathode on the right.

(b) The two solid metallic strips immersed in the solutions act as the electrodes where electron transfer occurs.

(c) The external wire provides a low-resistance path that allows electrons to travel from the anode over to the cathode.

(d) The inverted U-shaped tube designated as Tube W directly connects the solutions in both half-cells.

(e) This component represents the salt bridge, which contains an inert electrolyte gel that prevents charge accumulation by supplying ions to neutralize excess charges as the reaction proceeds.

Final Answer: Tube W represents the salt bridge component that internally links the two isolated half-cell electrolyte solutions.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
Salt hydrolysis is a chemical process in which the constituent ions of a dissolved salt interact with water molecules to disturb the autoionization equilibrium of water, producing either an acidic, basic, or neutral solution. Salts derived from different combinations of strong or weak acids and bases show distinct behavior. A salt formed from a weak acid and a strong base undergoes anionic hydrolysis, where the conjugate base of the weak acid extracts a proton from water, liberating excess hydroxide ions that turn the chemical solution basic. This basic nature is traditionally confirmed when the solution turns red litmus paper blue.

Solution:

(a) Sodium acetate (CH_3COONa) is a salt synthesized from the neutralization of a weak organic acid (CH_3COOH) with a highly alkaline strong base ($NaOH$).

(b) Upon dissolution in an aqueous medium, the salt dissociates completely into its component sodium cations (Na^+) and acetate anions (CH_3COO^-).

(c) While the sodium ion remains spectator due to its strong base origin, the acetate ion undergoes significant anionic hydrolysis with water molecules.

(d) This reversible hydrolytic reaction is represented by the equilibrium equation: $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$.

(e) The generation of free hydroxide ions increases the pH of the aqueous solution well above the neutral threshold of seven, turning red litmus paper blue.

Final Answer: The salt solution undergoes anionic hydrolysis to release excess hydroxide ions, causing a color transition in litmus indicators.

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:

Henry's law is a fundamental gas law formulated by William Henry, describing the solubility behavior of a gas dissolved in a liquid solvent at a constant temperature. It establishes a quantitative boundary conditions for gas-liquid solutions where no chemical reaction takes place between the solute gas and the dissolving fluid. The law notes that the amount of gas tracking into the liquid phase depends directly on the frequency of gas molecule impacts against the liquid surface, which is managed by the spatial crowding and pressure conditions of the gas phase situated immediately above.

Solution:

(a) Henry's law mathematically states that at a fixed thermodynamic temperature, the mass or concentration of a gas dissolved in a unit volume of liquid is directly proportional to its partial pressure.

(b) Alternatively, using mole fraction (x) to express solubility, the law is written as: $p = K_H \cdot x$, where p is the partial pressure and K_H is Henry's constant.

(c) Increasing the partial pressure of the gas above the liquid surface increases the collision rate of gas molecules with the surface interface.

(d) This mechanical compression forces a greater number of gaseous molecules to cross the boundary layer and enter the intermolecular spaces of the liquid solvent.

(e) Other factors like system volume do not alter this solubility ratio, while temperature adjustments change the baseline value of the proportionality constant itself.

Final Answer: The mass or concentration of a dissolved gas depends directly on the specific partial pressure exerted by that gas above the solution.

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept:
The overall order of a chemical reaction is an experimentally determined kinetic parameter that represents the sum of the exponents or power terms to which the reactant concentrations are raised within the differential rate equation. While the molecularity of an elementary step must be an integer, the reaction order can be zero, fractional, or negative, because it reflects the complex step-by-step pathway of the reaction mechanism. Determining this value provides an understanding of how changes in reactant concentration scale the overall velocity of a chemical process.
Solution:

(a) The experimental differential rate equation provided for this particular chemical transformation is given as: Rate $= k[A]^2[B]^{1/2}$.

(b) In this mathematical expression, the exponent for reactant species A is equal to 2, indicating second-order kinetics with respect to component A.

(c) The exponent corresponding to reactant species B is equal to $1/2$ or 0.5, demonstrating fractional-order dependence for this specific component.

(d) To compute the overall kinetic order of the entire process, these separate exponential values must be added together: Overall Order $= 2 + 1/2$.

(e) Calculating the final algebraic sum yields a total value of 2.5, which represents the combined concentration dependence of the reaction rate.

Final Answer: Summing the individual concentration exponents gives a total fractional reaction order of two point five.

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept:
The thermodynamic behavior of ideal solutions containing multiple volatile liquid components is described by Raoult's law, formulated by François-Marie Raoult. An ideal solution is defined as a mixture where the intermolecular forces between different components are identical to those within the pure liquids, resulting in zero net enthalpy change and zero volume change upon mixing. To determine the total vapor pressure exerted by such a liquid mixture at equilibrium, the individual vapor pressures of the pure fluids must be adjusted by their respective mole fractions within the liquid phase.

Solution:

(a) Raoult's law states that the partial vapor pressure of any volatile component in an ideal solution is equal to the vapor pressure of that pure component multiplied by its mole fraction.

(b) For a binary liquid mixture containing components A and B, the individual partial pressures are expressed as: $P_A = P_A^\circ \cdot x_A$ and $P_B = P_B^\circ \cdot x_B$.

(c) Dalton's law of partial pressures states that the total vapor pressure (P_{total}) over the solution is the sum of these partial pressures: $P_{\text{total}} = P_A + P_B$.

(d) Combining these expressions yields the standard ideal solution equation: $P_{\text{total}} = P_A^\circ \cdot x_A + P_B^\circ \cdot x_B$.

(e) Other options like Ostwald's dilution law relate to weak electrolyte dissociation, making Raoult's law the correct choice for vapor pressure calculations.

Final Answer: The total equilibrium vapor pressure of a binary ideal solution is determined using Raoult's law.

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:
The systematic nomenclature of coordination compounds is governed by IUPAC rules to provide an unambiguous chemical name based on the structure of the complex. When naming a coordination compound, the cation is always named before the anion, regardless of whether the complex ion carries a net positive or negative charge. Within the coordination sphere, ligands are listed alphabetically before the central metal atom, using prefixes to indicate ligand quantities. The oxidation state of the central metal atom is specified as a Roman numeral in parentheses immediately following the metal's name.

Solution:

(a) In the coordination compound $[Co(NH_3)_5Cl]Cl_2$, the coordination sphere acts as the cation, while the two chloride ions outside the brackets serve as counter-anions.

(b) Inside the coordination sphere, two distinct types of ligands are present: five ammine ligands (NH_3) and one chlorido ligand (Cl^-).

(c) Arranging these ligands alphabetically places ammine before chlorido, which gives the combined ligand prefix name: pentaamminechlorido.

(d) The oxidation state of cobalt is calculated by balancing charges: $x+5(0)+1(-1)+2(-1) = 0$, which simplifies to $x = +3$.

(e) Combining these components gives the full IUPAC name, with a space separating the cationic sphere from the counter-anion.

Final Answer: The systematic IUPAC name for the given coordination compound is pentaamminechlorocobalt(III) chloride.

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept:
Structural isomerism in coordination chemistry occurs when compounds with the same empirical formula possess different atom-to-atom bonding connections. Ionization isomerism is a specific type of structural isomerism that arises when the ligand exchange occurs between an ion directly coordinated to the central metal atom inside the inner coordination sphere and an ion acting as a counter-ion in the outer coordination sphere. While these isomers share an identical elemental composition, they dissociate into entirely different ionic species when dissolved in water, which can be verified using chemical precipitation tests.

Solution:

(a) The pair of coordination complexes provided in the question consists of $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$.

(b) In the first complex, the sulfate ion is directly coordinated to the cobalt center, while the bromide ion balances the charge as a counter-ion.

(c) In the second complex, the positions are reversed: the bromide ion is coordinated inside the sphere, while the sulfate ion acts as the counter-ion.

(d) Dissolving the first compound in water yields free bromide ions, which react with silver nitrate to form a cream-colored silver bromide precipitate.

(e) Dissolving the second compound yields free sulfate ions, which form a white barium sulfate precipitate upon adding barium chloride, confirming ionization isomerism.

Final Answer: The exchange of ions between the inner coordination sphere and the outer sphere represents ionization isomerism.

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:
Crystal Field Theory and Valence Bond Theory describe the electronic structure, hybridization, and magnetic properties of transition metal complexes. For an octahedral complex, the central metal atom undergoes hybridization involving its d, s, and p orbitals to form six equivalent coordination bonds. The choice between inner orbital (d^2sp^3) and outer orbital (sp^3d^2) hybridization depends on the field strength of the ligands. Strong-field ligands create a large crystal field splitting energy, forcing the electrons in the metal's d orbitals to pair up against Hund's rule, which alters the number of unpaired electrons.

Solution:

(a) In the hexacyandoferrate(III) complex ion, $[Fe(CN)_6]^{3-}$, the iron central atom exhibits a formal oxidation state of +3, leaving it with a d^5 valence electron configuration.

(b) The cyanide ion (CN^-) is a strong-field ligand that causes significant splitting of the d orbitals into lower energy t_{2g} and higher energy e_g subsets.

(c) The large crystal field splitting forces the five d electrons to pair up within the lower t_{2g} orbitals, leaving only one unpaired electron.

(d) This pairing leaves two internal 3d orbitals vacant, allowing them to combine with the 4s and 4p orbitals to form six hybrid orbitals.

(e) The resulting orbital mixing corresponds to an inner-orbital d^2sp^3 hybridization state, matching the low-spin octahedral geometry of the complex.

Final Answer: The strong-field cyanide ligands force electron pairing, resulting in inner-orbital hybridization and a single unpaired electron.

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:
The systematic nomenclature of organic molecules is regulated by IUPAC rules to ensure each distinct chemical structure corresponds to a unique name. Identifying the correct IUPAC name requires a step-by-step procedure. First, determine the longest continuous carbon chain that contains the principal functional group, which establishes the parent alkane name. Next, number the carbon atoms in this primary chain starting from the end that gives the lowest locant number to the principal functional group. Finally, identify any alkyl substituents and list them alphabetically as prefixes with their corresponding position numbers.

Solution:

(a) Analyzing the provided TikZ chemical structure reveals a continuous four-carbon main chain containing a hydroxyl group (–OH) and a methyl branch (–CH3).

(b) Numbering the main chain from right to left assigns position locants of 2 to the hydroxyl group and 3 to the methyl branch.

(c) Numbering from left to right would yield locants of 3 for the hydroxyl group and 2 for the methyl branch, which violates the principal group priority rule.

(d) Because the principal hydroxyl group takes numbering priority over the alkyl substituent, the right-to-left numbering sequence is correct.

(e) This numbering establishes a four-carbon parent chain (butan-2-ol) with a methyl group at the third carbon, yielding the name 3-methylbutan-2-ol.

Final Answer: Numbering the primary carbon chain to give priority to the hydroxyl group yields the name 3-methylbutan-2-ol.

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:
Electrophilic aromatic substitution reactions involve the attack of an electron-deficient electrophile on a nucleophilic benzene ring. The reaction rate and regioselectivity are determined by the electron density distribution, which is shaped by the substituents already attached to the ring. Substituents control this distribution through a combination of inductive effects and resonance effects. Inductive effects operate through sigma bonds due to electronegativity differences, whereas resonance effects involve the delocalization of pi electrons or lone pairs between the substituent and the aromatic system.

Solution:

(a) Substituents that withdraw electron density from the aromatic ring decrease its nucleophilicity, slowing the substitution rate compared to benzene.

(b) The nitro group (–NO2) contains a positively polarized nitrogen atom bonded to electronegative oxygen atoms, making it a strong electron-withdrawing group.

(c) The nitro group withdraws electron density through both a strong negative inductive effect (–I) and a powerful negative resonance effect (–M).

(d) This electron withdrawal removes significant electron density from the ortho and para positions, leaving the meta position relatively more electron-rich.

(e) Consequently, incoming electrophiles are directed to the meta position, making the nitro group a strongly deactivating meta-director.

Final Answer: The strong electron-withdrawing nitro group deactivates the aromatic ring and directs incoming electrophiles to the meta position.

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept:
The hydrolysis of metal carbides is an important laboratory and industrial method for synthesizing lower alkanes, alkenes, or alkynes, depending on the crystal structure and ionic composition of the starting carbide. Carbides are classified into distinct categories based on the specific carbon anions present within their interstitial lattices. Methanides contain isolated carbon monomers (C^{4-}) and yield methane gas upon hydrolysis, whereas acetylides contain diatomic dicarbon units (C_2^{2-}) that form carbon-carbon triple bonds upon protonation.

Solution:

(a) Calcium carbide (CaC_2) is an ionic salt-like carbide composed of calcium cations (Ca^{2+}) and dicarbon acetylide anions (C_2^{2-}).

(b) When calcium carbide reacts with water, it undergoes a rapid exothermic hydrolysis reaction at room temperature.

(c) The acetylide anion extracts two protons from the surrounding water molecules to achieve a stable, neutral valence configuration.

(d) This chemical transformation is represented by the balanced reaction equation: $CaC_2 + 2H_2O \to Ca(OH)_2 + C_2H_2$.

(e) The reaction produces solid calcium hydroxide as a byproduct and releases ethyne gas, commonly known as acetylene, as the primary organic product.

Final Answer: Hydrolysis of the acetylide units in calcium carbide produces acetylene gas as the major organic product.

Answer: (D)

Go Back to Question 30

Q31.

Solution

Concept:

Organic reaction mechanisms classify the fission of covalent bonds into two primary pathways based on how the shared electron pair is distributed. Homolytic cleavage occurs when a covalent bond between two atoms breaks symmetrically, allowing each fragment to retain exactly one electron from the shared pair. This process typically takes place in non-polar bonds under the influence of heat, ultraviolet light, or peroxide initiators. The resulting neutral chemical fragments carry an unpaired valence electron, making them highly reactive intermediates with transient lifetimes.

Solution:

(a) When a symmetric carbon-carbon single bond breaks, the cleavage type is determined by the reaction conditions and the electronegativity difference.

(b) In homolytic fission, the shared pair of electrons in the sigma bond splits equally between the two bonded carbon atoms.

(c) The thermodynamic cleavage equation can be written as: $R - R \xrightarrow{\Delta \text{ or } h\nu} R\cdot + \cdot R$.

(d) Because each fragmented carbon atom withdraws one electron, no ionic charges are generated, ruling out both carbocations and carbanions.

(e) The production of neutral chemical species possessing a single unpaired electron defines the generation of free radical reaction intermediates.

Final Answer: Symmetrical homolytic cleavage of a carbon-carbon bond produces highly reactive free radicals.

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept:

Geometric isomerism, or cis-trans isomerism, is a type of stereoisomerism found in organic compounds where the spatial arrangement of substituents is locked into a fixed configuration. For geometric isomers to exist, a molecule must contain a structural feature that prevents parts of the molecule from rotating freely relative to one another. In alkenes, this rigidity is provided by the nature of the carbon-carbon double bond, which restricts rotational movement and allows different spatial orientations to remain chemically distinct.

Solution:

(a) A standard carbon-carbon single bond is a sigma bond formed by head-on orbital overlap, permitting free cylindrical rotation around the bond axis.

(b) In an alkene, the central linkage consists of one strong sigma bond and one weaker pi bond formed by the lateral overlap of unhybridized p orbitals.

(c) Rotating one of the carbon atoms by ninety degrees would completely disrupt the parallel alignment of these p orbitals, effectively breaking the pi bond.

(d) Because breaking this orbital overlap requires a significant input of thermal energy, free molecular rotation is strictly restricted at room temperature.

(e) This rigid carbon-carbon double bond locks the attached substituents into fixed positions, giving rise to distinct cis and trans geometric isomers.

Final Answer: The restricted rotation of the carbon-carbon double bond enables the formation of stable geometric isomers.

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:
Multi-step organic synthesis pathways involve a sequential series of chemical transformations where the product of one step becomes the starting material for the next. Analyzing these networks requires identifying the specific functional group conversions caused by each chemical reagent under the given conditions. Alkanes undergo free radical substitution, alkyl halides encounter nucleophilic substitution when treated with strong aqueous bases, and primary alcohols are oxidized to carboxylic acids when exposed to powerful transition metal oxidizing agents.

Solution:

(a) Ethane reacts with chlorine gas in the presence of ultraviolet light via a free radical mechanism to yield chloroethane as intermediate X.

(b) Treating chloroethane with aqueous potassium hydroxide initiates a nucleophilic substitution where hydroxide replaces the chloride ion, forming ethanol as intermediate Y.

(c) Ethanol is a primary alcohol containing a terminal –CH2OH functional group that is highly susceptible to oxidative modification.

(d) Alkaline potassium permanganate is a powerful oxidizing agent that oxidizes the primary alcohol past the aldehyde stage to a carboxylic acid.

(e) The final product Z obtained from this complete oxidation sequence is ethanoic acid, commonly referred to as acetic acid.

Final Answer: The organic reaction sequence converts ethane into chloroethane, then to ethanol, and finally oxidizes it to ethanoic acid.

Answer: (C)

Go Back to Question 33

Q34.

Solution

Concept:
The addition of hydrogen halides to unsymmetrical alkenes is governed by Markovnikov's rule, which predicts the regiochemical outcome based on intermediate stability. Alkenes are unsaturated hydrocarbons characterized by a electron-rich pi bond that acts as a nucleophile. The reaction mechanism begins with the attack of this pi electron cloud on an electron-deficient species, generating a reactive carbocation intermediate. The pathway that forms the more stable carbocation proceeds with a lower activation energy, determining the primary product of the reaction.

Solution:

(a) In the hydrohalogenation of propene with hydrogen bromide, the polar H–Br molecule serves as the source of an electron-deficient proton electrophile.

(b) The electron-rich pi bond of propene attacks the proton, adding it to the terminal carbon to generate a more stable secondary carbocation.

(c) Because the rate-determining step involves the addition of an electrophile to create this intermediate, the reaction is classified as an electrophilic addition.

(d) The remaining bromide nucleophile then rapidly attacks the carbocation center to complete the addition process.

(e) This mechanism rules out free radical pathways, which only occur in the presence of peroxides to yield anti-Markovnikov products.

Final Answer: The addition of hydrogen halides to alkenes proceeds via a mechanism initiated by electrophilic attack.

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept:

Soil mineralogy classifies clay minerals into distinct groups based on their crystalline sheet arrangements and chemical behavior. Regur soil, commonly known as black cotton soil, is widely distributed across the Deccan trap region of India and is characterized by high water-retaining capacity, plasticity, and sticky properties. These macroscopic physical features are directly determined by the microscopic structure of the dominant secondary silicate clay mineral present within the soil matrix, which controls its swelling and shrinking behavior.

Solution:

(a) Black soil contains a high percentage of fine-grained secondary aluminosilicate clay minerals that dictate its engineering and agricultural utility.

(b) The predominant clay mineral group responsible for the distinct nature of regur soil is the smectite family, primarily montmorillonite.

(c) Montmorillonite features a 2:1 expanding crystal lattice structure consisting of one internal octahedral alumina sheet sandwiched between two tetrahedral silica sheets.

(d) The structural bonds between these composite layers are weak, allowing water molecules to easily enter the crystal lattice.

(e) This hydration causes significant swelling when wet and severe shrinking and cracking when dry, a defining characteristic of Indian black soils.

Final Answer: The clay mineral that defines the properties of black regur soil is montmorillonite.

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept:
Plant physiology divides essential inorganic nutrients into macronutrients and micronutrients based on the absolute concentrations required to sustain healthy growth, reproduction, and metabolic functions. Macronutrients are consumed in larger quantities, typically exceeding ten millimoles per kilogram of dry plant matter. In addition to quantitative needs, these elements are classified by the specific ionic chemical species absorbed by root systems from the surrounding soil solution, which can be either cationic or anionic.

Solution:

(a) Among the elements listed, zinc, copper, and iron are required in trace amounts, classifying them as essential micronutrients rather than macronutrients.

(b) Phosphorus is an essential macronutrient required for synthesizing nucleic acids, phospholipids, and energy transfer molecules like adenosine triphosphate.

(c) Plant roots cannot absorb elemental phosphorus directly; it must be taken up from the soil solution as dissolved ionic species.

(d) At typical agricultural soil pH ranges, phosphorus is absorbed primarily as orthophosphate anions, specifically dihydrogen phosphate or monohydrogen phosphate.

(e) This dual criteria of high quantitative requirement and anionic absorption distinguishes phosphorus from the metallic micronutrient cations.

Final Answer: Phosphorus is an essential plant macronutrient that is absorbed from the soil solution in anionic form.

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept:
The nitrogen cycle involves a series of biological transformations that convert nitrogen between various chemical forms, allowing it to circulate through terrestrial and aquatic ecosystems. Soil decomposers, including heterotrophic bacteria and fungi, break down complex organic matter return nutrients to the soil. One key step in this cycle is the breakdown of nitrogenous organic waste products, such as proteins, nucleic acids, and urea, from dead plants and animals into simpler inorganic compounds that can be utilized by the soil microbial community.

Solution:

(a) Ammonification is a mineralization process conducted by saprophytic microorganisms during the decomposition of organic matter.

(b) Complex organic nitrogen is stored in large polymers like proteins, which are broken down into amino acids by extracellular enzymes.

(c) Deaminating enzymes then strip the amino groups from these molecules, releasing inorganic ammonia or ammonium ions into the soil solution.

(d) This process is distinct from nitrification, which oxidizes ammonium into nitrite and nitrate ions using autotrophic bacteria.

(e) It is also distinct from denitrification, which reduces nitrate back into atmospheric nitrogen gas, completing the cycle.

Final Answer: Ammonification is the biological conversion of organic nitrogenous waste into inorganic ammonium compounds.

Answer: (C)

Go Back to Question 37

Q38.

Solution

Concept:
A soil profile is a vertical cross-section displaying distinct horizontal layers, known as horizons, that develop over time through various pedogenic processes. These processes include the transformation, translocation, addition, and loss of mineral and organic matter within the profile. Eluviation refers to the downward transport of dissolved or suspended materials, such as clay, iron oxides, and organic matter, from upper horizons by percolating rainwater. The horizon where this leaching loss is most pronounced develops a characteristic light color and sandy texture.

Solution:

(a) The O horizon consists of organic litter, while the underlying A horizon, or topsoil, is a mineral layer enriched with humified organic matter.

(b) In highly weathered or leached soils, a distinct master horizon designated as the E horizon forms directly underneath the A horizon.

(c) When an E horizon is not explicitly separated, the lower portion of the A horizon serves as the primary zone of maximum eluviation.

(d) Water moving down through this layer strips away silicate clays, iron, and aluminum oxides, leaving behind a residue of resistant quartz.

(e) These leached materials accumulate further down in the B horizon, which acts as the zone of illuviation, while the C horizon represents parent material.

Final Answer: The topsoil horizon is the primary zone where maximum eluviation and leaching of minerals occur.

Answer: (B)

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Q39.

Solution

Concept:
Chemical fertilizers are classified into distinct groups based on the number of primary plant nutrients—nitrogen, phosphorus, and potassium—they supply to the soil. Straight fertilizers provide only a single primary nutrient element, whereas complex or compound fertilizers contain two or more primary nutrients chemically combined within a single granule. Utilizing complex fertilizers ensures a more uniform distribution of nutrients across agricultural fields during application.

Solution:

(a) Urea ($CO(NH_2)_2$) and ammonium sulfate ($(NH_4)_2SO_4$) are straight nitrogenous fertilizers, providing only nitrogen as a primary nutrient.

(b) Single super phosphate is a straight phosphatic fertilizer that supplies phosphorus along with secondary nutrients like calcium and sulfur.

(c) Diammonium phosphate, represented by the chemical formula $(NH_4)_2HPO_4$, is synthesized by reacting phosphoric acid with ammonia.

(d) This chemical structure contains both nitrogen atoms and a phosphate group within the same compound.

(e) Because it supplies two primary plant nutrients—nitrogen and phosphorus—diammonium phosphate is classified as a complex fertilizer.

Final Answer: Diammonium phosphate is classified as a complex fertilizer because it supplies multiple primary nutrients.

Answer: (C)

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Q40.

Solution

Concept:
Sodic or alkali soils are characterized by a high exchangeable sodium percentage and an alkaline pH, typically exceeding eight point five. This excess sodium deflocculates clay particles, disrupting soil structure, reducing porosity, and severely limiting water infiltration and root growth. Reclaiming these degraded soil profiles requires replacing the exchangeable sodium ions on the clay complex with divalent calcium ions, followed by leaching to remove the displaced sodium from the root zone.

Solution:

(a) Adding calcium carbonate is ineffective for sodic soil reclamation because its low solubility in alkaline conditions limits the release of calcium ions.

(b) Calcium sulfate dihydrate, commonly known as gypsum, is a moderately soluble salt that serves as an effective source of divalent calcium ions.

(c) When applied to sodic soil, gypsum dissolves to release calcium ions, which displace exchangeable sodium from the clay exchange complex.

(d) This cation exchange reaction can be represented as: Clay-Na_2 + $CaSO_4$ $\rightarrow$ Clay-Ca + Na_2SO_4.

(e) The displaced sodium forms soluble sodium sulfate, which can be leached out of the root zone with irrigation water, restoring soil structure.

Final Answer: Gypsum application provides calcium ions to displace exchangeable sodium, enabling the reclamation of sodic soils.

Answer: (B)

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Answer Key

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