Rajasthan JET Chemistry Sample Paper-8

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 represents the highest energy orbital for a multi-electron atom?

(A) n = 4, l = 0, m = 0, s = +1/2

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

(C) n = 4, l = 1, m = 0, s = +1/2

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

Q2. The correct order of increasing first ionization enthalpy for the elements B, C, N, and O is:

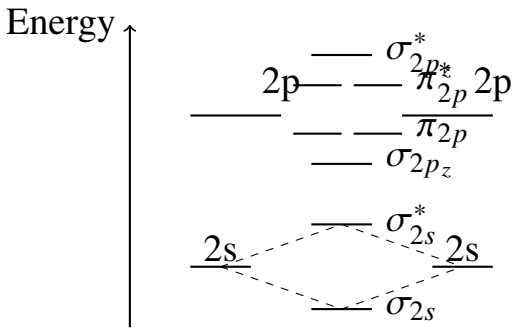
(A) B < C < O < N

(B) B < C < N < O

(C) C < B < O < N

(D) O < N < F < B

Q3. Consider the following TikZ diagram representing the molecular orbital energy levels of a homonuclear diatomic molecule. Identify the molecule that possesses a bond order of 2 and is paramagnetic in nature.



(A) C_2

(B) N_2

(C) O_2

(D) F_2

Q4. The hybridization of the central atom and the geometry of XeF_4 are respectively:

(A) sp^3d, Trigonal bipyramidal

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

(C) sp^3d^2, Octahedral

(D) sp^3, Tetrahedral

Q5. In the chemical reaction $3Br_2 + 6CO_3^{2-} + 3H_2O \rightarrow 5Br^- + BrO_3^- + 6HCO_3^-$, the element bromine undergoes:

(A) Oxidation only

(B) Reduction only

(C) Both oxidation and reduction

(D) Neither oxidation nor reduction

Q6. The empirical formula of a compound containing 50% element X (atomic mass = 10) and 50% element Y (atomic mass = 20) by mass is:

(A) XY

(B) X_2Y

(C) XY_2

(D) X_2Y_3

Q7. Which of the following molecules shows the maximum dipole moment?

(A) NF_3

(B) NH_3

(C) BF_3

(D) CCl_4

Q8. The maximum number of electrons that can be accommodated in a subshell with orbital quantum number $l = 3$ is:

(A) 6

(B) 10

(C) 14

(D) 18

Q9. According to the periodic law, the properties of elements are a periodic function of their:

(A) Atomic weight

(B) Atomic volume

(C) Atomic number

(D) Mass number

Q10. The oxidation state of chromium in $K_2Cr_2O_7$ is:

(A) +3

(B) +5

(C) +6

(D) +7

Q11. An element has the electronic configuration $[Ar]3d^{10}4s^24p^3$. To which group of the modern periodic table does it belong?

(A) Group 13

(B) Group 14

(C) Group 15

(D) Group 17

Q12. The fundamental particles responsible for maintaining the stability and identity of an atomic nucleus are:

(A) Protons and electrons

(B) Neutrons and electrons

(C) Protons and neutrons

(D) Electrons and positrons

Q13. For a first-order chemical reaction, the time required for 99.9% completion is approximately how many times the half-life ($t_{1/2}$) of the reaction?

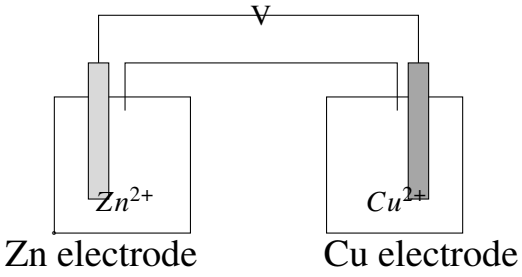
(A) 2 times

(B) 4 times

(C) 10 times

(D) 100 times

Q14. Consider the following TikZ schematic representation of an electrochemical cell operating under standard conditions. Identify the correct cell notation and direction of electron flow through the external circuit.



(A) $Cu|Cu^{2+}||Zn^{2+}|Zn$, electron flows from Cu to Zn

(B) $Zn|Zn^{2+}||Cu^{2+}|Cu$, electron flows from Zn to Cu

(C) $Zn|Zn^{2+}||Cu^{2+}|Cu$, electron flows from Cu to Zn

(D) $Cu|Cu^{2+}||Zn^{2+}|Zn$, electron flows from Zn to Cu

Q15. For the reversible gas-phase reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, the relationship between the equilibrium constants K_p and K_c is given by:

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

(B) $K_p = K_c$

(C) $K_p = K_c(RT)$

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

Q16. An aqueous solution of an unknown solute boils at 100.52°C. Given that the molal boiling point elevation constant (K_b) for water is 0.52 K kg mol^{-1}, what is the molality of this solution?

(A) 0.1 m

(B) 0.5 m

(C) 1.0 m

(D) 2.0 m

Q17. For an endothermic chemical reaction that proceeds spontaneously at high temperatures but remains non-spontaneous at low temperatures, the thermodynamic criteria must be:

(A) $\Delta H < 0$ and $\Delta S > 0$

(B) $\Delta H > 0$ and $\Delta S > 0$

(C) $\Delta H > 0$ and $\Delta S < 0$

(D) $\Delta H < 0$ and $\Delta S < 0$

Q18. The pH of a 1.0×10^{-8} M aqueous solution of hydrochloric acid (HCl) at 25°C is:

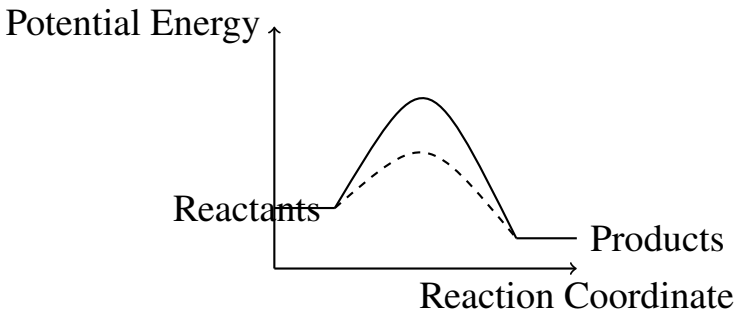
(A) Exactly 8.00

(B) Exactly 6.00

(C) Slightly less than 7.00

(D) Slightly greater than 7.00

Q19. Consider the given TikZ potential energy profile diagram for a chemical reaction. What is the effect of adding a catalyst on the values of the activation energy for the forward reaction ($E_{a,f}$) and the total enthalpy change (ΔH)?



(A) Both $E_{a,f}$ and ΔH decrease

(B) $E_{a,f}$ decreases, while ΔH remains unchanged

(C) $E_{a,f}$ remains unchanged, while ΔH decreases

(D) $E_{a,f}$ decreases, while ΔH increases

Q20. According to Kohlrausch's law, the limiting molar conductivity of an electrolyte A_xB_y is equal to:

(A) $\Lambda_m^\circ = \lambda_A^\circ + \lambda_B^\circ$

(B) $\Lambda_m^\circ = x\lambda_A^\circ + y\lambda_B^\circ$

(C) $\Lambda_m^\circ = y\lambda_A^\circ + x\lambda_B^\circ$

(D) $\Lambda_m^\circ = (x + y)(\lambda_A^\circ + \lambda_B^\circ)$

Q21. Which of the following aqueous solutions will exhibit the lowest freezing point temperature?

(A) 0.1 M Glucose

(B) 0.1 M Sodium Chloride

(C) 0.1 M Calcium Chloride

(D) 0.1 M Aluminium Sulfate

Q22. If the rate constant of a chemical reaction is $k = 2.5 \times 10^{-4}\,\text{L mol}^{-1}\text{s}^{-1}$, the overall order of the reaction is:

(A) Zero order

(B) First order

(C) Second order

(D) Third order

Q23. The conjugate base of the bisulfate ion (HSO_4^-) is:

(A) H_2SO_4

(B) SO_4^{2-}

(C) SO_3^{2-}

(D) OH^-

Q24. The heat capacity of a system at constant volume (C_v) is thermodynamically defined as:

(A) $\left(\frac{\partial U}{\partial T}\right)_V$

(B) $\left(\frac{\partial H}{\partial T}\right)_P$

(C) $\left(\frac{\partial Q}{\partial P}\right)_V$

(D) $\left(\frac{\partial G}{\partial T}\right)_V$

Q25. The IUPAC name of the organic compound $CH_3 - CH(OH) - CH_2 - CO - CH_3$ is:

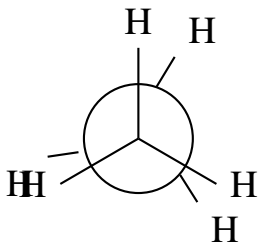
(A) 4-Hydroxypentan-2-one

(B) 2-Hydroxypentan-4-one

(C) 4-Oxopentan-2-ol

(D) Pentan-2-ol-4-one

Q26. Consider the following TikZ chemical structure representing a specific conformation of ethane. Identify the correct conformational isomer name and its relative stability compared to other conformations.



(A) Eclipsed conformation, maximum stability

(B) Staggered conformation, maximum stability

(C) Eclipsed conformation, minimum stability

(D) Gauche conformation, intermediate stability

Q27. The primary reason for the exceptional stability of the benzene ring towards addition reactions is its large:

(A) Inductive effect

(B) Resonance/Delocalization energy

(C) Electromeric effect

(D) Steric hindrance

Q28. The structural formula of the coordination compound Potassium trioxalatochromate(III) is written as:

(A) $K[Cr(C_2O_4)_3]$

(B) $K_2[Cr(C_2O_4)_3]$

(C) $K_3[Cr(C_2O_4)_3]$

(D) $K_3[Cr(C_2O_4)_2Cl_2]$

Q29. Which of the following organic compounds will give a positive test with Tollens' reagent?

(A) $CH_3 - CO - CH_3$

(B) $CH_3 - CH_2 - CHO$

(C) $CH_3 - CH_2 - O - CH_3$

(D) $CH_3 - COOH$

Q30. The type of isomerism exhibited by the pair of coordination compounds $[Co(NH_3)_5SO_4]Br$ and $[Co(NH_3)_5Br]SO_4$ is known as:

(A) Linkage isomerism

(B) Coordination isomerism

(C) Ionization isomerism

(D) Solvate isomerism

Q31. When calcium carbide (CaC_2) undergoes controlled hydrolysis with water, the gaseous hydrocarbon produced is:

(A) Methane

(B) Ethane

(C) Ethylene

(D) Acetylene

Q32. Which of the following electronic configurations of a transition metal ion will show the maximum value of spin-only magnetic moment (μ_s)?

(A) $3d^3$

(B) $3d^5$

(C) $3d^6$

(D) $3d^7$

Q33. The permanent heterolytic cleavage of a covalent bond where the shared pair of electrons is completely retained by one of the atoms results in the formation of:

(A) Free radicals

(B) Carbocations and Carbanions

(C) Carbene intermediates

(D) Non-polar molecules

Q34. The geometric arrangement and the number of unpaired d-electrons in the high-spin complex $[Fe(H_2O)_6]^{2+}$ are respectively:

(A) Tetrahedral, 4

(B) Octahedral, 4

(C) Octahedral, 5

(D) Square planar, 2

Q35. The conversion of atmospheric nitrogen gas into plant-available chemical forms like ammonium (NH_4^+) or nitrate (NO_3^-) by soil microorganisms is ecologically classified as:

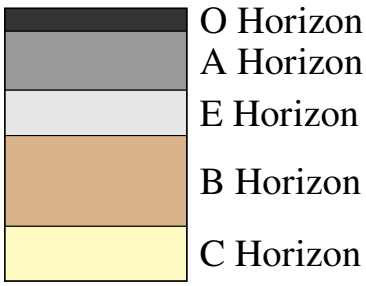
(A) Nitrification

(B) Denitrification

(C) Nitrogen fixation

(D) Ammonification

Q36. Consider the following TikZ cross-sectional schematic diagram of a typical well-developed soil profile. Identify the master horizon labeled as the zone of maximum eluvation (leaching of clay, iron, and aluminum oxides).



(A) A Horizon

(B) E Horizon

(C) B Horizon

(D) C Horizon

Q37. Which of the following essential plant micronutrients plays a crucial structural role in the synthesis of auxin hormones and acts as an activator for carbonic anhydrase enzymes?

(A) Iron (Fe)

(B) Zinc (Zn)

(C) Copper (Cu)

(D) Boron (B)

Q38. The application of agricultural gypsum ($CaSO_4 \cdot 2H_2O$) is a highly recommended chemical reclamation practice for amending which class of degraded soils?

(A) Acid soils

(B) Sodic/Alkali soils

(C) Saline soils

(D) Peat soils

Q39. The fundamental building block units that comprise the crystalline layers of a 2:1 silicate clay mineral (such as montmorillonite) are:

(A) One silica sheet and one alumina sheet

(B) Two silica sheets and one alumina sheet

(C) One silica sheet and two alumina sheets

(D) Two silica sheets and two alumina sheets

Q40. Which of the following chemical fertilizers is classified as a concentrated organic nitrogenous fertilizer and undergoes rapid enzymatic hydrolysis to form ammonium carbonate in the soil?

(A) Ammonium sulfate

(B) Urea

(C) Calcium ammonium nitrate

(D) Single superphosphate

Detailed Solutions

Q1.

Solution

Concept:

In multi-electron atoms, the energy levels of atomic orbitals do not depend solely on the principal quantum number n. Instead, the electronic energy is determined by the combination of both the principal quantum number n and the azimuthal quantum number l. This behavior is governed by the Bohr-Bury $(n + l)$ rule, which dictates that orbitals with a higher sum of $n + l$ possess a higher energy state due to decreased nuclear shielding.

Solution:

(a) According to the $(n + l)$ rule, the orbital with the higher value of $(n + l)$ has higher energy. If two different orbitals share the exact same $(n + l)$ value, the orbital containing the larger principal quantum number n is positioned higher in energy.

(b) Let us systematically compute the value of $(n + l)$ for each given set of quantum numbers:

- For option (A): $n = 4, l = 0$. Thus, $n + l = 4 + 0 = 4$ (This corresponds to a $4s$ orbital).
- For option (B): $n = 3, l = 2$. Thus, $n + l = 3 + 2 = 5$ (This corresponds to a $3d$ orbital).
- For option (C): $n = 4, l = 1$. Thus, $n + l = 4 + 1 = 5$ (This corresponds to a $4p$ orbital).
- For option (D): $n = 3, l = 1$. Thus, $n + l = 3 + 1 = 4$ (This corresponds to a $3p$ orbital).

(c) Comparing these sums, options (B) and (C) both yield the highest sum of 5. Therefore, they are higher in energy than options (A) and (D).

(d) To resolve the tie between the $3d$ and $4p$ orbitals, we evaluate their principal quantum numbers. Since option (C) has $n = 4$ and option (B) has $n = 3$, the $4p$ orbital undergoes greater shielding and experiences a weaker effective nuclear charge. This makes it less stable and higher in energy than the $3d$ orbital.

Final Answer: The highest energy orbital is represented by n = 4, l = 1, m = 0, s = +1/2.

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 from left to right due to an increase in effective nuclear charge and a decrease in atomic radius. However, anomalous deviations arise due to the extra stability associated with exactly half-filled or fully-filled electronic subshells.

Solution:

(a) The elements Boron (B), Carbon (C), Nitrogen (N), and Oxygen (O) all belong to the second period of the modern periodic table.

(b) Looking at the general trend across the period, the expected order of increasing ionization energy would be $B < C < N < O$ due to the progressive contraction of atomic size and tighter binding of valence electrons.

(c) However, we must analyze the ground-state valence shell electronic configurations of Nitrogen and Oxygen:

- Nitrogen ($Z = 7$) has the configuration $2s^2 2p^3$.
- Oxygen ($Z = 8$) has the configuration $2s^2 2p^4$.

(d) The $2p$ subshell of Nitrogen is exactly half-filled, which imparts extra stability due to symmetrical distribution of electron density and maximum exchange energy. Removing an electron disrupts this stable state. Conversely, removing an electron from Oxygen relieves inter-electronic repulsion between paired electrons in its $2p$ orbital, yielding a stable half-filled $2p^3$ configuration.

(e) Consequently, it requires more energy to ionize a Nitrogen atom than an Oxygen atom, making the first ionization enthalpy of Nitrogen higher than that of Oxygen. Boron and Carbon follow the normal trend since Boron ($2s^2 2p^1$) easily loses its single p-electron and Carbon ($2s^2 2p^2$) holds its electrons more tightly than Boron.

Final Answer: The correct order of increasing first ionization enthalpy is B < C < O < N.

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

Molecular Orbital (MO) Theory describes the covalent bonding in homonuclear diatomic molecules by mixing atomic orbitals to generate bonding and antibonding molecular orbitals. The sequence of filling these molecular orbitals depends on the total number of electrons. For molecules heavier than Nitrogen (like O_2 and F_2), the σ_{2p_z} orbital is lower in energy than the π_{2p_x} and π_{2p_y} orbitals due to the absence of significant $s - p$ mixing.

Solution:

(a) The given TikZ diagram illustrates the higher energy molecular orbital configuration where σ_{2p_z} is lower in energy than the degenerate π_{2p} bonding orbitals. This specific energy ordering is characteristic of O_2 and F_2.

(b) Let us analyze the total valence electron distribution for the Oxygen molecule (O_2), which contains 16 total electrons (or 12 valence electrons beyond the core $1s$ shells).

(c) Filling these 12 valence electrons into the valence molecular orbitals according to the Aufbau principle, Hund's rule, and the Pauli exclusion principle yields:

- σ_{2s} receives 2 electrons, σ^*_{2s} receives 2 electrons.
- σ_{2p_z} receives 2 electrons.
- π_{2p_x} and π_{2p_y} receive 2 electrons each (total 4).
- The remaining 2 electrons must enter the degenerate antibonding $\pi^*_{2p_x}$ and $\pi^*_{2p_y}$ orbitals. Following Hund's rule, they enter singly with parallel spins.

(d) We calculate the bond order using the standard formula: Bond Order $= \frac{N_b - N_a}{2}$, where N_b is the number of bonding electrons and N_a is the number of antibonding electrons. For the valence shell of O_2, Bond Order $= \frac{8-4}{2} = 2$.

(e) Because there are two unpaired electrons residing in the π^*_{2p} antibonding subshell, the molecule interacts with external magnetic fields and exhibits paramagnetism. This perfectly matches the criteria.

Final Answer: The molecule that possesses a bond order of 2 and is paramagnetic is O_2.

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept:

The geometry and hybridization of a molecule can be determined using the Valence Shell Electron Pair Repulsion (VSEPR) theory and steric number calculations. The steric number is the sum of the number of sigma bonds formed by the central atom and the number of lone pairs residing on that central atom. This total number of electron pairs dictates the hybridization state and the spatial arrangement of the electron domains.

Solution:

(a) Xenon (Xe) is a noble gas belonging to Group 18, meaning it possesses 8 valence electrons in its outermost shell.

(b) In the Xenon tetrafluoride (XeF_4) molecule, Xenon forms four single sigma bonds with four individual fluorine atoms. This consumes 4 of its valence electrons.

(c) The remaining 4 valence electrons stay on the Xenon central atom as non-bonding electrons, organizing themselves into exactly 2 distinct lone pairs.

(d) We calculate the steric number (S_n) of the central Xenon atom as follows: S_n = Number of bonded atoms + Number of lone pairs = 4 + 2 = 6.

(e) A steric number of 6 implies that the central atom requires six hybrid orbitals, which corresponds to sp^3d^2 hybridization. This hybrid state corresponds to an octahedral basic electron geometry.

(f) To minimize the strong lone pair-lone pair repulsions according to VSEPR theory, the two lone pairs position themselves exactly opposite to each other (180° apart) along the axial positions. This leaves the four fluorine atoms occupying the four equatorial corners, resulting in a stable square planar molecular geometry.

Final Answer: The hybridization and geometry of $XeF_4 are sp^3d^2 and Square planar$.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept:

Redox chemistry classifies reactions based on concurrent shifts in the oxidation numbers of the participating chemical species. A disproportionation reaction is a specific type of redox process in which a single chemical element in a specific oxidation state simultaneously undergoes both oxidation (an increase in oxidation state) and reduction (a decrease in oxidation state) to form two distinct chemical products.

Solution:

(a) Let us analyze the chemical equation given: $3Br_2 + 6CO_3^{2-} + 3H_2O \rightarrow 5Br^- + BrO_3^- + 6HCO_3^-$. We must systematically assign oxidation numbers to the bromine atoms across both sides of the equation.

(b) On the reactant side, bromine exists as elemental molecular bromine (Br_2). By definition, the oxidation state of any element in its free homoatomic form is exactly 0.

(c) On the product side, bromine appears in two separate chemical species:

- In the bromide ion (Br^-), the oxidation state is equal to the net charge of the monoatomic ion, which is -1.
- In the bromate ion (BrO_3^-), we can calculate the oxidation state of bromine (let it be x). Knowing oxygen generally exhibits an oxidation state of -2, we set up the equation: $x + 3(-2) = -1 \Rightarrow x - 6 = -1 \Rightarrow x = +5$.

(d) Looking at the transformation from $Br_2 \rightarrow Br^-$, the oxidation state decreases from 0 to -1. This represents a gain of electrons, which is a reduction process.

(e) Looking at the transformation from $Br_2 \rightarrow BrO_3^-$, the oxidation state increases from 0 to $+5$. This represents a loss of electrons, which is an oxidation process.

(f) Since the same element, bromine, is simultaneously oxidized and reduced, it undergoes a disproportionation reaction.

Final Answer: The element bromine undergoes Both oxidation and reduction.

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:

The empirical formula represents the simplest whole-number ratio of the various atoms present in a chemical compound. To deduce this formula from mass percentages, one must convert the relative mass of each element into its corresponding molar proportions using the respective atomic masses. These molar values are then normalized to determine the simplest ratio.

Solution:

(a) Assume we have a 100 g sample of the unknown compound. Based on the given mass percentages, the sample contains exactly 50 g of element X and 50 g of element Y.

(b) Next, we calculate the number of moles (n) for each constituent element by dividing the mass by its given atomic mass:

- Moles of element X: $n_X = \frac{\text{Mass of X}}{\text{Atomic mass of X}} = \frac{50\,\text{g}}{10\,\text{g/mol}} = 5.0\,\text{moles}.$
- Moles of element Y: $n_Y = \frac{\text{Mass of Y}}{\text{Atomic mass of Y}} = \frac{50\,\text{g}}{20\,\text{g/mol}} = 2.5\,\text{moles}.$

(c) To establish the simplest atomic ratio, we divide the number of moles of each element by the smallest calculated mole value, which is 2.5:

- Relative ratio for X = $\frac{5.0}{2.5} = 2$.
- Relative ratio for Y = $\frac{2.5}{2.5} = 1$.

(d) The resulting whole numbers reveal that for every single atom of element Y, there are two atoms of element X. Combining these indices yields the simplest empirical formula.

Final Answer: The empirical formula of the compound is X_2Y.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

The net dipole moment of a polyatomic molecule is the vector sum of its individual bond dipole moments, factoring in the spatial orientation dictated by its molecular geometry. Highly symmetrical molecules can have individual polar bonds whose dipoles completely cancel each other out, resulting in a net dipole moment of zero. For non-symmetrical structures or those containing lone pairs, the orientation of the lone pair dipole relative to the bond dipoles significantly influences the net molecular dipole.

Solution:

(a) Let us evaluate each option:

- BF_3 has a trigonal planar geometry (sp^2 hybridized). The three highly polar $B-F$ bonds point symmetrically towards the corners of an equilateral triangle at 120° angles, canceling completely ($\mu = 0$).
- CCl_4 possesses a perfectly symmetrical tetrahedral shape (sp^3 hybridized). The four $C-Cl$ bond dipoles cancel out perfectly, resulting in a net dipole moment of zero ($\mu = 0$).

(b) This leaves us to compare the pyramidal molecules NH_3 and NF_3, which both have sp^3 hybridization with three bonding pairs and one lone pair.

(c) In NH_3, nitrogen is more electronegative than hydrogen. The individual $N-H$ bond dipoles point inward toward the nitrogen atom. The dipole moment of the lone pair points outward away from the nucleus. Consequently, the bond dipoles and lone pair dipole reinforce each other, resulting in a large net dipole moment.

(d) In NF_3, fluorine is far more electronegative than nitrogen. The $N-F$ bond dipoles point outward away from the nitrogen atom. This opposes the lone pair dipole pointing in the opposite direction. The opposing vectors partially cancel out, making the net dipole moment of NF_3 significantly smaller than that of NH_3.

Final Answer: The molecule showing the maximum dipole moment is NH_3.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

The electronic architecture of an atom is organized into shells, subshells, and individual orbitals, which are defined by quantum numbers. The azimuthal quantum number (l) specifies the subshell type and determines its angular momentum. Each subshell contains a specific number of degenerate orbitals determined by the magnetic quantum number (m_l), and each orbital can accommodate a maximum of two electrons with opposing spins according to the Pauli exclusion principle.

Solution:

(a) The given azimuthal quantum number is $l = 3$, which designates an f subshell.

(b) The number of individual atomic orbitals contained within any given subshell is calculated using the formula: Number of orbitals $= 2l + 1$.

(c) Substituting $l = 3$ into this relation gives: Number of orbitals $= 2(3) + 1 = 6 + 1 = 7$ distinct orbitals. These orbitals correspond to the magnetic quantum number values $m_l = -3, -2, -1, 0, +1, +2, +3$.

(d) According to the Pauli exclusion principle, a single atomic orbital can hold a maximum of 2 electrons, which must possess opposite spin directions ($s = +1/2$ and $s = -1/2$).

(e) Therefore, the total electron capacity (N_{max}) of this entire subshell is determined by multiplying the total number of constituent orbitals by 2:

$$N_{max} = 2 \times (2l + 1) = 2 \times 7 = 14 \text{ electrons.}$$

(f) This means an f subshell can accommodate a maximum of 14 electrons.

Final Answer: The maximum number of electrons that can be accommodated is 14.

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept:

The classification of chemical elements evolved significantly from early models based on macroscopic properties to modern models based on internal atomic structure. The historical periodic law proposed by Dmitri Mendeleev stated that chemical properties are periodic functions of atomic weights. However, the Modern Periodic Law, formulated following the breakthrough experimental work of Henry Moseley, updated this definition to link periodicity to atomic structure.

Solution:

(a) Henry Moseley conducted systematic X-ray spectroscopy experiments by bombarding various elemental targets with high-energy electrons.

(b) He measured the frequencies (ν) of the characteristic X-rays emitted by these elements and discovered a precise mathematical relationship.

(c) He found that the square root of the emitted X-ray frequency ($\sqrt{\nu}$) is directly proportional to the nuclear charge, which corresponds to the atomic number (Z), rather than the atomic mass (A).

(d) This discovery proved that the atomic number—representing the total number of protons in the nucleus and the number of electrons in a neutral atom—is a far more fundamental property than atomic weight.

(e) The electronic configuration of an element is directly determined by its atomic number. Since valence electronic structures govern chemical reactivity and bonding tendencies, properties recur periodically when elements are arranged by increasing atomic number.

(f) Therefore, according to the modern periodic law, the physical and chemical properties of elements are periodic functions of their atomic numbers.

Final Answer: The properties of elements are a periodic function of their Atomic number.

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept:

The oxidation state or oxidation number is the formal charge an atom would carry if all bonding pairs were assigned to the more electronegative element. To determine the unknown oxidation state of a transition metal within a neutral coordination compound or polyatomic salt, we set up a conservation of charge equation. The sum of the oxidation numbers of all individual constituent atoms must equal the net overall charge of the chemical formula unit, which is zero for a neutral salt.

Solution:

(a) The given chemical formula is Potassium Dichromate, $K_2Cr_2O_7$, which is a neutral ionic compound.

(b) We assign standard known oxidation numbers to the non-variable counter ions and ligands based on periodic trends:

- Potassium (K) is an alkali metal belonging to Group 1, so it consistently exhibits an oxidation state of +1.
- Oxygen (O) is highly electronegative and typically exhibits an oxidation state of -2 in oxoanions where no peroxide bonds are present.

(c) Let x represent the unknown oxidation state of a single Chromium (Cr) atom.

(d) Since there are 2 Potassium atoms, 2 Chromium atoms, and 7 Oxygen atoms in the formula unit, we write the balancing equation:

$$2(+1) + 2(x) + 7(-2) = 0$$

(e) Simplifying the algebraic expression:

$$2 + 2x - 14 = 0 \Rightarrow 2x - 12 = 0 \Rightarrow 2x = 12 \Rightarrow x = +6.$$

(f) Thus, each chromium atom in the dichromate structure exists in a +6 oxidation state.

Final Answer: The oxidation state of chromium in $K_2Cr_2O_7 is + 6$.

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:

The position of an element within the modern periodic table can be systematically determined from its ground-state electronic configuration. The specific group number of a block element is determined by analyzing the valence shell architecture. For a p-block element, where the outermost electrons enter a p-subshell, the group assignment accounts for the filled s-orbitals, the ten intervening d-block transition elements, and the valence electrons.

Solution:

(a) The given ground-state electronic configuration of the unknown element is $[Ar]3d^{10}4s^24p^3$.

(b) First, we identify the principal quantum number of the outermost shell (n), which dictates the period. Here, the maximum value of n is 4, indicating that this element belongs to the fourth period of the periodic table.

(c) Next, we determine the block allocation by observing which subshell is currently being filled. Since the highest-energy electrons are entering the $4p$ subshell, the element is classified as a p-block element.

(d) For any given p-block element, the standard formula used to determine its specific group number is: Group Number = 10 + Number of electrons in ns subshell + Number of electrons in np subshell.

(e) Substituting the values from the given configuration, where there are 2 electrons in the $4s$ subshell and 3 electrons in the $4p$ subshell, we calculate: Group Number $= 10 + 2 + 3 = 15$.

(f) This matches Group 15, which is also known as the nitrogen family or pnictogens. This specific element is Arsenic (As, $Z = 33$).

Final Answer: The element belongs to Group 15.

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept:

An atomic nucleus contains subatomic particles collectively termed nucleons. The stability, mass, and chemical identity of any given nuclide are governed by the balance between these nucleons and the nuclear forces acting over short distances. While the number of protons uniquely establishes the atomic number and chemical identity, neutrons provide the necessary attractive strong nuclear force to counteract electrostatic repulsion.

Solution:

(a) An atom is structurally divided into a peripheral electron cloud and a dense central nucleus. The electrons revolve around the nucleus and are responsible for chemical bonding, but they do not reside inside or stabilize the nucleus itself.

(b) The atomic nucleus is composed of two primary fundamental particles: positively charged protons and electrically neutral neutrons.

(c) Protons carry a positive electrical charge, which creates immense electrostatic repulsion over short distances within the compact volume of the nucleus.

(d) If a nucleus contained only protons, this repulsive Coulomb force would instantly cause it to fly apart. Neutrons act as a nuclear glue. They experience the attractive strong nuclear force without adding any destabilizing electrostatic repulsion.

(e) The strong nuclear force operates between proton-proton, neutron-neutron, and proton-neutron pairs. This force holds the nucleons together and maintains nuclear stability.

(f) Furthermore, the number of protons defines the identity of the element, while the number of neutrons determines the specific isotope. Thus, these two nucleons are responsible for the stability and identity of the nucleus.

Final Answer: The fundamental particles are Protons and neutrons.

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:

Chemical kinetics defines a first-order reaction as a process where the reaction rate is directly proportional to the concentration of a single reactant. The integrated rate equation for a first-order reaction describes an exponential decay over time. Crucially, the half-life ($t_{1/2}$) of a first-order reaction is a constant value that depends only on the rate constant, remaining independent of the initial reactant concentration.

Solution:

(a) The integrated rate expression for a first-order chemical reaction is given by the mathematical formula: $k = \frac{2.303}{t} \log\left(\frac{[A]_0}{[A]_t}\right)$, where $[A]_0$ represents the initial concentration and $[A]_t$ is the remaining concentration at time t.

(b) The half-life period ($t_{1/2}$) corresponds to the time required for exactly 50% completion, meaning $[A]_t = 0.5[A]_0$. Substituting this gives the constant relationship: $t_{1/2} = \frac{2.303 \log(2)}{k} = \frac{0.693}{k}$.

(c) Now, consider a reaction that has reached 99.9% completion. The remaining concentration of the reactant at this time ($t_{99.9\%}$) is calculated as: $[A]_t = [A]_0 - 0.999[A]_0 = 0.001[A]_0 = 10^{-3}[A]_0$.

(d) Substituting this value into the integrated rate equation allows us to solve for $t_{99.9\%}$:

$$t_{99.9\%} = \frac{2.303}{k} \log\left(\frac{[A]_0}{10^{-3}[A]_0}\right) = \frac{2.303}{k} \log(10^3) = \frac{3 \times 2.303}{k} = \frac{6.909}{k}$$

(e) To find the proportional relationship between these two time values, we divide the expression for $t_{99.9\%}$ by the expression for $t_{1/2}$:

$$\frac{t_{99.9\%}}{t_{1/2}} = \frac{\frac{3 \times 2.303}{k}}{\frac{0.301 \times 2.303}{k}} = \frac{3}{0.301} \approx 10$$

(f) This shows that the time required for 99.9% completion is exactly ten times the half-life.

Final Answer: The time required is approximately 10 times the half-life.

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept:

An electrochemical or galvanic cell converts chemical energy from spontaneous redox reactions into electrical energy. Standard notation conventions dictate that the anode half-cell, where oxidation occurs, is always written on the left side, while the cathode half-cell, where reduction occurs, is written on the right side. The two halves are separated by a vertical double line representing the salt bridge, and electron flow proceeds from the electron-rich anode to the cathode.

Solution:

(a) The provided TikZ schematic depicts a standard Daniell cell composed of a zinc electrode immersed in a zinc ion solution on the left, and a copper electrode immersed in a copper ion solution on the right.

(b) We evaluate the standard reduction potentials for the two metallic systems: $E^{\circ}_{Zn^{2+}/Zn} = -0.76\,\text{V}$ and $E^{\circ}_{Cu^{2+}/Cu} = +0.34\,\text{V}$.

(c) Because zinc has a more negative standard reduction potential, it acts as a stronger reducing agent and undergoes oxidation at the anode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$.

(d) Copper ions have a more positive reduction potential, so they undergo reduction at the cathode: $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$.

(e) Following the IUPAC cell notation rules, the anode components are written first, followed by the cathode components: $Zn|Zn^{2+}||Cu^{2+}|Cu$.

(f) Oxidation releases electrons at the zinc electrode, making it the negative terminal. These electrons travel through the external wire circuit toward the copper electrode, where reduction occurs. Thus, electrons flow from the Zn electrode to the Cu electrode.

Final Answer: The correct notation is Zn | $Zn^{2+}||Cu^{2+}|Cu, and electron flows from Zn to Cu.$

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:

Chemical equilibrium constants can be expressed either in terms of partial pressures (K_p) for gas-phase reactions or molar concentrations (K_c). The mathematical relationship connecting these two constants is derived from the Ideal Gas Law ($PV = nRT$). The conversion factor depends directly on the change in the number of moles of gaseous products and reactants, denoted as Δn_g.

Solution:

(a) The general mathematical relationship connecting the pressure-based and concentration-based equilibrium constants is: $K_p = K_c(RT)^{\Delta n_g}$, where R is the universal gas constant, T is the absolute temperature in Kelvin, and Δn_g is the net change in gaseous moles.

(b) The parameter Δn_g is computed using the stoichiometry of the balanced chemical equation: $\Delta n_g = \sum n_{\text{gaseous products}} - \sum n_{\text{gaseous reactants}}$.

(c) Let us analyze the given gas-phase dissociation reaction: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$.

(d) Counting the stoichiometric coefficients of the gaseous species on both sides:

- Total moles of gaseous products = 1 mole of PCl_3 + 1 mole of Cl_2 = 2.
- Total moles of gaseous reactants = 1 mole of PCl_5 = 1.

(e) Substituting these values gives the net change in gaseous moles: $\Delta n_g = 2 - 1 = 1$.

(f) Finally, substituting $\Delta n_g = 1$ back into the primary thermodynamic relationship yields: $K_p = K_c(RT)^1 = K_c(RT)$. This matches the expression for a dissociation reaction where volume increases.

Final Answer: The relationship is given by $K_p = K_c(RT)$.

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept:

The elevation of boiling point is a colligative property, meaning it depends solely on the total number of solute particles dissolved in a given mass of solvent, regardless of their chemical identity. When a non-volatile solute is dissolved in a volatile solvent, the vapor pressure decreases, requiring a higher temperature to match atmospheric pressure. This elevation in boiling point (ΔT_b) is directly proportional to the molal concentration of the solution.

Solution:

(a) The boiling point elevation equation is expressed as: $\Delta T_b = T_b - T_b^\circ = K_b \times m$, where T_b is the boiling point of the solution, T_b° is the boiling point of the pure solvent, K_b is the molal boiling point elevation constant, and m is the molality.

(b) The pure solvent here is water, which has a standard boiling point (T_b°) of exactly 100.00°C under standard atmospheric pressure.

(c) The given boiling point of this aqueous solution is 100.52°C. We calculate the net temperature elevation (ΔT_b) as follows:

$$\Delta T_b = 100.52^\circ\text{C} - 100.00^\circ\text{C} = 0.52^\circ\text{C} = 0.52\,\text{K}$$

(d) The molal boiling point elevation constant (K_b) for water is provided as $0.52\,\text{K kg mol}^{-1}$.

(e) Rearranging the primary colligative formula to isolate the solution molality (m) gives: $m = \frac{\Delta T_b}{K_b}$.

(f) Substituting our values into this rearranged expression yields:

$$m = \frac{0.52\,\text{K}}{0.52\,\text{K kg mol}^{-1}} = 1.0\,\text{mol kg}^{-1} = 1.0\,\text{m}$$

(g) Thus, the solution has a concentration of exactly 1.0 molal.

Final Answer: The molality of this solution is 1.0 m.

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept:

The spontaneity of a chemical reaction under conditions of constant temperature and pressure is dictated by the change in Gibbs Free Energy (ΔG), as defined by the Gibbs-Helmholtz equation: $\Delta G = \Delta H - T\Delta S$. For a process to occur spontaneously, ΔG must be strictly negative. When enthalpy (ΔH) and entropy (ΔS) have the same algebraic sign, temperature acts as the deciding factor determining spontaneity.

Solution:

(a) The prompt states that the chemical reaction is explicitly endothermic. By thermodynamic definition, all endothermic processes absorb heat from the surroundings, meaning the change in enthalpy must be positive ($\Delta H > 0$).

(b) We substitute this positive enthalpy condition into the Gibbs-Helmholtz equation: $\Delta G = (+)\Delta H - T\Delta S$.

(c) For the reaction to be non-spontaneous at low temperatures, ΔG must be positive at those temperatures. When T is small, the magnitude of the $T\Delta S$ term is minimal, so the positive ΔH term dominates, ensuring $\Delta G > 0$.

(d) For the reaction to switch and become spontaneous at high temperatures, ΔG must become negative. As temperature increases, the magnitude of the $T\Delta S$ factor grows larger.

(e) For a large $T\Delta S$ term to overcome a positive ΔH and drive ΔG below zero, the entropy change (ΔS) must be positive ($\Delta S > 0$). This ensures the $-T\Delta S$ term is negative, allowing it to dominate at high temperatures.

(f) Therefore, a reaction that is spontaneous only at high temperatures must have both $\Delta H > 0$ and $\Delta S > 0$.

Final Answer: The thermodynamic criteria must be $\Delta H > 0 and \Delta S > 0$.

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept:

The pH of an aqueous solution is mathematically defined as the negative logarithm of the total hydronium ion concentration: $\text{pH} = -\log[H_3O^+]$. In highly dilute solutions of strong acids (concentrations around 10^{-7} M or lower), the autoionization of water cannot be ignored. Water molecules dissociate to contribute a baseline concentration of H^+ ions that must be factored in alongside the acid to determine the true pH.

Solution:

(a) Hydrochloric acid (HCl) is a strong monobrotic acid that dissociates completely in water. A 1.0×10^{-8} M HCl solution yields 1.0×10^{-8} M of H^+ ions from the acid.

(b) If we incorrectly calculate pH using only this value, we get: $\text{pH} = -\log(10^{-8}) = 8$. This is chemically impossible, as adding an acid to neutral water cannot produce an alkaline solution with a pH greater than 7 at 25°C.

(c) To find the true acidity, we must include the hydronium ions produced by the autoionization of water: $H_2O \rightleftharpoons H^+ + OH^-$.

(d) Let x be the concentration of H^+ ions originating from water dissociation. Because water produces H^+ and OH^- ions in equal amounts, the concentration of OH^- ions is also x.

(e) The total concentration of hydronium ions in the solution is the sum from both sources: $[H^+]_{\text{total}} = (1.0 \times 10^{-8} + x)$ M.

(f) We substitute these concentrations into the water equilibrium constant expression ($K_w = 1.0 \times 10^{-14}$ at 25°C):

$$K_w = [H^+]_{\text{total}}[OH^-] \Rightarrow (1.0 \times 10^{-8} + x)(x) = 1.0 \times 10^{-14}$$

(g) This forms the quadratic equation: $x^2 + 1.0 \times 10^{-8}x - 1.0 \times 10^{-14} = 0$. Solving for the positive root yields $x \approx 9.5 \times 10^{-8}$ M.

(h) The total hydronium concentration is: $[H^+]_{\text{total}} = 1.0 \times 10^{-8} + 9.5 \times 10^{-8} = 1.05 \times 10^{-7}$ M. Calculating the pH gives: $\text{pH} = -\log(1.05 \times 10^{-7}) \approx 6.98$, which is slightly less than 7.00.

Final Answer: The pH of the solution is Slightly less than 7.00.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept:

A chemical catalyst accelerates the rate of a chemical reaction without being consumed in the process. It achieves this by providing an alternative reaction pathway with a lower activation energy barrier. Crucially, a catalyst lowers the energy of the transition state for both the forward and reverse reaction directions equally. It alters reaction kinetics but has no effect on the initial energy of the reactants or final energy of the products.

Solution:

(a) The provided TikZ potential energy profile show two distinct pathways: a solid line representing the uncatalyzed reaction and a dashed line representing the catalyzed pathway.

(b) The activation energy for the forward reaction ($E_{a,f}$) is the energy barrier that reactants must overcome to reach the transition state. It is measured as the energy difference between the transition state peak and the reactant energy level.

(c) Looking at the diagram, the dashed line peak is lower than the solid line peak. This shows that the catalyst significantly lowers the activation energy ($E_{a,f}$) for the forward reaction.

(d) The total enthalpy change of the reaction (ΔH) is a state function defined as the net difference between the potential energy of the products and the potential energy of the reactants: $\Delta H = H_{\text{products}} - H_{\text{reactants}}$.

(e) Because a catalyst does not alter the identity or baseline potential energy levels of either the starting reactants or the final products, the net value of ΔH remains completely unchanged.

(f) Consequently, the catalyst increases the reaction velocity by lowering the activation energy barrier, while leaving the overall thermodynamic enthalpy change unaffected.

Final Answer: $\mathrm{E}_{a,f} decreases, while \Delta H remains unchanged.$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept:

Kohlrausch's Law of Independent Migration of Ions states that at infinite dilution, where inter-ionic attractions become negligible, each ion of an electrolyte migrates independently of its co-ion. Consequently, the limiting molar conductivity (Λ_m°) of an entire electrolyte can be calculated as the sum of the individual limiting molar conductivities of its constituent anions and cations, each multiplied by the number of ions present in the formula unit.

Solution:

(a) Consider a general salt or electrolyte designated by the formula A_xB_y.

(b) When this electrolyte dissolves in water, it undergoes complete dissociation into its constituent ions according to the balanced equation: $A_xB_y(aq) \rightarrow xA^{y+}(aq) + yB^{x-aq)}$.

(c) This ionization profile shows that every single formula unit of the A_xB_y electrolyte releases exactly x moles of cations (A^{y+}) and y moles of anions (B^{x-}).

(d) Let λ_A° represent the limiting molar conductivity of an individual cation, and let λ_B° represent the limiting molar conductivity of an individual anion.

(e) According to Kohlrausch's law, because the ions migrate independently at infinite dilution, the total limiting molar conductivity is the sum of the conductivity contributions from all ions.

(f) Multiplying each individual ionic conductivity by its stoichiometric coefficient yields the expression:

$$\Lambda_m^\circ = x\lambda_A^\circ + y\lambda_B^\circ$$

(g) This standard equation is used to calculate the maximum electrical conductivity of strong and weak electrolytes at infinite dilution.

Final Answer: The limiting molar conductivity is equal to $\Lambda_m^\circ = x\lambda_A^\circ + y\lambda_B^\circ$.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:

Freezing point depression is a significant colligative property that depends entirely on the total number of solute particles present in the solution rather than their chemical identity. When an electrolyte dissolves in water, it dissociates into ions, increasing the total particle concentration. This effect is quantitatively adjusted using the van 't Hoff factor (i), which counts the number of moles of particles produced per mole of solute formula unit.

Solution:

(a) The mathematical equation governing freezing point depression is given by the relation: $\Delta T_f = i \times K_f \times m$, where $\Delta T_f = T_f^\circ - T_f$ represents the drop in freezing point, K_f is the cryoscopic constant of water, and m is the concentration.

(b) Since all the solutions provided share an identical molar concentration (0.1 M), the magnitude of the freezing point depression depends directly on the van 't Hoff factor (i) of each individual solute.

(c) Let us evaluate the value of i for each given option assuming complete dissociation:

- Glucose is a non-electrolyte that does not dissociate in water, meaning $i = 1$.
- Sodium Chloride dissociates into two ions (Na^+ and Cl^-), meaning $i = 2$.
- Calcium Chloride dissociates into three ions (Ca^{2+} and $2Cl^-$), meaning $i = 3$.
- Aluminium Sulfate dissociates into five total ions ($2Al^{3+}$ and $3SO_4^{2-}$), meaning $i = 5$.

(d) The solute Aluminium Sulfate yields the largest van 't Hoff factor ($i = 5$), which produces the highest total concentration of dissolved particles in solution.

(e) Consequently, Aluminium Sulfate creates the maximum freezing point depression (ΔT_f). A larger depression lowers the actual final freezing temperature (T_f) furthest below 0°C, resulting in the lowest freezing point.

Final Answer: Aluminium Sulfate will exhibit the lowest freezing point temperature.

Answer: (D)

Go Back to Question 21

Q22.

Solution

Concept:

In chemical kinetics, the overall reaction order represents the sum of the exponents to which the reactant concentrations are raised in the experimental rate law equation. While the numerical value of the rate constant (k) changes based on temperature and reaction conditions, the corresponding units of k are strictly determined by the overall order of the reaction. This allows the reaction order to be identified directly by analyzing the units of the rate constant.

Solution:

(a) Let us establish a general rate equation for a chemical reaction with an arbitrary overall order designated by n: Rate $= k[\text{Reactant}]^n$.

(b) We substitute the fundamental units for each variable into this expression to isolate the units of the rate constant. Reaction rate is measured as change in concentration per unit time (mol $L^{-1}s^{-1}$), while concentration is measured in mol L^{-1}:

$$\text{mol } L^{-1}s^{-1} = [k] \times \left(\text{mol } L^{-1}\right)^n$$

(c) Rearranging this algebraic relation to solve for the units of k yields the general formula:

$$[k] = \left(\text{mol } L^{-1}\right)^{1-n} s^{-1} = L^{n-1}\text{mol}^{1-n}s^{-1}$$

(d) The prompt specifies that the experimental rate constant value is $k = 2.5 \times 10^{-4}$ L $\text{mol}^{-1}s^{-1}$. Comparing the units, we can map the exponent of the Liter unit directly to our derived equation: $n - 1 = 1$.

(e) Solving this simple equation for n gives: $n = 1 + 1 = 2$.

(f) A value of $n = 2$ indicates that this chemical process follows second-order kinetics overall. This means the reaction rate quadruples if the concentration of a single primary reactant is doubled.

Final Answer: The overall order of the reaction is Second order.

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept:

According to the Brønsted-Lowry acid-base theory, an acid is defined as a chemical species that acts as a proton (H^+) donor, whereas a base functions as a proton acceptor. When a Brønsted-Lowry acid undergoes a chemical reaction and successfully donates its acidic proton, the remaining molecular fragment is capable of re-accepting a proton. This remaining chemical fragment is defined as the conjugate base of the original acid.

Solution:

(a) The chemical species specified in the question is the bisulfate ion, which is represented by the formula HSO_4^-.

(b) To identify the conjugate base of this polyatomic ion, we treat the bisulfate ion as a Brønsted-Lowry acid that must donate exactly one proton (H^+) to its chemical environment.

(c) We write out the formal chemical equation representing this proton donation step:

$$HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$$

(d) Removing a single positively charged hydrogen nucleus (H^+) from the bisulfate ion leaves behind the sulfate chemical group.

(e) We compute the final charge of the resulting fragment by subtracting +1 from the initial charge of the reactant: $-1 - (+1) = -2$. This yields the divalent sulfate anion, which is written as SO_4^{2-}.

(f) Conversely, if a proton were added to the bisulfate ion, it would act as a base to form sulfuric acid (H_2SO_4), which represents its conjugate acid rather than its conjugate base. Thus, the correct remaining basic species is sulfate.

Final Answer: The conjugate base of the bisulfate ion is SO_4^{2-}.

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:

The heat capacity of a thermodynamic system represents the quantity of thermal energy required to raise its absolute temperature by exactly one Kelvin. Because heat is a path function rather than a state function, the specific value of heat transfer depends on the constraints placed on the system during the process. When heating occurs under a rigid constant volume constraint, no boundary work can be performed, locking the energy path into changes in internal energy.

Solution:

(a) The first law of thermodynamics states that the differential change in internal energy (dU) is equal to the heat added to the system (dQ) minus the boundary work performed (dW): $dU = dQ - dW$.

(b) Expansion or boundary work is defined mathematically by the pressure-volume relation: $dW = PdV$. Substituting this back into the first law yields the expression: $dU = dQ - PdV$.

(c) The system described is maintained under a strict constant volume constraint (V = constant). This means the change in volume is exactly zero ($dV = 0$), which simplifies the equation to: $dU = dQ_V$.

(d) This relation indicates that all thermal energy transferred into the system at constant volume goes directly into increasing the internal energy (U) of the particles, rather than being redirected into mechanical expansion work.

(e) The heat capacity at constant volume (C_v) is defined as the rate of change of heat with respect to temperature under isometric conditions: $C_v = \left(\frac{\partial Q}{\partial T}\right)_V$.

(f) Substituting the constant volume condition ($dQ_V = dU$) into this partial derivative yields the final thermodynamic definition: $C_v = \left(\frac{\partial U}{\partial T}\right)_V$.

Final Answer: The heat capacity at constant volume is defined as $\left(\frac{\partial U}{\partial T}\right)_V$.

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:

The systematic nomenclature of polyfunctional organic molecules follows strict IUPAC rules to select and number the principal carbon chain. When a chemical structure contains more than one functional group, a seniority priority hierarchy determines which group serves as the principal functional group, which dictates the suffix name of the molecule. All other remaining functional groups are treated as secondary substituents and are designated using appropriate prefixes.

Solution:

(a) Let us analyze the structural formula provided: $CH_3 - CH(OH) - CH_2 - CO - CH_3$.

(b) This molecule contains two functional groups: a hydroxyl group ($-OH$) attached to the second carbon from the left, and a carbonyl ketone group ($-CO-$) positioned along the chain.

(c) According to the IUPAC priority rules, a ketone carbonyl group has a higher nomenclatural priority than a hydroxyl group. Therefore, the ketone serves as the principal functional group, assigning the suffix "-one" to the root name, while the hydroxyl group is designated as a "hydroxy" prefix.

(d) Next, we select the longest continuous carbon chain containing both functional groups. This chain consists of 5 carbon atoms, which corresponds to the parent alkane name "pentane".

(e) We number the carbon chain from right to left to give the principal ketone carbonyl carbon the lowest possible locant number:

- C – 1 is the methyl carbon on the far right.
- C – 2 is the carbonyl ketone carbon.
- C – 3 is the central methylene carbon.
- C – 4 is the carbon bearing the secondary hydroxyl substituent.
- C – 5 is the terminal methyl carbon on the far left.

(f) Combining these components places the "hydroxy" prefix at position 4 and the "one" suffix at position 2, giving the name 4-hydroxypentan-2-one.

Final Answer: The IUPAC name of the organic compound is 4-Hydroxypentan-2-one.

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept:

Conformational isomerism describes the distinct spatial arrangements of atoms that arise from the rotation of a covalent bond about a single σ-axis. For an ethane molecule, these structures are typically analyzed using Newman projections looking directly down the carbon-carbon bond axis. The relative stability of these different conformations is governed by torsional strain, which is caused by electrostatic repulsions between electron pairs in adjacent bonding orbitals.

Solution:

(a) The provided TikZ diagram shows a Newman projection of an ethane molecule. In this drawing, the central intersection represents the front carbon, while the larger outer circle represents the back carbon atom.

(b) Let us examine the relative angular positioning of the hydrogen atoms attached to the front and back carbons. The front hydrogen atoms are rotated exactly 60° relative to the back hydrogen atoms.

(c) This specific geometry, where the dihedral angle between adjacent C-H bonds is exactly 60°, is known as the staggered conformation of ethane.

(d) In this staggered arrangement, the hydrogen atoms and their localized covalent bonding electron clouds are positioned as far apart from each other as possible in three-dimensional space.

(e) This maximum separation minimizes the destabilizing electronic repulsions and torsional strain between the adjacent bonds. As a result, the staggered conformation occupies a potential energy minimum.

(f) This low potential energy state makes the staggered conformation the most stable conformation of ethane, unlike the eclipsed conformation where aligned bonds maximize torsional strain.

Final Answer: The structure represents the Staggered conformation, maximum stability.

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:

Benzene is a cyclic, planar aromatic hydrocarbon with a closed loop of continuously overlapping p-orbitals containing 6 π-electrons. This architecture satisfies Hückel's criteria for aromaticity ($4n + 2 = 6$ for $n = 1$). This continuous cyclic delocalization provides significant energetic stabilization, known as resonance energy or delocalization energy, which makes benzene far more stable than a hypothetical localized alkene.

Solution:

(a) Structurally, benzene consists of a ring of six carbon atoms, each participating in a delocalized π-system rather than alternating isolated double and single bonds.

(b) Typical alkenes readily undergo electrophilic addition reactions across their localized double bonds because breaking a π-bond requires relatively little energy and produces stable saturated compounds.

(c) If a benzene ring were to undergo a standard addition reaction, two new single covalent bonds would form, but this would disrupt the continuous cyclic loop of overlapping p-orbitals.

(d) Breaking this continuous conjugation destroys the aromatic circuit, costing the system its large resonance stabilization energy (approximately 152 kJ/mol).

(e) Because losing this delocalization energy creates an immense thermodynamic barrier, benzene resists addition reactions. Instead, it prefers electrophilic aromatic substitution reactions.

(f) Substitution allows the benzene ring to undergo chemical modification while preserving the intact π-cloud and retaining its high resonance stabilization energy.

Final Answer: The exceptional stability is due to its large Resonance/Delocalization energy.

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:

Writing the chemical formulas of coordination compounds follows strict IUPAC rules. The coordination sphere containing the central transition metal atom and its directly coordinated ligands is enclosed inside square brackets. The counter ions are listed outside these brackets to balance the net electrical charge of the complex. The stoichiometry of the counter ions is determined by matching their charge with the net oxidation state of the central metal ion.

Solution:

(a) Let us break down the systematic name provided: Potassium trioxalatochromate(III).

(b) The central transition metal ion is chromium, indicated by the root name. The "ate" suffix added to the metal name shows that the coordination sphere carries a net negative charge, making it an anionic complex. The Roman numeral (III) specifies that the oxidation state of the chromium atom is +3.

(c) The ligand is "trioxalato", which indicates the presence of three oxalato ($C_2O_4^{2-}$) ligands. The oxalato group is a bidentate ligand, and each carries a charge of -2.

(d) We calculate the net electrical charge (q) of the coordination sphere by summing the charges of the metal ion and the ligands:

$$q = (\text{Oxidation state of Cr}) + 3 \times (\text{Charge of oxalato})$$

(e) Substituting the values gives: $q = (+3) + 3(-2) = 3 - 6 = -3$. This shows that the coordination sphere forms a trivalent anion represented by $[Cr(C_2O_4)_3]^{3-}$.

(f) Potassium (K^+) serves as the counter cation, carrying a +1 charge. To achieve electrical neutrality, exactly three potassium cations are required to balance the -3 charge of the complex anion, giving the formula $K_3[Cr(C_2O_4)_3]$.

Final Answer: The structural formula is written as $K_3[Cr(C_2O_4)_3]$.

Answer: (C)

Go Back to Question 28

Q29.

Solution

Concept:

Tollens' reagent is a mild chemical oxidizing agent consisting of an aqueous solution of silver ammonium nitrate, represented as $[Ag(NH_3)_2]^+$. This test is used to distinguish between aldehydes and ketones. Because aldehydes are easily oxidized to carboxylic acids, they reduce the silver complex in Tollens' reagent to metallic silver, which deposits on the inner wall of the reaction vessel to form a reflective silver mirror.

Solution:

(a) Let us analyze the structural characteristics and functional groups of each given organic compound option:

- Option (A) is propanone ($CH_3 - CO - CH_3$), which is a ketone. Ketones lack an oxidizable hydrogen atom directly bonded to the carbonyl carbon, making them unreactive toward mild oxidizing agents like Tollens' reagent.
- Option (C) is an ether ($CH_3 - CH_2 - O - CH_3$), and Option (D) is propanoic acid ($CH_3 - CH_2 - COOH$). Neither ethers nor carboxylic acids possess reducing properties under standard test conditions.
- Option (B) is propanal ($CH_3 - CH_2 - CHO$), which contains a classic aldehyde functional group ($-CHO$).

(b) The carbonyl carbon of an aldehyde retains a single hydrogen atom. This C-H bond is easily oxidized, allowing aldehydes to act as strong reducing agents.

(c) When propanal is treated with Tollens' reagent, the aldehyde undergoes oxidation to form a propanoate carboxylate ion, while the silver ions are simultaneously reduced:

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

(d) This precipitate forms the characteristic silver mirror, confirming a positive test.

Final Answer: The compound that will give a positive test is $CH_3 - CH_2 - CHO$.

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept:

Structural isomerism in coordination chemistry describes compounds that share an identical chemical formula but differ in the specific connectivity of their constituent atoms or ligands around the central transition metal ion. Ionization isomerism occurs when a coordination compound can exchange a ligand directly bonded to the central metal within the inner coordination sphere with an uncoordinated counter ion located in the outer sphere.

Solution:

(a) Let us examine the chemical formulas of the two coordination compounds provided: $[Co(NH_3)_5SO_4]Br$ and $[Co(NH_3)_5Br]SO_4$.

(b) Both complexes contain exactly one Cobalt atom, five ammonia ligands, one sulfate group, and one bromine atom, confirming they are structural isomers.

(c) In the first compound, $[Co(NH_3)_5SO_4]Br$, the sulfate group is directly bound to the cobalt center as an inner-sphere ligand, while the bromide ion acts as the outer-sphere counter ion. Dissolving this salt in water releases free bromide ions (Br^-).

(d) In the second compound, $[Co(NH_3)_5Br]SO_4$, the positions are reversed. The bromide ion is now an inner-sphere ligand, and the sulfate group acts as the outer-sphere counter ion. Dissolving this salt in water releases free sulfate ions (SO_4^{2-}).

(e) Because these two isomers produce entirely different ions when dissolved in an aqueous solution, they can be distinguished using standard precipitation tests.

(f) This specific form of structural isomerism, driven by the exchange of ions between the inner coordination sphere and the outer ionization sphere, is known as ionization isomerism.

Final Answer: The type of isomerism exhibited is Ionization isomerism.

Answer: (C)

Go Back to Question 30

Q31.

Solution

Concept:

Hydrolysis reactions involve the chemical breakdown of a compound due to its reaction with water. Calcium carbide is an industrial solid-state chemical consisting of calcium cations and acetylide anions. When exposed to protic solvents like water, the strongly basic acetylide ions undergo rapid protonation steps to yield a corresponding gaseous unsaturated hydrocarbon compound and calcium hydroxide as a byproduct.

Solution:

(a) Calcium carbide is represented by the empirical chemical formula CaC_2, containing the ionic carbide or acetylide unit ($[C \equiv C]^{2-}$).

(b) When water is added directly to solid calcium carbide, a vigorous exothermic reaction occurs at room temperature.

(c) Each acetylide ion abstracts two protons from two separate water molecules to neutralize its negative electrical charge.

(d) The balanced chemical equation describing this industrial preparation method is written as:

$$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$$

(e) The resulting gaseous hydrocarbon byproduct, C_2H_2, contains a carbon-carbon triple bond and belongs to the alkyne homologous series.

(f) The systematic IUPAC name for this gaseous product is ethyne, while its globally recognized common name is acetylene. This gas is widely used in industrial oxy-acetylene welding torches due to its high combustion temperature.

Final Answer: The gaseous hydrocarbon produced is Acetylene.

Answer: (D)

Go Back to Question 31

Q32.

Solution

Concept:

The magnetic behavior of transition metal coordination complexes and isolated ions depends heavily on the total number of unpaired electrons residing within their valence subshells. According to the spin-only formula, the magnetic moment increases monotonically with the quantity of unpaired spins. To determine the maximum magnetic moment, one must maximize the number of unpaired electrons using Hund's rule of maximum multiplicity.

Solution:

(a) The spin-only magnetic moment (μ_s) is quantitatively calculated using the mathematical relationship: $\mu_s = \sqrt{n(n+2)}$ Bohr Magnetons (BM), where n represents the total number of unpaired electrons.

(b) Based on this formula, a higher count of unpaired valence electrons (n) directly produces a larger spin-only magnetic moment value.

(c) Let us evaluate the exact count of unpaired electrons for each given $3d$ subshell configuration using Hund's rule:

- For $3d^3$: The 3 electrons enter separate orbitals with parallel spins, giving $n = 3$.
- For $3d^5$: All 5 orbitals are half-filled with parallel spins, giving $n = 5$.
- For $3d^6$: One orbital is paired and 4 are half-filled, giving $n = 4$.
- For $3d^7$: Two orbitals are paired and 3 are half-filled, giving $n = 3$.

(d) The $3d^5$ configuration possesses the maximum possible number of unpaired electrons ($n = 5$) for a d-subshell.

(e) Substituting $n = 5$ into the spin-only equation yields: $\mu_s = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92\,\text{BM}$. This represents the highest achievable magnetic moment among the choices.

Final Answer: The configuration that shows the maximum value is $3d^5$.

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:

Covalent bond cleavage can occur via two primary pathways: homolytic or heterolytic fission. Homolytic cleavage involves an equal split where each atom retains one electron, forming free radicals. Conversely, heterolytic cleavage is an asymmetrical process driven by differences in electronegativity or solvent stabilization, where one atom retains both electrons from the shared pair, generating ions.

Solution:

(a) A covalent bond is formed by the sharing of an electron pair between two bonded atoms, represented generally as A – B.

(b) The prompt specifies that the cleavage is heterolytic and permanent, meaning the shared pair of bonding electrons is completely retained by one of the atoms.

(c) We can express this asymmetrical bond breaking process using curly arrow notation:

$$A - B \rightarrow A^{+} + : B^{-}$$

(d) The less electronegative atom (A) loses its valence electron entirely, which leaves it with a net positive charge and transforms it into a carbocation if the center is carbon.

(e) The more electronegative atom (B) captures both electrons from the broken bond, gaining a lone pair and a net negative charge, transforming it into a carbanion if the center is carbon.

(f) Therefore, heterolytic cleavage of a covalent bond prevents the formation of neutral free radicals. Instead, it directly leads to the simultaneous generation of distinct cationic and anionic chemical intermediates.

Final Answer: The cleavage results in the formation of Carbocations and Carbanions.

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

Crystal Field Theory (CFT) explains how the five degenerate d-orbitals of a transition metal split into distinct energy levels when surrounded by an electrostatic field of ligands. In an octahedral ligand field, the orbitals split into a lower-energy triplet (t_{2g}) and a higher-energy doublet (e_g). The electron distribution among these levels depends on whether the ligand is a weak-field or strong-field donor.

Solution:

(a) In the coordination complex $[Fe(H_2O)_6]^{2+}$, the iron center is surrounded by six aqua ligands, establishing an octahedral geometric arrangement.

(b) The central iron atom exhibits an oxidation state of +2. The ground-state configuration of neutral iron is $[Ar]3d^6 4s^2$, so the Fe^{2+} cation has a $3d^6$ configuration.

(c) Water (H_2O) is classified as a weak-field ligand in the spectrochemical series. It produces a small crystal field splitting energy (Δ_o) that cannot overcome the electron pairing energy (P).

(d) Because $\Delta_o < P$, the complex adopts a high-spin state. Electrons will preferentially occupy higher-energy orbitals rather than pairing up prematurely in lower ones.

(e) We distribute the 6 valence electrons across the split octahedral levels according to Hund's rule:

- First, 3 electrons fill the lower t_{2g} triplet individually: $(t_{2g})^3$.
- Next, 2 electrons move up to fill the higher e_g doublet individually: $(e_g)^2$.
- The final 6th electron must pair up in a t_{2g} orbital, yielding: $(t_{2g})^4(e_g)^2$.

(f) Counting the single electrons shows 2 paired and 4 unpaired d-electrons remaining in the complex.

Final Answer: The arrangement and number of unpaired electrons are Octahedral, 4.

Answer: (B)

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Q35.

Solution

Concept:

The global nitrogen cycle consists of several distinct biological and chemical transformations mediated by specific communities of soil microorganisms. While nitrogen gas (N_2) is abundant in the atmosphere, it is chemically inert due to its strong triple bond and cannot be directly assimilated by plants. Converting this inert gas into bioavailable forms is essential for sustaining primary productivity in ecosystems.

Solution:

(a) The process described involves breaking the exceptionally strong chemical triple bond ($N \equiv N$) of atmospheric nitrogen gas to convert it into reactive chemical compounds.

(b) Soil microorganisms, such as free-living *Azotobacter* or symbiotic *Rhizobium* bacteria associated with legumes, use the nitrogenase enzyme complex to drive this reduction.

(c) This biological conversion of gaseous atmospheric nitrogen into plant-available forms like ammonium (NH_4^+) or nitrates (NO_3^-) is ecologically classified as nitrogen fixation.

(d) Let us review the other terms to avoid confusion:

- Nitrification is the biochemical oxidation of ammonium ions into nitrite and subsequently into nitrate.
- Denitrification is the reduction of nitrates back into gaseous nitrogen, closing the cycle.
- Ammonification is the decomposition of organic nitrogenous waste from dead matter into ammonia.

(e) Thus, the initial assimilation of atmospheric gas into the soil ecosystem is strictly defined as nitrogen fixation.

Final Answer: The process is ecologically classified as Nitrogen fixation.

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept:

A developed soil profile consists of parallel vertical layers called master horizons, each defined by distinct physical and chemical characteristics. These horizons form via pedogenic processes such as leaching, accumulation, and organic decomposition. The upper zones are shaped by downward water movement, which strips away soluble materials and redeposits them in lower layers.

Solution:

(a) Let us analyze the cross-sectional soil profile provided in the TikZ schematic diagram from top to bottom:

- The O Horizon is the uppermost layer, composed primarily of organic litter.
- The A Horizon is the topsoil layer, rich in humified organic matter blended with mineral components.
- The E Horizon is a light-colored mineral layer positioned beneath the A horizon.

(b) The letter "E" stands for eluvation, which describes the systematic leaching of mobile constituents out of a soil layer.

(c) As net rainfall percolates downward through the upper horizons, it dissolves and carries away silicate clay, iron, and aluminum oxides.

(d) This intense leaching strips the E horizon of its coloring agents, leaving behind a bleached, sand- and silt-rich matrix dominated by resistant quartz.

(e) These eluviated materials accumulate further down in the B Horizon, which is the zone of maximum illuvation. Therefore, the E horizon is the master zone of maximum eluvation.

Final Answer: The master horizon labeled is E Horizon.

Answer: (B)

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Q37.

Solution

Concept:

Plant micronutrients are essential elements required in trace amounts to regulate metabolic, enzymatic, and physiological processes. While they do not serve as primary structural elements like macronutrients, they act as indispensable cofactors or structural activators for specific enzymes. A deficiency in any key micronutrient can disrupt biochemical pathways and impair plant hormone synthesis.

Solution:

(a) The micronutrient specified in the prompt plays a dual role: it regulates biochemical growth regulators and activates metallic enzymes.

(b) Zinc (Zn) is an essential micronutrient absorbed by plants as the divalent cation Zn^{2+}.

(c) Zinc acts as a vital structural component and activator for several key enzymes, including carbonic anhydrase, alcohol dehydrogenase, and various carboxypeptidases.

(d) Carbonic anhydrase catalyzes the reversible hydration of carbon dioxide ($CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$), which is crucial for maintaining photosynthetic efficiency in guard cells.

(e) Furthermore, zinc is involved in biosynthesis pathways for indole-3-acetic acid (IAA), the primary naturally occurring auxin hormone in plants. It acts as a cofactor for enzymes that convert tryptophan to IAA.

(f) A zinc deficiency leads to stunted growth, shortened internodes (rosetting), and small leaves due to disrupted auxin production, confirming its unique biological role.

Final Answer: The essential plant micronutrient is Zinc (Zn).

Answer: (B)

Go Back to Question 37

Q38.

Solution

Concept:

Soil degradation occurs through various chemical processes, including acidification, salinization, and sodication. Sodic or alkali soils are characterized by a high exchangeable sodium percentage (ESP), which degrades soil structure. Reclaiming these degraded soils requires adding chemical amendments that supply divalent calcium ions to displace the harmful monovalent sodium ions from the clay exchange complex.

Solution:

(a) Sodic or alkali soils contain high concentrations of exchangeable sodium ions (Na^+) bound to clay particles. This causes clay dispersion, collapses soil aggregates, destroys soil structure, and reduces water permeability.

(b) Agricultural gypsum is hydrated calcium sulfate, represented by the chemical formula $CaSO_4 \cdot 2H_2O$.

(c) When gypsum is applied to sodic soils, it dissolves in the soil solution to release free calcium cations (Ca^{2+}) and sulfate anions (SO_4^{2-}).

(d) Flocculation occurs as the divalent calcium ions displace the monovalent sodium ions from the negative exchange sites on the clay particles via cation exchange:

$$2Na^-[Clay] + CaSO_4 \rightarrow Ca^{2-}[Clay] + Na_2SO_4$$

(e) The displaced sodium ions react with the sulfate anions to form sodium sulfate (Na_2SO_4), a highly soluble salt that can be safely leached down into the lower water table.

(f) Replacing sodium with calcium restores soil aggregation, improves water infiltration, and successfully reclaims sodic/alkali soils.

Final Answer: Gypsum is recommended for amending Sodic/Alkali soils.

Answer: (B)

Go Back to Question 38

Q39.

Solution

Concept:

Silicate clay minerals are crystalline aluminosilicates composed of repeating sheets of coordinate sub-units. These structures feature two primary structural units: silicon-oxygen tetrahedra and aluminum-oxygen/hydroxyl octahedra. The classification of these clay minerals (such as 1:1 or 2:1 types) depends on how these tetrahedral silica sheets and octahedral alumina sheets are stacked to form individual crystalline layers.

Solution:

(a) Montmorillonite is a primary representative of the smectite group, which is classified as an expanding 2:1 type silicate clay mineral.

(b) The designation "2:1" describes the structural stacking pattern of the individual crystal sheets that make up a single layer.

(c) In a 2:1 clay mineral, each individual layer consists of one central octahedral alumina sheet sandwiched securely between two outer tetrahedral silica sheets.

(d) Let us look at the structure of these sheets:

- The silica sheets consist of silicon atoms coordinated tetrahedrally with four oxygen atoms.
- The alumina sheet consists of aluminum atoms coordinated octahedrally with six oxygen atoms or hydroxyl groups.

(e) This 2:1 sandwich structure exposes oxygen atoms on both outer faces of the layer. This creates weak van der Waals forces between adjacent layers, allowing water molecules to enter and causing the characteristic swelling behavior of montmorillonite clay.

Final Answer: The fundamental units comprise Two silica sheets and one alumina sheet.

Answer: (B)

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Q40.

Solution

Concept:

Chemical nitrogen fertilizers are classified based on the chemical form of their nitrogen content, such as ammoniacal, nitrate, or amide forms. Amide fertilizers are unique because their nitrogen is bound in an organic molecular structure rather than as inorganic salts. Once applied to the soil, these organic compounds must undergo microbial enzymatic transformations to convert the nitrogen into inorganic forms that plants can assimilate.

Solution:

(a) Urea is represented by the chemical formula $CO(NH_2)_2$. Because it contains carbon-nitrogen covalent bonds, it is classified as a concentrated organic amide nitrogen fertilizer, containing roughly 46% total nitrogen by mass.

(b) Unlike inorganic salts such as ammonium sulfate or calcium ammonium nitrate, the amide nitrogen in urea cannot be directly absorbed by plant root systems.

(c) When urea is applied to agricultural soil, it dissolves in the soil moisture and undergoes rapid enzymatic hydrolysis. This reaction is catalyzed by the widespread soil enzyme urease, which is secreted by soil microbes.

(d) The chemical hydrolysis reaction converts the dissolved urea into an intermediate compound, ammonium carbonate:

$$CO(NH_2)_2 + 2H_2O \xrightarrow{\text{Urease}} (NH_4)_2CO_3$$

(e) The resulting ammonium carbonate is unstable and quickly dissociates into ammonium ions (NH_4^+), bicarbonate ions, and hydroxyl ions, making the nitrogen available for plant uptake or subsequent nitrification.

Final Answer: The chemical fertilizer classified is Urea.

Answer: (B)

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Answer Key

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