Rajasthan JET Chemistry Sample Paper-6

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. An organic compound contains 40% carbon, 6.7% hydrogen, and the rest oxygen. If the vapor density of the compound is 30, what is its molecular formula?

(A) CH_2O

(A) $C_2H_4O_2$

(A) $C_3H_6O_3$

(A) $C_4H_8O_4$

Q2. The rate constant of a first-order reaction is $2.303 \times 10^{-3}\ s^{-1}$. What is the time required for the initial concentration of the reactant to reduce to $\frac{1}{10}$th of its original value?

(A) 100 s

(B) 230.3 s

(C) 1000 s

(D) 693 s

Q3. Consider the coordination compound $[Co(NH_3)_5Cl]Cl_2$. When 1 mole of this complex is treated with an excess of $AgNO_3$ solution, how many moles of $AgCl$ precipitate will be formed?

(A) 1 mole

(B) 2 moles

(C) 3 moles

(D) 0 moles

Q4. Which type of soil colloid possesses the highest cation exchange capacity (CEC) among the following options under standard neutral pH conditions?

(A) Kaolinite

(B) Illite

(C) Montmorillonite

(D) Humus

Q5. The following dynamic equilibrium is established in a closed container at a certain temperature:

$$A(g) + B(g) \rightleftharpoons C(g) + \text{Heat}$$

According to Le Chatelier's principle, which combination of conditions will shift the equilibrium to favor the maximum formation of product $C(g)$?

(A) High temperature and High pressure

(B) Low temperature and High pressure

(C) High temperature and Low pressure

(D) Low temperature and Low pressure

Q6. What is the correct order of increasing field strength of ligands according to the spectrochemical series?

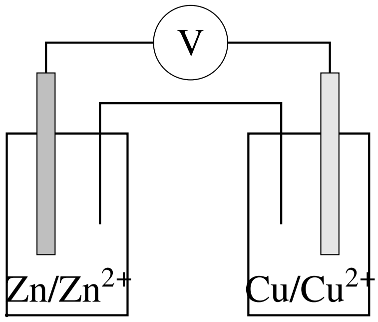
(A) $I^- < Cl^- < F^- < H_2O < CN^-$

(B) $CN^- < H_2O < F^- < Cl^- < I^-$

(C) $H_2O < I^- < Cl^- < F^- < CN^-$

(D) $F^- < Cl^- < I^- < CN^- < H_2O$

Q7. An electrochemical cell is set up as shown below. What is the standard cell potential (E°_{cell}) for this system at 298 K?



Given: $E^\circ_{Zn^{2+}/Zn} = -0.76$ V and $E^\circ_{Cu^{2+}/Cu} = +0.34$ V.

(A) +0.42 V

(B) −1.10 V

(C) +1.10 V

(D) −0.42 V

Q8. Which soil amendment is most scientifically suitable and extensively used for reclaiming highly alkaline soils in Rajasthan?

(A) Calcium carbonate (Lime)

(B) Calcium sulfate dihydrate (Gypsum)

(C) Sodium chloride

(D) Urea

Q9. The maximum number of electrons accommodated within a subshell possessing an azimuthal quantum number $l = 3$ is equal to:

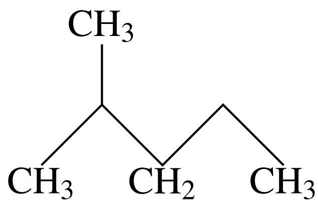
(A) 6

(B) 10

(C) 14

(D) 2

Q10. What is the correct IUPAC designation for the following branched hydrocarbon structure?



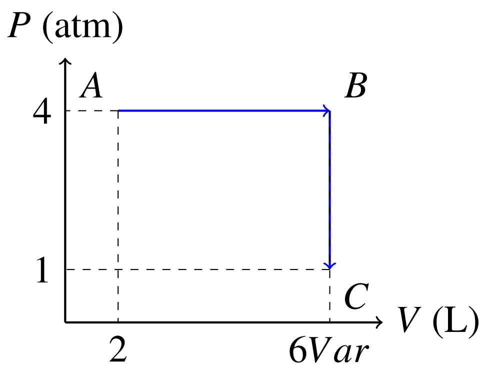
(A) 2-Methylbutane

(B) Iso-pentane

(C) 3-Methylbutane

(D) 2-Ethylpropane

Q11. A specific quantity of an ideal gas undergoes a thermodynamic state transformation represented by the pressure-volume ($P - V$) indicator diagram below. What is the total work done (W) by the gas along the path $A \longrightarrow B \longrightarrow C$?



(A) $16\ \mathrm{L \cdot atm}$

(B) $12\ \mathrm{L \cdot atm}$

(C) $4\ \mathrm{L \cdot atm}$

(D) $0\ \mathrm{L \cdot atm}$

Q12. The oxidation state of Chromium (Cr) in Potassium dichromate ($K_2Cr_2O_7$) is:

(A) +3

(B) +5

(C) +6

(D) +4

Q13. Which of the following elements has the highest negative electron gain enthalpy value in its ground state?

(A) Fluorine (F)

(B) Chlorine (Cl)

(C) Bromine (Br)

(D) Iodine (I)

Q14. What is the total number of σ (sigma) and π (pi) bonds present in a molecule of Ethyne (C_2H_2)?

(A) Three σ and two π bonds

(B) Two σ and three π bonds

(C) Three σ and one π bond

(D) Five σ and zero π bonds

Q15. What is the ideal pH range optimal for the availability of most essential plant nutrients in typical agricultural soil profiles?

(A) 4.0 to 5.0

(B) 6.5 to 7.5

(C) 8.5 to 9.5

(D) 2.0 to 3.5

Q16. The formal ground-state magnetic behavior of the complex ion $[Fe(CN)_6]^{3-}$ is classified as:

(A) Diamagnetic with zero unpaired electrons

(B) Paramagnetic with one unpaired electron

(C) Paramagnetic with five unpaired electrons

(D) Ferromagnetic

Q17. Which molecular geometry and hybridization are matching correctly for Phosphorus pentachloride (PCl_5) in the gas phase?

(A) Square pyramidal, sp^3d^2

(B) Trigonal bipyramidal, sp^3d

(C) Octahedral, sp^3d^2

(D) Tetrahedral, sp^3

Q18. What is the osmotic pressure (Π) of a 0.1 M aqueous solution of non-electrolyte sucrose at 300 K? (Use $R = 0.0821\ \text{L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$)

(A) 2.46 atm

(B) 24.6 atm

(C) 0.246 atm

(D) 1.23 atm

Q19. Identify the principal product obtained when Propene reacts with Hydrogen bromide (HBr) in the presence of organic peroxides.

$$CH_3 - CH = CH_2 + HBr \xrightarrow{\text{Peroxide}} \textbf{Product ?}$$

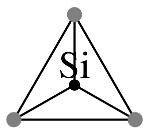
(A) 2-Bromopropane

(B) 1-Bromopropane

(C) 1,2-Dibromopropane

(D) 2,2-Dibromopropane

Q20. Which type of chemical bonding dominates inside the fundamental building block of silicate minerals represented by the geometric network model below?



(A) Purely Metallic

(B) Polar Covalent

(C) High-spin Interstitial

(D) Coordinate Dative only

Q21. What is the total number of structural isomers possible for the alkane molecular formula C_4H_{10}?

(A) 2

(B) 3

(C) 4

(D) 5

Q22. If the solubility product constant (K_{sp}) of a sparingly soluble salt $AgCl$ is 1.0×10^{-10} at 298 K, what is its molar solubility in pure water?

(A) 1.0×10^{-5} mol/L

(B) 1.0×10^{-10} mol/L

(C) 2.0×10^{-5} mol/L

(D) 1.0×10^{-7} mol/L

Q23. Which chemical compound acts as the major constituent responsible for the chemical synthetic manufacturing of Nitrogenous commercial fertilizers like Urea?

(A) Ammonium sulfate

(B) Calcium ammonium nitrate

(C) Carbamide (NH_2CONH_2)

(D) Ammonium chloride

Q24. When an atom undergoes an electronic transition between energy states, the wavelength emitted satisfies an inverse relation. Which of the following atomic radii values is expected to correspond to the smallest physical size?

(A) Na

(B) Mg

(C) Al

(D) Si

Q25. For a spontaneous chemical process occurring under conditions of constant temperature and pressure, the change in Gibbs Free Energy (ΔG) must fulfill which criterion?

(A) $\Delta G > 0$

(B) $\Delta G < 0$

(C) $\Delta G = 0$

(D) $\Delta G = \Delta H$

Q26. The fundamental driving organic intermediate formed during the acid-catalyzed dehydration mechanism of Ethanol to Ethene is a:

(A) Free radical

(B) Carbanion

(C) Carbocation

(D) Carbene

Q27. What is the conjugate base of the chemical species HCO_3^- in an aqueous medium?

(A) H_2CO_3

(B) CO_3^{2-}

(C) OH^-

(D) CO_2

Q28. Which fundamental organic test uniquely separates an Aldehyde functional cluster from a Ketone assembly?

(A) Tiffeneau test

(B) Tollen's Reagent Test

(C) Hinsberg test

(D) Lucas test

Q29. How many total structural nodes are present in a 3s atomic orbital ($n = 3, l = 0$)?

(A) 0

(B) 1

(C) 2

(D) 3

Q30. The core physical mechanism by which essential macro-nutrients like Potassium ions (K^+) move through clay soil structures into plant roots involves:

(A) Vapor condensation

(B) Cation Exchange and Diffusion

(C) Reverse osmosis

(D) Sublimation

Q31. Which gas laws are synthesized together to construct the Ideal Gas Equation state function ($PV = nRT$)?

(A) Boyle's Law, Charles's Law, and Avogadro's Law

(B) Graham's Law, Henry's Law, and Dalton's Law

(C) Gay-Lussac's Law and Raoult's Law

(D) Kelvin's Law and Faraday's Law

Q32. What is the primary organic product generated via the landmark Kolbe's electrolytic synthesis using sodium acetate solution?

(A) Methane

(B) Ethane

(C) Propane

(D) Butane

Q33. The elevation in boiling point (ΔT_b) for a 1 m solution of a non-volatile electrolyte that dissociates into two ions completely in water is proportional to:

(A) K_b

(B) $2 \times K_b$

(C) $0.5 \times K_b$

(D) $4 \times K_b$

Q34. Which primary structural type of linkage joins individual amino acid monomers together to build massive functional polypeptide architectures?

(A) Glycosidic bond

(B) Peptide bond

(C) Phosphodiester bond

(D) Ester linkage

Q35. The formal empirical ratio representing the vital nutrient combination index heavily assessed across commercial dry chemical bags is:

(A) C:N:O

(B) N:P:K

(C) Ca:Mg:S

(D) Fe:Mn:Cu

Q36. Under acidic laboratory workflows, the reduction half-reaction of the Permanganate ion (MnO_4^-) involves the transfer of how many moles of electrons per mole of Permanganate?

(A) 2

(B) 3

(C) 5

(D) 7

Q37. What is the total number of unpaired electrons found inside a gas-phase ground-state isolated Fe^{2+} cation (Atomic Number = 26)?

(A) 6

(B) 4

(C) 5

(D) 2

Q38. Which type of isomerism is demonstrated by the compound pair 1-Butanol and 2-Butanol?

(A) Chain isomerism

(B) Position isomerism

(C) Functional isomerism

(D) Metamerism

Q39. The parameter defined by the negative logarithm of hydrogen ion activity $(-\log[H^+])$ is fundamentally known as:

(A) pK_w

(B) pH

(C) pOH

(D) pK_a

Q40. The systematic biological converter mechanism transforming fixed soil ammonium resources back into gaseous molecular dinitrogen molecules escaping back towards atmospheric columns is termed:

(A) Nitrification

(B) Ammonification

(C) Denitrification

(D) Nitrogen Fixation

Detailed Solutions

Q1.

Solution

Concept:
The empirical formula represents the simplest whole-number ratio of atoms in a compound, whereas the molecular formula shows the actual number of each type of atom. The molecular mass is twice the vapor density.

Solution:

(a) Assume a 100 g sample. The mass of Carbon is 40 g, Hydrogen is 6.7 g, and Oxygen is $100 - (40 + 6.7) = 53.3$ g.

(b) Calculate the moles of each element: Moles of C = $40/12 = 3.33$ Moles of H = $6.7/1 = 6.7$ Moles of O = $53.3/16 = 3.33$

(c) Divide by the smallest value (3.33) to find the simplest ratio: C = 1, H = 2, O = 1. The empirical formula is CH_2O.

(d) The empirical formula mass is $12 + 2(1) + 16 = 30$ g/mol.

(e) The molecular mass is $2 \times$ Vapor Density $= 2 \times 30 = 60$ g/mol.

(f) Find the multiplier n = Molecular Mass/Empirical Mass = $60/30 = 2$.

(g) Multiply the empirical formula by 2 to get the molecular formula: $C_2H_4O_2$.

Final Answer: The molecular formula of the compound is $C_2H_4O_2$.

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
For a first-order chemical reaction, the integrated rate law connects time, the rate constant, and the changing concentrations of reactants. The rate is independent of the reactant concentration squared.

Solution:

(a) The first-order integrated rate expression is given by the formula: $t = \frac{2.303}{k} \log\left(\frac{[A]_0}{[A]_t}\right)$.

(b) The problem states that the initial concentration reduces to $\frac{1}{10}$th of its original value, which means $[A]_t = \frac{[A]_0}{10}$, or $\frac{[A]_0}{[A]_t} = 10$.

(c) Substitute the given rate constant $k = 2.303 \times 10^{-3}\ s^{-1}$ into the integrated rate equation.

(d) This yields: $t = \frac{2.303}{2.303 \times 10^{-3}} \log(10)$.

(e) Simplify the fraction to find that $\frac{2.303}{2.303 \times 10^{-3}} = 10^3 = 1000$.

(f) Since $\log(10) = 1$ in base-10 logarithms, the expression becomes $t = 1000 \times 1$.

(g) Therefore, the total time required for this concentration reduction is exactly 1000 seconds.

Final Answer: The time required for the first-order reaction is 1000 s.

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:
In coordination chemistry, Werner's theory distinguishes between the primary valence (ionizable groups outside the coordination sphere) and secondary valence (non-ionizable ligands directly bound to the metal center).

Solution:

(a) Examine the chemical formula of the coordination complex provided: $[Co(NH_3)_5Cl]Cl_2$.

(b) The square brackets enclose the complex coordination sphere, containing the cobalt central ion, five neutral ammine ligands, and one chlorido ligand. These do not dissociate in solution.

(c) The two chloride ions located outside the brackets balance the charge of the complex cation and represent the ionizable counter-ions.

(d) When dissolved in water, 1 mole of $[Co(NH_3)_5Cl]Cl_2$ fully dissociates into 1 mole of $[Co(NH_3)_5Cl]^{2+}$ complex cations and 2 moles of free Cl^- anions.

(e) Treating this dissolved mixture with an excess of silver nitrate ($AgNO_3$) causes a precipitation reaction with the free chloride ions.

(f) The reaction is: $2Cl^- + 2Ag^+ \rightarrow 2AgCl \downarrow$.

(g) Consequently, exactly 2 moles of white silver chloride precipitate are produced per mole of complex.

Final Answer: The number of moles of precipitate formed is 2 moles.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:
Cation Exchange Capacity (CEC) measures the total capacity of a soil colloid to hold and exchange exchangeable cations. It depends heavily on the specific structural mineralogy and surface functional groups.

Solution:

(a) Soil colloids are categorized into inorganic crystalline silicate clays, non-crystalline clays, and organic humic colloids.

(b) Kaolinite is a 1:1 non-expanding type clay mineral with a low specific surface area and a very low CEC, typically ranging from 3 to 15 cmol/kg.

(c) Illite is a 2:1 non-expanding silicate clay mineral with intermediate CEC values ranging between 20 and 40 cmol/kg.

(d) Montmorillonite belongs to the 2:1 expanding Smectite group, featuring significant isomorphous substitution and a large internal surface area, giving it a high CEC of 80 to 150 cmol/kg.

(e) Humus is the decomposed organic fraction of soil, packed with carboxyl, phenolic, and hydroxyl functional groups that deprotonate at neutral pH conditions.

(f) Due to this immense density of negative pH-dependent charges, humus possesses an exceptionally high CEC ranging from 150 to 300 cmol/kg.

(g) Therefore, organic humus vastly outperforms all crystalline silicate clay minerals in holding nutrient cations.

Final Answer: The soil colloid with the highest cation exchange capacity is Humus.

Answer: (D)

Go Back to Question 4

Q5.

Solution

Concept:
Le Chatelier's principle states that if a chemical system at equilibrium experiences a change in temperature, pressure, or concentration, the equilibrium shifts to counteract the imposed change.
Solution:

(a) Analyze the given reversible reaction equation: $A(g) + B(g) \rightleftharpoons C(g) + \text{Heat}$.

(b) The forward reaction releases thermal energy, meaning it is an exothermic process.

(c) According to thermodynamic principles, raising the temperature adds heat, driving an exothermic equilibrium backward. Conversely, lowering the temperature shifts the system forward to generate more heat.

(d) Next, analyze the gas volume changes by counting the stoichiometric coefficients of gaseous species on both sides.

(e) The reactant side has 2 moles of gas (A + B), while the product side contains only 1 mole of gas (C).

(f) Increasing the total pressure forces the system to shift toward the side with fewer gas moles to relieve the stress. Thus, high pressure shifts this reaction to the right.

(g) Combining these insights, a environment of low temperature and high pressure maximizes the yield of product C.

Final Answer: The optimal conditions are Low temperature and High pressure.

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:
The spectrochemical series is an empirically derived sequence that orders chemical ligands based on their crystal field splitting energy (Δ), which determines low-spin or high-spin behavior.
Solution:

(a) Ligands that produce small crystal field splitting energies are weak-field ligands, while those causing large splitting are strong-field ligands.

(b) Halide ions generally act as weak-field ligands due to electrostatic considerations and poor pi-donation profiles.

(c) Within the halides, splitting capability follows ionic size and polarizability trends: iodide is the weakest, followed by bromide, chloride, and then fluoride.

(d) Neutral oxygen-donor or nitrogen-donor molecules like water (H_2O) and ammonia (NH_3) occupy intermediate positions in the sequence.

(e) Carbon-donor or carbon-containing pi-acceptor ligands like cyanide (CN^-) and carbon monoxide (CO) create the strongest crystal field splitting.

(f) Gathering these elements together builds the ascending field strength sequence: $I^- < Cl^- < F^- < H_2O < CN^-$.

(g) This sequence matches the order presented in option A, accurately moving from weakest to strongest.

Final Answer: The correct order of ligand field strength is $I^- < Cl^- < F^- < H_2O < CN^-$.

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:
The standard potential of a galvanic cell (E°_{cell}) is an intensive thermodynamic property calculated from the standard reduction potentials of the cathode and anode half-cells.
Solution:

(a) Identify the anode and cathode from the given cell diagram. Zinc is oxidation-active and acts as the anode, while Copper undergoes reduction at the cathode.

(b) The standard formula for computing cell potential is: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, where both values are standard reduction potentials.

(c) The provided standard reduction potential for the copper cathode system is $E^\circ_{\text{Cu}^{2+}/\text{Cu}} = +0.34$ V.

(d) The provided standard reduction potential for the zinc anode system is $E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.76$ V.

(e) Substitute these values directly into the cell potential formula: $E^\circ_{\text{cell}} = (+0.34 \text{ V}) - (-0.76 \text{ V})$.

(f) The double negative converts into an addition step: $E^\circ_{\text{cell}} = 0.34 + 0.76$.

(g) Performing the calculation gives $E^\circ_{\text{cell}} = +1.10$ V. A positive value confirms the cell operates spontaneously.

Final Answer: The standard cell potential for this system is +1.10 V.

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept:
Soil reclamation relies on matching the appropriate chemical amendment to specific soil chemical imbalances, such as high exchangeable sodium percentages and elevated pH levels.
Solution:

(a) Alkaline or sodic soils contain an excess of exchangeable sodium ions (Na^+) bound to clay surfaces, causing soil dispersion, structural collapse, and high pH.

(b) Calcium carbonate (Lime) is alkaline and is used to treat acidic soils, so adding it would further increase the pH of alkaline soil.

(c) Sodium chloride adds more sodium ions, which worsens the sodicity and salinity of the soil matrix.

(d) Urea is a nitrogen fertilizer that does not supply the divalent cations needed to remediate dispersed sodic clay structures.

(e) Gypsum, chemically known as calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), provides soluble divalent calcium (Ca^{2+}) ions.

(f) These calcium ions displace exchangeable sodium from the clay colloid: $\text{Clay-Na}_2 + CaSO_4 \rightarrow \text{Clay-Ca} + Na_2SO_4$.

(g) The displaced sodium forms soluble sodium sulfate, which can be leached out of the root zone, successfully reclaiming the alkaline soil profile.

Final Answer: The chemical amendment used for reclaiming alkaline soils is Gypsum.

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
Quantum numbers define the energy levels and electron distributions within an atom. The azimuthal quantum number (l) dictates the shape and total degenerate orbital count of a subshell.
Solution:

(a) The principal quantum number (n) describes the primary shell, while the azimuthal quantum number (l) defines the subshell category.

(b) The specific values of l correspond to distinct subshells: $l = 0$ is an s subshell, $l = 1$ is p, $l = 2$ is d, and $l = 3$ represents an f subshell.

(c) For any given subshell with quantum number l, the number of degenerate orbitals is given by the formula: $2l + 1$.

(d) Substitute $l = 3$ into this expression to find the number of orbitals: $2(3) + 1 = 6 + 1 = 7$ orbitals.

(e) According to the Pauli Exclusion Principle, each individual orbital can hold a maximum of 2 electrons with opposing spins.

(f) Therefore, the total maximum electron capacity of a subshell is calculated using the formula: $2(2l + 1)$.

(g) For $l = 3$, the capacity is $2 \times 7 = 14$ electrons.

Final Answer: The maximum number of electrons in a subshell with $l = 3$ is 14.

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept:
IUPAC nomenclature rules require identifying the longest continuous carbon chain as the parent structure, numbering it to give substituents the lowest possible positions, and naming them alphabetically.
Solution:

(a) Analyze the chemical structure represented in the coordinate drawing system line path.

(b) Trace the longest continuous carbon chain. The main horizontal path contains four sequential carbon atoms, which corresponds to a butane parent chain.

(c) Next, locate any branching groups attached to this continuous main backbone.

(d) There is a single-carbon methyl group (CH_3) branching off the second carbon from the left.

(e) Number the carbon chain from left to right to give this substituent the lowest possible index: C1 is on the far left, C2 holds the branch, C3 is a CH_2 group, and C4 is on the far right.

(f) Numbering from right to left would place the methyl group at position 3, which violates the lowest-locant rule.

(g) Combining the substituent position, name, and parent chain yields the systematic name: 2-Methylbutane.

Final Answer: The correct IUPAC designation for the hydrocarbon structure is 2-Methylbutane.

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept:
Work done by an ideal gas during thermodynamic processes can be determined using a pressure-volume ($P - V$) indicator diagram. The net work done during multiple sequential steps is computed as the sum of the work performed during each individual transition.

Solution:

(a) The path consists of two distinct segments: an isobaric expansion ($A \rightarrow B$) followed by an isochoric pressure drop ($B \rightarrow C$).

(b) For the segment $A \rightarrow B$, the pressure remains constant at $P = 4$ atm while the volume increases from $V_A = 2$ L to $V_B = 6$ L.

(c) The work done during this isobaric process is calculated using the formula: $W_{AB} = P \times (V_B - V_A)$.

(d) Substituting the values gives: $W_{AB} = 4 \text{ atm} \times (6 \text{ L} - 2 \text{ L}) = 4 \times 4 = 16 \text{ L} \cdot \text{atm}$.

(e) For the segment $B \rightarrow C$, the volume remains completely constant at $V = 6$ L while the pressure decreases from 4 atm to 1 atm.

(f) Since the change in volume is zero ($\Delta V = 0$), the work done during this isochoric transformation is explicitly zero: $W_{BC} = 0 \text{ L} \cdot \text{atm}$.

(g) The total work done along the entire composite path is the sum of both parts: $W_{\text{total}} = W_{AB} + W_{BC} = 16 + 0 = 16 \text{ L} \cdot \text{atm}$.

Final Answer: The total work done by the gas along the path is $16 \text{ L} \cdot \text{atm}$.

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:
The oxidation state of an atom within a chemical compound reflects the hypothetical charge it would carry if all its bonding components were parsed as purely ionic. It is derived using the oxidation numbers of surrounding counter-atoms.

Solution:

(a) Potassium dichromate is a neutral chemical compound represented by the molecular formula $K_2Cr_2O_7$, meaning the total sum of all internal oxidation states must equal zero.

(b) Potassium is an alkali metal belonging to Group 1 of the periodic table, so it consistently exhibits an oxidation state of +1 in stable structural compounds.

(c) Oxygen is a highly electronegative non-metal that typically displays an oxidation state of −2 in standard oxo-anions and oxides.

(d) Let the unknown oxidation state of a single Chromium atom be represented by the variable x.

(e) Formulate a linear equation matching the stoichiometry of the compound: $2(\text{Oxidation State of K}) + 2(\text{Oxidation State of Cr}) + 7(\text{Oxidation State of O}) = 0$.

(f) Substitute the known values into the equation: $2(+1) + 2(x) + 7(-2) = 0$.

(g) Simplify the algebraic terms: $2 + 2x - 14 = 0$, which reduces further to $2x - 12 = 0$. Solve for x to get $2x = 12$, which gives $x = +6$.

Final Answer: The oxidation state of Chromium is +6.

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:
Electron gain enthalpy represents the enthalpy change associated with adding an electron to an isolated gaseous atom in its ground state. While periodic trends suggest a regular increase across a period, local valence shell electron-electron repulsions create prominent exceptions.

Solution:

(a) Halogens possess an outer valence electronic configuration of ns^2np^5, meaning they require exactly one additional electron to achieve a highly stable noble gas octet shell.

(b) Consequently, halogens release a significant amount of energy upon gaining an electron, resulting in highly negative electron gain enthalpy values.

(c) Moving down Group 17 from Fluorine to Iodine, the atomic radius progressively increases, causing the incoming electron to feel less electrostatic attraction from the shielded nucleus.

(d) Following this periodic trend, Fluorine would be expected to have the most negative value; however, Fluorine has an exceptionally compact $2p$ valence subshell.

(e) The high electron density within this small $2p$ cloud creates significant inter-electronic repulsion against any incoming electron, which reduces the net energy released.

(f) Chlorine possesses a larger, more accommodating $3p$ subshell where electron-electron repulsions are minimal, allowing it to release more energy upon electron capture.

(g) Therefore, Chlorine exhibits the highest negative electron gain enthalpy value among all elements in the periodic table.

Final Answer: The element with the highest negative electron gain enthalpy is Chlorine.

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
Covalent chemical bonding involves the sharing of valence electrons between atoms. A single bond consists of one σ bond, a double bond contains one σ and one π bond, and a triple bond comprises one σ and two π bonds.

Solution:

(a) Ethyne, commonly known as acetylene, is a linear hydrocarbon with the molecular formula C_2H_2.

(b) Analyze the structural connectivity of the molecule, which can be drawn as: $H-C\equiv C-H$.

(c) Each carbon atom in ethyne undergoes sp hybridization to form a linear framework with a bond angle of 180 degrees.

(d) Examine the terminal linkages: there are two individual Carbon-Hydrogen $(C-H)$ single bonds formed by the axial overlap of hybrid orbitals. Each single bond constitutes exactly one σ bond.

(e) Next, look at the central carbon-carbon interaction, which is a triple bond $(C\equiv C)$.

(f) A triple bond consists of one strong axial σ bond along the internuclear axis and two perpendicular π bonds formed by the lateral overlap of unhybridized p orbitals.

(g) Summing these components gives: $2\ (C-H)\ \sigma$ bonds $+\ 1\ (C-C)\ \sigma$ bond $= 3\ \sigma$ bonds, along with $2\ (C-C)\ \pi$ bonds.

Final Answer: The molecule contains three σ and two π bonds.

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
Soil pH is a critical chemical indicator that regulates the solubility, chemical form, and biological availability of essential macro- and micro-nutrients to plant root systems.
Solution:

(a) The availability of mineral nutrients in soil systems is governed by chemical precipitation reactions, microbial activity, and cation exchange processes.

(b) In strongly acidic soils (pH below 5.5), nutrients like Phosphorus get tightly fixed by Aluminum and Iron oxides into insoluble forms, while toxicities from free metal ions increase.

(c) In highly alkaline soils (pH above 8.0), Calcium ions react with soluble phosphate species to form insoluble calcium phosphates, drastically reducing nutrient availability.

(d) Micronutrients such as Iron, Manganese, Zinc, and Copper also undergo severe precipitation as insoluble hydroxides in highly alkaline environments.

(e) A slightly acidic to neutral pH range balance avoids both extreme fixation mechanisms and preserves optimal conditions for soil microbial processes like nitrification.

(f) Within the pH window of 6.5 to 7.5, major macronutrients (N, P, K, S, Ca, Mg) and essential micronutrients achieve their highest joint solubility.

(g) Therefore, this neutral range provides the most balanced and productive chemical profile for standard agricultural crops.

Final Answer: The ideal pH range for nutrient availability is 6.5 to 7.5.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
The magnetic behavior and spin state of transition metal complexes depend on the oxidation state of the metal ion and the field strength of the surrounding ligands according to Crystal Field Theory (CFT).

Solution:

(a) Determine the oxidation state of Iron in the complex ion $[Fe(CN)_6]^{3-}$. Let x be the oxidation state of Iron.

(b) Cyanide (CN^-) is an anionic ligand with a charge of -1. Setting up the net charge equation gives: $x + 6(-1) = -3$, which simplifies to $x = +3$.

(c) An isolated Iron atom has the ground-state electronic configuration $[Ar]3d^6 4s^2$. Stripping three electrons yields the configuration for the Fe^{3+} cation: $[Ar]3d^5$.

(d) According to Crystal Field Theory, the five degenerate $3d$ orbitals split into lower-energy t_{2g} and higher-energy e_g levels in an octahedral crystal field.

(e) Cyanide is a strong-field ligand that creates a large splitting energy (Δ_o), which forces electrons to pair up in the lower-energy orbitals rather than occupying the higher levels.

(f) Distribute the five $3d$ electrons into the t_{2g} subshell following pairing rules. This results in two paired sets of electrons and one remaining unpaired electron: $(t_{2g})^5(e_g)^0$.

(g) The presence of a single unpaired electron imparts a paramagnetic character to the complex ion.

Final Answer: The complex ion is paramagnetic with one unpaired electron.

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:
Valence Shell Electron Pair Repulsion (VSEPR) theory and valence bond hybridization models describe the geometric layout and spatial arrangement of bonding pairs around a central atom.
Solution:

(a) Identify the central atom in Phosphorus pentachloride (PCl_5), which is Phosphorus (P). Phosphorus belongs to Group 15 and has 5 valence electrons.

(b) In the gas phase, Phosphorus shares all five of its valence electrons to form five single covalent bonds with five surrounding Chlorine atoms.

(c) Calculate the steric number by summing the total number of bonded atoms and lone pairs on the central atom: Steric Number = 5 (bonds) + 0 (lone pairs) = 5.

(d) A steric number of 5 requires a mixing of five atomic orbitals to form a set of equivalent hybrid structures, corresponding to sp^3d hybridization.

(e) According to VSEPR theory, five electron pairs around a central atom minimize electrostatic repulsion by adopting a trigonal bipyramidal geometry.

(f) In this arrangement, three chlorine atoms occupy the equatorial positions with 120-degree separations, while two chlorine atoms occupy the axial positions along a vertical axis.

(g) Therefore, the correct combination of hybridization and spatial structure is sp^3d and trigonal bipyramidal.

Final Answer: The geometry and hybridization are Trigonal bipyramidal and sp^3d.

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept:

Osmotic pressure (Π) is a colligative property of solutions that depends directly on the total molar concentration of solute particles present, rather than the chemical identity of the solute itself.

Solution:

(a) The mathematical expression for calculating osmotic pressure is given by the van 't Hoff equation: $\Pi = i \times C \times R \times T$.

(b) The parameter i represents the van 't Hoff factor. Since sucrose is a non-electrolyte molecular sugar, it does not dissociate or associate in aqueous solution, meaning $i = 1$.

(c) The given molar concentration (C) of the sucrose solution is 0.1 M, which is equal to 0.1 mol/L.

(d) The absolute temperature (T) of the solution is given as 300 K.

(e) The universal gas constant (R) to be used for pressure calculations in atmospheres is $0.0821\ \text{L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$.

(f) Substitute these values into the expression: $\Pi = 1 \times 0.1\ \text{mol/L} \times 0.0821\ \text{L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \times 300\ \text{K}$.

(g) Combine the terms arithmetically: $\Pi = 0.1 \times 24.63 = 2.463$ atm. Rounding to two decimal places gives 2.46 atm.

Final Answer: The osmotic pressure of the sucrose solution is 2.46 atm.

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept:
The addition of hydrogen halides to unsymmetrical alkenes follows different regiochemical pathways depending on the presence of radical initiators, shifting between Markovnikov and anti-Markovnikov addition.

Solution:

(a) Propene ($CH_3 - CH = CH_2$) is an unsymmetrical alkene with two distinct reactive carbon environments across its double bond.

(b) When HBr reacts with propene in the absence of peroxides, the reaction proceeds via a stable carbocation intermediate, yielding 2-bromopropane as the major Markovnikov product.

(c) However, the addition of organic peroxides completely alters the mechanism, driving it through a free-radical chain pathway known as the Kharasch effect.

(d) Peroxides break down homolytically to generate reactive alkoxy radicals, which abstract a hydrogen atom from HBr to produce a bromine radical ($Br^\bullet$).

(e) The bromine radical attacks the alkene double bond first. It adds to the terminal carbon to form a more stable secondary carbon radical intermediate ($CH_3 - C^\bullet H - CH_2Br$).

(f) This secondary radical then abstracts a hydrogen atom from another HBr molecule, completing the anti-Markovnikov addition.

(g) Consequently, the reaction yields 1-bromopropane as the major product instead of the standard Markovnikov option.

Final Answer: The principal product obtained is 1-Bromopropane.

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept:
Silicate minerals comprise the bulk of Earth's crustal geometry. Their fundamental structural subunit consists of a central Silicon atom coordinated to surrounding Oxygen atoms, where bonding properties are dictated by electronegativity differences.
Solution:

(a) The basic building block of all silicate configurations is the anionic silicon-oxygen tetrahedron, represented by the formula SiO_4^{4-}.

(b) In this tetrahedral arrangement, a central Silicon atom forms covalent linkages with four surrounding Oxygen atoms located at the vertices.

(c) Evaluate the electronegativity values of the interacting elements: Silicon has an electronegativity of approximately 1.9, while Oxygen stands at 3.4.

(d) The electronegativity difference ($\Delta\chi = 3.4 - 1.9 = 1.5$) shows that electrons are shared unequally, resulting in a bond with significant polar covalent character.

(e) This difference means the shared electron pair is strongly distorted toward the oxygen nuclei, giving each bond about 50 percent covalent and 50 percent ionic character.

(f) In the context of localized molecular networks, these linkages are classified as polar covalent bonds rather than purely metallic or purely ionic interactions.

(g) Therefore, polar covalent bonding stabilizes the interior of these tetrahedral network units.

Final Answer: The chemical bonding that dominates inside silicates is Polar Covalent.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
Structural isomers are compounds that share the same molecular formula but possess different connectivities or structural arrangements among their constituent atoms. Alkanes exhibit chain isomerism by varying the configuration of their carbon skeleton.

Solution:

(a) The given molecular formula is C_4H_{10}, which corresponds to a saturated open-chain alkane following the general formula C_nH_{2n+2}.

(b) To identify the structural isomers, consider all unique ways to arrange the four carbon atoms in a continuous or branched chain layout.

(c) The first possibility is a straight, unbranched continuous chain of four carbon atoms. This arrangement forms the molecule known as butane, structurally drawn as $CH_3 - CH_2 - CH_2 - CH_3$.

(d) The second possibility involves creating a branched carbon framework. By reducing the main parent chain to three carbon atoms, we can place the remaining carbon atom as a substituent.

(e) Attaching a methyl branch to the central carbon of the three-carbon chain gives 2-methylpropane, commonly called isobutane, drawn as $CH_3 - CH(CH_3) - CH_3$.

(f) Attempting to attach the branch to either of the terminal carbons simply regenerates the unbranched straight chain of butane.

(g) Thus, only two unique skeletal configurations exist for this molecular formula, yielding a total of exactly 2 structural isomers.

Final Answer: The total number of structural isomers possible is 2.

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept:
The solubility product constant (K_{sp}) is an equilibrium constant that governs the dissolution of a sparingly soluble salt in water. It represents the product of the molar concentrations of the constituent ions raised to their stoichiometric coefficients.

Solution:

(a) Silver chloride (AgCl) is a sparingly soluble binary salt that dissociates in an aqueous solution according to the equilibrium expression: $\text{AgCl}(s) \rightleftharpoons \text{Ag}^+(aq) + \text{Cl}^-(aq)$.

(b) Let the molar solubility of AgCl in pure water at equilibrium be represented by the variable S in units of mol/L.

(c) Based on the stoichiometry of the dissolution reaction, 1 mole of dissolved salt produces exactly 1 mole of silver cations and 1 mole of chloride anions.

(d) Therefore, the equilibrium concentrations of the individual ions in solution are expressed as: $[\text{Ag}^+] = S$ and $[\text{Cl}^-] = S$.

(e) Write the mathematical formula for the solubility product constant: $K_{sp} = [\text{Ag}^+][\text{Cl}^-] = S \times S = S^2$.

(f) Substitute the given numerical value of K_{sp} into this algebraic relationship: $1.0 \times 10^{-10} = S^2$.

(g) Solve for the molar solubility by taking the square root of both sides: $S = \sqrt{1.0 \times 10^{-10}} = 1.0 \times 10^{-5}$ mol/L.

Final Answer: The molar solubility of silver chloride in pure water is 1.0×10^{-5} mol/L.

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept:
The commercial synthetic manufacturing of specific nitrogenous chemical fertilizers relies on defining the major organic compound or amide constituent that delivers concentrated nitrogen content directly to crops.

Solution:

(a) Nitrogenous fertilizers are essential agrochemicals formulated to supply high levels of bioavailable nitrogen to boost plant growth and overall agricultural yields.

(b) Ammonium sulfate, calcium ammonium nitrate, and ammonium chloride are all inorganic nitrogenous salts manufactured via alternative chemical pathways.

(c) Urea is an organic amide compound synthesized on an industrial scale by reacting liquid ammonia with gaseous carbon dioxide under high pressure and temperature conditions.

(d) The direct chemical name for urea in structural organic chemistry is carbamide, which is represented by the formula NH_2CONH_2.

(e) Carbamide stands out because it possesses a exceptionally high nitrogen content of approximately 46 percent by mass, making it highly economical.

(f) Within commercial chemical packaging and manufacturing workflows, carbamide is recognized as the identical main constituent and synonymous label for solid urea fertilizer.

(g) Therefore, carbamide serves as the primary compound responsible for this massive industrial manufacturing sector.

Final Answer: The chemical compound that acts as the major constituent is Carbamide (NH_2CONH_2).

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept:
Atomic radius exhibits periodic trends across a row of the periodic table. As you move from left to right, the atomic size decreases due to the regular increase in the effective nuclear charge pulling the electron shell inward.

Solution:

(a) Identify the periodic locations of the given four chemical elements: Sodium (Na), Magnesium (Mg), Aluminum (Al), and Silicon (Si).

(b) All four of these elements belong to Period 3 of the modern periodic table, meaning their valence electrons reside within the third principal electronic shell ($n = 3$).

(c) Moving left to right from Group 1 to Group 14, the atomic numbers increase sequentially as: Na (11) $<$ Mg (12) $<$ Al (13) $<$ Si (14).

(d) With each subsequent element, an additional proton is added to the nucleus, while the added electrons occupy the same principal energy shell.

(e) Because electrons in the same shell do not shield each other effectively, the effective nuclear charge (Z_{eff}) experienced by the outer electrons increases steadily.

(f) This stronger electrostatic attraction exerts a greater inward pull on the electron cloud, causing the atomic boundaries to contract.

(g) Consequently, Silicon experiences the highest effective nuclear charge among the choices, resulting in the smallest physical atomic radius.

Final Answer: The element that corresponds to the smallest physical size is Si.

Answer: (D)

Go Back to Question 24

Q25.

Solution

Concept:
The criterion for chemical spontaneity under conditions of constant temperature and pressure is dictated by the second law of thermodynamics, which is measured through changes in the Gibbs Free Energy function (ΔG).

Solution:

(a) The change in Gibbs Free Energy combines enthalpy, absolute temperature, and entropy into a single thermodynamic indicator expression: $\Delta G = \Delta H - T\Delta S$.

(b) For any chemical or physical transformation occurring at constant temperature and pressure, the direction of spontaneous change always moves toward lower free energy.

(c) If ΔG is greater than zero ($\Delta G > 0$), the forward process is non-spontaneous and requires an external input of work to proceed.

(d) If ΔG is exactly equal to zero ($\Delta G = 0$), the chemical system has achieved a state of dynamic thermodynamic equilibrium where no net change occurs.

(e) For a process to occur spontaneously without external intervention, the net change in Gibbs Free Energy must be negative, which mathematically means $\Delta G < 0$.

(f) This negative value indicates that energy is freed up during the process, helping drive the reaction forward.

(g) Therefore, a negative ΔG serves as the definitive thermodynamic requirement for spontaneity.

Final Answer: The change in Gibbs Free Energy must fulfill the criterion $\Delta G < 0$.

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:
Organic reaction mechanisms describe the step-by-step breaking and forming of chemical bonds. Dehydration of alcohols catalyzed by acids proceeds through an elimination pathway involving a distinct reactive intermediate.

Solution:

(a) The acid-catalyzed dehydration of ethanol (CH_3CH_2OH) to produce ethene ($CH_2 = CH_2$) involves three main sequential mechanistic steps.

(b) In the first step, the lone pair of electrons on the oxygen atom of ethanol accepts a proton from the acid catalyst, forming a protonated oxonium ion.

(c) In the second step, the weak carbon-oxygen bond cleaves heterolytically, resulting in the departure of a neutral water molecule as a leaving group.

(d) This leaving group departure removes a bonding electron pair from the adjacent carbon atom, generating an ethyl carbocation intermediate ($CH_3CH_2^+$).

(e) This positively charged trivalent carbon structure is highly reactive and serves as the primary driving intermediate that controls the overall rate of the reaction.

(f) In the final step, a base abstracts a proton from the adjacent carbon, causing the remaining electron pair to shift and form the carbon-carbon double bond of ethene.

(g) Therefore, a carbocation is the fundamental intermediate driving this specific elimination mechanism.

Final Answer: The fundamental driving organic intermediate formed is a Carbocation.

Answer: (C)

Go Back to Question 26

Q27.

Solution

Concept:
According to the Brønsted-Lowry acid-base theory, an acid is a chemical species that donates a proton (H^+), whereas its corresponding conjugate base is the chemical remnant left behind after donation.

Solution:

(a) The bicarbonate ion (HCO_3^-) is an amphiprotic chemical species, meaning it can act as either a Brønsted-Lowry acid or a Brønsted-Lowry base depending on the environment.

(b) When acting as a base, bicarbonate accepts a proton to form its conjugate acid, carbonic acid (H_2CO_3).

(c) To determine the conjugate base of bicarbonate, it must act strictly as an acid by donating one of its hydrogen ions to the surrounding aqueous medium.

(d) Write out the chemical equation representing this proton donation process: $HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$.

(e) Subtracting an H^+ ion from the bicarbonate formula removes both one hydrogen atom and one unit of positive charge.

(f) Reducing the charge of a -1 anion by one more negative step yields a net charge of -2, producing the carbonate ion (CO_3^{2-}).

(g) Therefore, the carbonate anion serves as the correct conjugate base of the bicarbonate species.

Final Answer: The conjugate base of the chemical species is CO_3^{2-}.

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:
Functional groups in organic compounds can be distinguished using specific diagnostic chemical tests that exploit differences in oxidation profiles between carbonyl subcategories.

Solution:

(a) Both aldehydes and ketones contain a central carbonyl group ($C = O$); however, aldehydes possess a terminal hydrogen atom, making them much easier to oxidize.

(b) The Hinsberg test uses benzenesulfonyl chloride to separate primary, secondary, and tertiary amines, so it cannot distinguish carbonyl compounds.

(c) The Lucas test uses a mixture of zinc chloride and hydrochloric acid to differentiate primary, secondary, and tertiary alcohols based on substitution rates.

(d) Aldehydes can be easily oxidized to carboxylic acids, whereas ketones generally resist mild oxidation because they lack a carbonyl-bound hydrogen.

(e) Tollen's Reagent Test utilizes an alkaline solution of silver ammonium nitrate, which acts as a mild oxidizing agent.

(f) When treated with Tollen's reagent, an aldehyde reduces the silver complex to metallic silver, coating the inner surface of the glass container with a shiny silver mirror.

(g) Ketones do not react under these mild conditions, making this test a unique method to separate these two functional groups.

Final Answer: The fundamental organic test is Tollen's Reagent Test.

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:
The spatial probability distributions of atomic orbitals contain structural nodes where the probability of finding an electron drops to zero. Total nodes comprise both spherical radial nodes and planar angular nodes.

Solution:

(a) Identify the relevant quantum numbers for the given $3s$ atomic orbital: the principal quantum number is $n = 3$ and the azimuthal quantum number is $l = 0$.

(b) The number of angular nodes in any atomic orbital is directly equal to the value of its azimuthal quantum number (l). For an s orbital, Angular Nodes $= 0$.

(c) The number of radial nodes within an orbital structure is determined using the quantum formula: Radial Nodes $= n - l - 1$.

(d) Substitute the quantum values of the $3s$ orbital into the radial node expression: Radial Nodes $= 3 - 0 - 1 = 2$.

(e) Calculate the total number of structural nodes by summing the radial nodes and angular nodes together: Total Nodes = Radial Nodes + Angular Nodes.

(f) Combining these values gives: Total Nodes $= 2 + 0 = 2$.

(g) Therefore, a $3s$ atomic orbital contains exactly 2 spherical radial nodes where the electron wave function passes through zero.

Final Answer: The total number of structural nodes present is 2.

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept:
The movement of mineral nutrient ions through complex soil matrix channels into plant root membranes is governed by fundamental soil chemistry principles and physical transport mechanisms.
Solution:

(a) Clay soil structures are made of mineral particles with negative surface charges that attract and bind positively charged cations like Potassium (K^+).

(b) These bound nutrient cations cannot move freely into plant roots until they are detached from the clay mineral exchange sites.

(c) Plant roots respire and release carbon dioxide, which reacts with soil water to form carbonic acid, yielding hydrogen ions (H^+).

(d) These hydrogen ions replace the bound potassium ions on the clay surfaces through a chemical process called cation exchange.

(e) Once released into the soil solution, the free potassium ions move toward the root surfaces down a concentration gradient.

(f) This passive physical transport process through the soil fluid is known as diffusion, which drives the ions toward the root borders.

(g) Therefore, a combined mechanism of cation exchange and diffusion explains how these macronutrients move into plant root systems.

Final Answer: The core physical mechanism involves Cation Exchange and Diffusion.

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept:
The Ideal Gas Law is a state function that relates pressure, volume, temperature, and number of moles of an ideal gas. It serves as a unified framework derived by combining independent empirical gas laws established by classical experimental chemists.

Solution:

(a) Consider the individual proportional relationships that describe macroscopic ideal gas behavior under various controlled conditions.

(b) Boyle's Law states that at a constant temperature and fixed amount of gas, the volume is inversely proportional to its pressure: $V \propto \frac{1}{P}$.

(c) Charles's Law demonstrates that at constant pressure and fixed amount of gas, the volume varies directly with its absolute thermodynamic temperature: $V \propto T$.

(d) Avogadro's Law establishes that at constant temperature and pressure, the volume of a gas is directly proportional to the number of moles of gas present: $V \propto n$.

(e) Combining these three independent mathematical proportions yields a single combined relationship for gas volume: $V \propto \frac{nT}{P}$.

(f) Introducing the universal gas constant (R) as the proportionality constant turns this relationship into an exact equation: $V = \frac{nRT}{P}$.

(g) Rearranging the variables into standard linear form gives the familiar ideal gas state function: $PV = nRT$.

Final Answer: The ideal gas equation is constructed by synthesizing Boyle's Law, Charles's Law, and Avogadro's Law.

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept:
Kolbe's electrolytic synthesis is an electrochemical method used to prepare symmetrical hydrocarbons. Passing an electric current through an aqueous solution of an alkali metal carboxylic acid salt drives a radical coupling reaction at the anode.

Solution:

(a) Sodium acetate (CH_3COONa) dissociates completely in an aqueous medium to form acetate anions (CH_3COO^-) and sodium cations (Na^+).

(b) During electrolysis, the negatively charged acetate anions migrate toward the positive electrode, which is the anode.

(c) At the anode, each acetate ion undergoes oxidation by losing one electron to form a highly reactive, unstable acetate free radical ($CH_3COO^\bullet$).

(d) This acetate radical quickly undergoes homolytic cleavage to release a molecule of carbon dioxide (CO_2), leaving behind a reactive methyl radical ($CH_3^\bullet$).

(e) Two of these generated methyl radicals then pair up and form a covalent carbon-carbon single bond through a radical coupling step: $CH_3^\bullet + CH_3^\bullet \rightarrow CH_3 - CH_3$.

(f) This coupling reaction produces ethane gas, which bubbles off as the primary organic product at the anode.

(g) Meanwhile, water reduction at the cathode generates hydrogen gas and leaves behind sodium hydroxide, making the solution basic.

Final Answer: The primary organic product generated is Ethane.

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:
The elevation in boiling point (ΔT_b) is a colligative property of solutions that depends on the total concentration of solute particles. For electrolyte solutions, it is calculated using the molal concentration, the ebullioscopic constant (K_b), and the van 't Hoff factor (i).
Solution:

(a) The mathematical equation governing the elevation of boiling point for an electrolyte solution is given by: $\Delta T_b = i \times K_b \times m$.

(b) The problem states that the concentration of the solution is exactly 1 m ($m = 1$ mol/kg).

(c) The solute is a non-volatile electrolyte that dissociates completely into exactly two ions per formula unit in water.

(d) Because dissociation is complete, the van 't Hoff factor (i), which counts the total number of particles formed per solute unit, is exactly $i = 2$.

(e) Substitute these values into the colligative property formula: $\Delta T_b = 2 \times K_b \times 1$.

(f) Simplifying the equation gives: $\Delta T_b = 2 \times K_b$.

(g) This result shows that the observed boiling point elevation is directly proportional to twice the ebullioscopic constant of the solvent.

Final Answer: The elevation in boiling point is proportional to $2 \times K_b$.

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

Polypeptides and proteins are biopolymers built from amino acid monomers. The primary structural backbone of these molecules is held together by covalent amide linkages formed through a biochemical condensation reaction.

Solution:

(a) Each individual amino acid monomer possesses both a basic amino functional group ($-NH_2$) and an acidic carboxylic acid functional group ($-COOH$).

(b) During protein synthesis, the carboxylic acid group of one amino acid reacts with the amino group of an adjacent amino acid.

(c) This reaction is a condensation process where a molecule of water (H_2O) is eliminated as the two groups join.

(d) The elimination creates a carbon-nitrogen amide linkage, represented structurally as $-CO-NH-$.

(e) In biochemistry, this specific inter-amino acid amide bond is called a peptide bond.

(f) Glycosidic bonds link carbohydrate sugars, phosphodiester bonds form the backbone of nucleic acids, and ester linkages connect fatty acids in lipids.

(g) Therefore, the peptide bond is the primary structural linkage responsible for chaining amino acids together into massive polypeptide architectures.

Final Answer: The primary structural type of linkage is the Peptide bond.

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:
Commercial chemical fertilizers are labeled with standard structural index ratios to indicate the relative percentages of the three primary macronutrients required for plant development and crop production.

Solution:

(a) Plants require a variety of chemical nutrients, which are categorized as primary macronutrients, secondary macronutrients, or micronutrients based on the quantities needed.

(b) Calcium, magnesium, and sulfur are secondary macronutrients, while iron, manganese, and copper are trace micronutrients needed in small amounts.

(c) The three primary macronutrients that plants consume in the largest quantities are Nitrogen, Phosphorus, and Potassium.

(d) Nitrogen drives vegetative leaf growth, Phosphorus promotes root development and flowering, and Potassium regulates water transport and disease resistance.

(e) Commercial dry fertilizer bags prominently display a standardized three-number label that represents the elemental ratio of these primary nutrients.

(f) This label is universally known as the N-P-K rating, representing the percentage content of Nitrogen (N), available Phosphate (P_2O_5), and soluble Potash (K_2O).

(g) Thus, the N:P:K ratio serves as the primary combination index for evaluating commercial fertilizer formulations.

Final Answer: The formal empirical ratio representing the vital nutrient combination index is N:P:K.

Answer: (B)

Go Back to Question 35

Q36.

Solution

Concept:
The number of moles of electrons transferred in a redox half-reaction is determined by calculating the difference between the initial and final oxidation states of the element undergoing reduction or oxidation.
Solution:

(a) In the permanganate reactant ion (MnO_4^-), assign the oxidation state of Manganese by letting it equal x.

(b) Oxygen has a standard oxidation state of −2. Setting up the net charge equation for the anion gives: $x + 4(-2) = -1$.

(c) Solving the equation: $x - 8 = -1$, which simplifies to $x = +7$. Thus, Manganese begins in the +7 oxidation state.

(d) Under acidic laboratory conditions, the permanganate ion undergoes reduction to form the stable, pale-pink divalent manganese cation (Mn^{2+}).

(e) In this final product state, the oxidation number of the free monoatomic ion is equal to its ionic charge, which is +2.

(f) Write out the balanced reduction half-reaction in acidic media: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$.

(g) The change in the oxidation state of Manganese goes from +7 to +2, which requires a gain of exactly 5 electrons per mole of permanganate.

Final Answer: The reduction half-reaction involves the transfer of 5 moles of electrons.

Answer: (C)

Go Back to Question 36

Q37.

Solution

Concept:
The number of unpaired electrons in a transition metal cation can be found by writing out its ground-state electronic configuration and applying Hund's rule to distribute the valence electrons across the degenerate d subshell.

Solution:

(a) A neutral, isolated Iron atom (Fe) has an atomic number of 26, giving it the ground-state electronic configuration: $[Ar]3d^6 4s^2$.

(b) When forming the divalent Fe^{2+} cation, the atom loses two electrons. Ionization rules dictate that electrons are stripped from the outermost principal energy shell first, which is the $4s$ orbital.

(c) Removing the two $4s$ electrons yields the electronic configuration for the Fe^{2+} cation: $[Ar]3d^6 4s^0$, or simply a $3d^6$ valence system.

(d) The $3d$ subshell consists of five degenerate atomic orbitals that can hold a maximum of ten electrons.

(e) According to Hund's rule of maximum multiplicity, electrons must occupy empty degenerate orbitals singly with parallel spins before they begin pairing up.

(f) Distribute the six valence electrons across the five $3d$ orbitals: place one electron into each of the five orbitals, then place the sixth electron into the first orbital with an opposite spin.

(g) This leaves one orbital paired and the remaining four orbitals occupied by single electrons, resulting in a total of 4 unpaired electrons.

Final Answer: The total number of unpaired electrons found inside the cation is 4.

Answer: (B)

Go Back to Question 37

Q38.

Solution

Concept:
Structural isomers can be classified into subcategories based on how their molecular frameworks differ. Position isomerism occurs when compounds share the same carbon skeleton and functional groups but differ in where the functional group is attached.

Solution:

(a) Examine the molecular structures of the given pair of constitutional isomers: 1-butanol and 2-butanol.

(b) Both molecules share the identical alkane molecular formula $C_4H_{10}O$ and belong to the same alcohol homologous series, containing the hydroxyl functional group ($-OH$).

(c) Sketch the carbon skeleton for 1-butanol: it consists of a straight unbranched four-carbon chain with the hydroxyl group attached to the terminal position: $CH_3-CH_2-CH_2-CH_2-OH$.

(d) Sketch the carbon skeleton for 2-butanol: it contains the exact same unbranched four-carbon chain, but the hydroxyl group is attached to the second carbon atom: $CH_3-CH_2-CH(OH)-CH_3$.

(e) Because the four-carbon parent chain remains unchanged, this pair does not exhibit chain isomerism.

(f) Since they contain the same hydroxyl group, they do not exhibit functional isomerism.

(g) The only structural difference is the numerical position of the hydroxyl group along the carbon chain, which defines this pair as position isomers.

Final Answer: The type of isomerism demonstrated by the pair is Position isomerism.

Answer: (B)

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Q39.

Solution

Concept:
The acidity or alkalinity of an aqueous solution is quantified using a logarithmic scale that tracks the active concentration of solvated hydrogen or hydronium ions present in the medium.
Solution:

(a) In aqueous solution chemistry, free hydrogen ions associate with water molecules to form hydronium ions (H_3O^+), though they are often written simply as H^+ for convenience.

(b) The absolute molar concentration of hydrogen ions can span many orders of magnitude, making standard linear concentration scales clumsy to use.

(c) To simplify working with these numbers, Danish biochemist Søren Sørensen introduced a negative logarithmic scale.

(d) Define the parameters: pK_a represents the negative logarithm of the acid dissociation constant, while pOH tracks hydroxide ion activity.

(e) The mathematical expression defined by taking the negative common logarithm (base 10) of hydrogen ion activity or concentration ($-\log[H^+]$) is known as pH.

(f) This logarithmic transformation converts small exponential concentrations into a simple scale that typically runs from 0 to 14.

(g) A lower pH value indicates a higher concentration of hydrogen ions (an acidic solution), making pH the standard parameter for measuring acidity.

Final Answer: The parameter defined by the negative logarithm of hydrogen ion activity is pH.

Answer: (B)

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Q40.

Solution

Concept:
The nitrogen cycle involves several distinct biological and chemical transformations that move nitrogen between soil, living organisms, and atmospheric reservoirs.

Solution:

(a) Nitrogen fixation is the process where atmospheric dinitrogen gas (N_2) is converted into reactive ammonia, either by specialized microbes or through industrial methods.

(b) Ammonification involves decomposers breaking down organic nitrogenous waste from dead plants and animals back into ammonium ions (NH_4^+) in the soil.

(c) Nitrification is a two-step aerobic process where soil bacteria oxidize ammonium resources first into nitrites (NO_2^-) and then into highly bioavailable nitrates (NO_3^-).

(d) The query describes a pathway that converts nitrogen resources back into gaseous molecular nitrogen (N_2) that escapes into the atmosphere.

(e) This pathway is known as denitrification. It is carried out under anaerobic conditions by specialized facultative bacteria like *Pseudomonas* and *Thiobacillus*.

(f) These denitrifying bacteria use oxidized nitrogen forms like nitrate as alternative electron acceptors for respiration when oxygen is scarce, reducing them back to nitrogen gas.

(g) Therefore, denitrification is the biological mechanism responsible for releasing fixed nitrogen back into the atmosphere.

Final Answer: The systematic biological converter mechanism is Denitrification.

Answer: (C)

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Answer Key

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