Rajasthan JET Chemistry Sample Paper-4

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

Instructions

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

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

(A) $n = 3, l = 2, m_l = -2, m_s = +\frac{1}{2}$

(B) $n = 4, l = 0, m_l = 0, m_s = -\frac{1}{2}$

(C) $n = 3, l = 3, m_l = -1, m_s = +\frac{1}{2}$

(D) $n = 2, l = 1, m_l = 0, m_s = -\frac{1}{2}$

Q2. The total number of solitary pairs (lone pairs) of electrons on the central atom in a XeF_4 molecule is:

(A) 1

(B) 2

(C) 3

(D) 4

Q3. For a first-order reaction, if the initial concentration of the reactant is doubled, the half-life period ($t_{1/2}$) of the reaction will:

(A) Become doubled

(B) Become halved

(C) Remain unchanged

(D) Become four times

Q4. The IUPAC name of the coordination compound $[Co(NH_3)_5(CO_3)]Cl$ is:

(A) Pentaamminecarbonatocobalt(III) chloride

(B) Carbonatopentaamminecobalt(III) chloride

(C) Pentaamminecarbonatocobalt(II) chloride

(D) Pentaamminecobalt(III) carbonate chloride

Q5. Which soil component has the highest cation exchange capacity (CEC)?

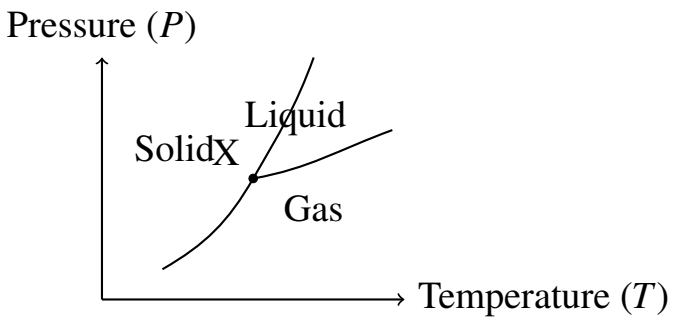
(A) Kaolinite clay

(B) Illite clay

(C) Montmorillonite clay

(D) Organic matter (Humus)

Q6. Consider the following phase diagram schematic for a one-component system. What state of matter or transition is represented by the triple point?



Point X in the TikZ schematic above represents:

(A) Critical temperature where gas cannot be liquefied

(B) Boiling point at standard atmospheric pressure

(C) Coexistence of solid, liquid, and vapor phases in equilibrium

(D) Sublimation point where solid turns directly to gas

Q7. The oxidation state of Chromium in $K_2Cr_2O_7$ is:

(A) +3

(B) +4

(C) +5

(D) +6

Q8. Which of the following elements has the highest negative electron gain enthalpy value?

(A) Fluorine

(B) Chlorine

(C) Bromine

(D) Iodine

Q9. At a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the surface of the liquid. This law is known as:

(A) Raoult's Law

(B) Henry's Law

(C) Dalton's Law

(D) Boyle's Law

Q10. The major product obtained when propene reacts with HBr in the presence of organic peroxides is:

(A) 2-Bromopropane

(B) 1-Bromopropane

(C) 1,2-Dibromopropane

(D) 2-Bromopropan-2-ol

Q11. Which type of fertilizer is classified as a micro-nutrient fertilizer for essential plant growth?

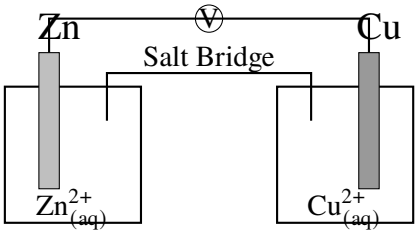
(A) Urea

(B) Zinc sulphate

(C) Single Super Phosphate

(D) Muriate of Potash

Q12. A electrochemical cell setup is illustrated below. Identify the direction of electron flow in the external circuit under standard conditions.



According to the cell diagram, electrons flow:

(A) From copper electrode to zinc electrode via the external wire

(B) From zinc electrode to copper electrode via the external wire

(C) From zinc beaker to copper beaker through the salt bridge

(D) From copper beaker to zinc beaker through the salt bridge

Q13. The hybridization of carbon atoms in ethyne (C_2H_2) is:

(A) sp^3

(B) sp^2

(C) sp

(D) dsp^2

Q14. According to the de Broglie relationship, the wavelength (λ) associated with a moving particle of mass m and velocity v is given by:

(A) $\lambda = \frac{h}{mv}$

(B) $\lambda = \frac{mv}{h}$

(C) $\lambda = hmv$

(D) $\lambda = \frac{E}{c^2}$

Q15. For the reversible reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, the relationship between K_p and K_c is expressed as:

(A) $K_p = K_c(RT)$

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

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

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

Q16. Which of the following organic compounds will show positive Tollens' test?

(A) Propanone

(B) Ethanal

(C) Ethanol

(D) Diethyl ether

Q17. The primary cause of temporary hardness in water is the presence of:

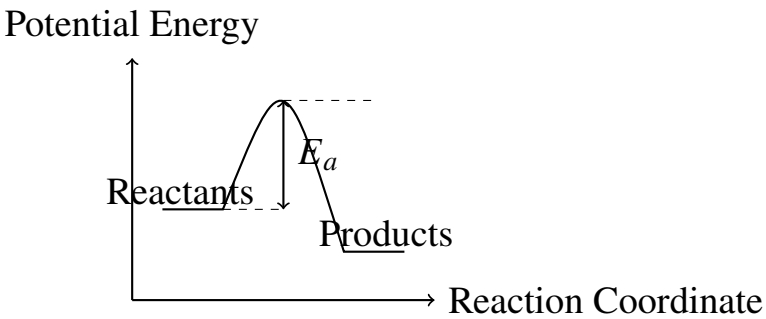
(A) Chlorides of Calcium and Magnesium

(B) Sulphates of Calcium and Magnesium

(C) Bicarbonates of Calcium and Magnesium

(D) Nitrates of Sodium and Potassium

Q18. An energy profile diagram for an exothermic chemical reaction is shown below. What does the interval labeled 'E_a' indicate?



The quantity E_a shown in the schematic graph represents:

(A) Enthalpy of reaction (ΔH)

(B) Activation energy of the forward reaction

(C) Total internal energy of the system

(D) Activation energy of the reverse reaction

Q19. The pair of molecules showing identical shape according to VSEPR theory is:

(A) CO_2 and SO_2

(B) BF_3 and NH_3

(C) CH_4 and SF_4 $BeCl_2$ and CO_2

Q20. Which of the following configuration states represents an element with the highest second ionization enthalpy?

(A) $1s^2 2s^2 2p^6 3s^1$

(B) $1s^2 2s^2 2p^6 3s^2$

(C) $1s^2 2s^2 2p^5$

(D) $1s^2 2s^2 2p^6$

Q21. The pH of a 1.0×10^{-3} M aqueous solution of NaOH at 298 K is:

(A) 3

(B) 11

(C) 7

(D) 14

Q22. How many structural isomers are possible for the alkane with molecular formula C_5H_{12}?

(A) 2

(B) 3

(C) 4

(D) 5

Q23. Which of the following organic functional groups contains a carbonyl group linked directly to a hydroxyl unit?

(A) Ester

(B) Aldehyde

(C) Carboxylic acid

(D) Alcohol

Q24. Black soil (Regur soil) in India is extensively derived from the weathering of which type of parent rock material?

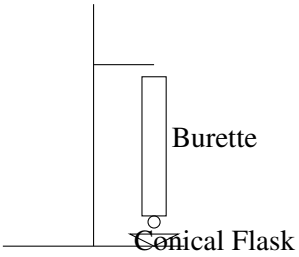
(A) Basaltic lava rocks

(B) Granite rocks

(C) Limestone rocks

(D) Sandstone rocks

Q25. A titration setup is assembled as shown below to determine the strength of an acid solution using a standard base. What point represents the neutralization target where the indicator changes color?



The precise stage during this procedure where stoichiometrically equivalent amounts of acid and base have reacted is called:

(A) Initial point

(B) Saturation point

(C) Equivalence point

(D) Decomposition point

Q26. Which property among the following is an intensive thermodynamic property?

(A) Mass

(B) Volume

(C) Total Enthalpy

(D) Density

Q27. According to the ideal gas equation, the value of the universal gas constant (R) in SI units (J K^{-1} mol^{-1}) is closest to:

(A) 0.0821

(B) 8.314

(C) 1.987

(D) 62.36

Q28. In which of the following species does the central atom show dsp^2 hybridization and possess a square planar geometry?

(A) $[NiCl_4]^{2-}$

(B) $[Ni(CN)_4]^{2-}$

(C) $[FeCl_4]^{-}$

(D) $[CoF_6]^{3-}$

Q29. The principal organic product formed when benzene reacts with methyl chloride in the presence of anhydrous $AlCl_3$ is:

(A) Chlorobenzene

(B) Toluene

(C) Nitrobenzene

(D) Benzyl chloride

Q30. Which chemical compound is widely applied as a soil amendment to reclaim highly alkaline (sodic) soils?

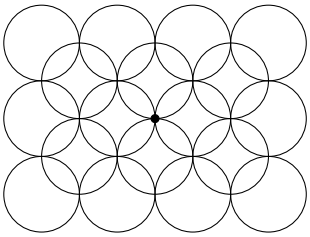
(A) Calcium carbonate (Limestone)

(B) Calcium sulphate dihydrate (Gypsum)

(C) Ammonium sulphate

(D) Sodium chloride

Q31. Consider the close packing of spheres in a two-dimensional layer shown below. What is the coordination number of any sphere inside this lattice?



The coordination number of a sphere in this standard hexagonal close-packed layer configuration is:

(A) 4

(B) 6

(C) 8

(D) 12

Q32. The equivalent conductance of an electrolytic solution generally increases with dilution because:

(A) The degree of dissociation increases

(B) The total number of ions per unit volume increases

(C) The ionic mobility decreases due to hydration

(D) The attractive forces between opposing ions increase

Q33. The number of atoms present per primitive simple cubic unit cell of a pure crystalline monoatomic element is:

(A) 1

(B) 2

(C) 4

(D) 8

Q34. Which of the following organic intermediates is structurally planar and possesses six valence electrons around the central positive carbon atom?

(A) Carbanion

(B) Carbon free radical

(C) Carbocation

(D) Carbene

Q35. The linkage isomerism is exhibited by coordination complexes containing which type of ligands?

(A) Chelate ligands

(B) Ambidentate ligands

(C) Unidentate neutral ligands

(D) Macrocyclic ligands

Q36. The plant macro-nutrient essential for activation of enzymes, sustaining osmotic balance, and regulating stomatal opening and closing is:

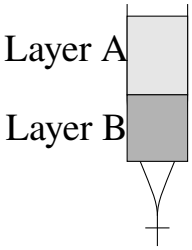
(A) Phosphorus (P)

(B) Nitrogen (N)

(C) Potassium (K)

(D) Magnesium (Mg)

Q37. A standard liquid-liquid extraction setup using a separating funnel is demonstrated. Which layer will be situated at the bottom if chloroform ($CHCl_3$, density ≈ 1.49 g/cm^3) and water (H_2O, density ≈ 1.00 g/cm^3) are shaken together?



According to the densities of the two immiscible solvent components, Layer B at the bottom will be:

(A) The aqueous layer containing water

(B) The organic layer containing chloroform

(C) A perfectly homogeneous mixed phase

(D) Gaseous component phase

Q38. What is the total number of σ (sigma) and π (pi) bonds present in a single molecule of benzene (C_6H_6)?

(A) 6 σ and 3 π

(B) 12 σ and 3 π

(C) 9 σ and 3 π

(D) 12 σ and 6 π

Q39. The oxidation reaction of an organic compound involves:

(A) Addition of hydrogen or loss of oxygen

(B) Addition of oxygen or loss of hydrogen

(C) Gain of electrons by the chemical species

(D) Decrease in the positive oxidation state

Q40. The major structural silicate clay mineral characteristic of expansive black soils that exhibits substantial swelling upon wetting and shrinking upon drying is:

(A) Illite

(B) Kaolinite

(C) Montmorillonite

(D) Chlorite

Detailed Solutions

Q1.

Solution

Concept: Quantum numbers describe the energy levels, shapes, orientations, and spins of atomic orbitals and their electrons. For any valid orbital configuration, the values must strictly satisfy the predefined bounds: the principal quantum number $n \geq 1$, the azimuthal number $0 \leq l \leq n-1$, the magnetic orbital constraint $-l \leq m_l \leq +l$, and the electron spin component $m_s = \pm\frac{1}{2}$.

Solution:

(a) Evaluating the constraints for option (A) yields $n = 3$, an allowed azimuthal index $l = 2$, a valid orientation parameter $m_l = -2$, and an acceptable spin state $m_s = +\frac{1}{2}$.

(b) Evaluating option (B) reveals a principal energy level $n = 4$, an orbital momentum value $l = 0$ for an s-subshell, a legal projection index $m_l = 0$, and a valid spin orientation $m_s = -\frac{1}{2}$.

(c) Analyzing option (C) presents a case where $n = 3$ and $l = 3$. This configuration violates the fundamental physical rule requiring the azimuthal quantum number l to be strictly less than n ($l \leq n-1$).

(d) Inspecting option (D) shows a ground configuration where $n = 2$, $l = 1$ for a p-subshell, a permitted value $m_l = 0$, and a correct spin parameter $m_s = -\frac{1}{2}$.

Final Answer: The configuration state is $n = 3, l = 3, m_l = -1, m_s = +\frac{1}{2}$.

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept: The number of lone pairs on a central atom within a molecular structure can be determined using Valence Shell Electron Pair Repulsion (VSEPR) theory. The valence shell contains localized bonding domains alongside unshared lone pairs that adjust the overall molecular geometry to optimize electrostatic stability.

Solution:

(a) Xenon is a noble gas located in group 18 of the periodic table, providing exactly eight electrons in its outermost valence shell to participate in bonding.

(b) In a xenon tetrafluoride (XeF_4) molecule, the central xenon atom shares four of its valence electrons to form single covalent bonds with four peripheral fluorine atoms.

(c) Subtracting these four bonding electrons from the original eight valence electrons leaves four non-bonding valence electrons localized on the central xenon atom.

(d) Grouping these remaining unshared valence electrons into pairs ($4/2 = 2$) reveals that the central xenon atom holds exactly two lone pairs of electrons.

Final Answer: The number of lone pairs is 2.

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: The half-life period ($t_{1/2}$) of a chemical reaction represents the time required for the initial reactant concentration to decrease to exactly half of its starting value. The dependence of this kinetic parameter on the initial concentration varies based on the overall reaction order.

Solution:

(a) For an integrated first-order chemical process, the rate law expression can be mathematically resolved to separate variables and isolate the time parameter.

(b) The derived mathematical formula for a first-order half-life is expressed precisely as $t_{1/2} = \frac{\ln(2)}{k} \approx \frac{0.693}{k}$, where k is the specific reaction rate constant.

(c) Examining this explicit kinetic relationship demonstrates that the half-life depends solely on the rate constant, with no concentration variables present in the expression.

(d) Consequently, doubling, tripling, or changing the initial concentration of the reactant leaves the total half-life period completely unaffected and constant.

Final Answer: The half-life will Remain unchanged.

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: The systematic naming of coordination complexes follows formal IUPAC nomenclature rules. Ligands are listed alphabetically ahead of the central metal atom, the metal oxidation state is written in Roman numerals inside parentheses, and counter-ions follow outside the sphere.

Solution:

(a) The coordination sphere contains five neutral ammine (NH_3) ligands and one anionic carbonato (CO_3^{2-}) ligand bound directly to the central cobalt core.

(b) Ordering the ligands alphabetically establishes "pentaammine" before "carbonato," yielding the combined prefix sequence pentaamminecarbonato.

(c) Let x represent the unknown oxidation state of cobalt; balancing the total charges gives $x + 5(0) + 1(-2) + 1(-1) = 0$, which evaluates to $x = +3$.

(d) Assembling the components into a single systematic word gives pentaamminecarbonato-cobalt(III), which is followed by the separate outer-sphere chloride ion.

Final Answer: The systematic name is Pentaamminecarbonatocobalt(III) chloride.

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: Cation exchange capacity (CEC) measures the total exchangeable cations that a soil component can retain on its negatively charged surfaces. This electrochemical behavior depends heavily on the surface area, structural substitution patterns, and functional group dissociation across soil constituents.

Solution:

(a) Kaolinite clay is a 1:1 structured silicate mineral that undergoes minimal isomorphous substitution, leading to a very low exchange capacity.

(b) Illite clay is a non-expanding 2:1 silicate structure with interlayer potassium ions that limit available surface sites, producing a moderate capacity.

(c) Montmorillonite clay is an expanding 2:1 mineral featuring high internal surface area and extensive isomorphous substitution, yielding a high inorganic capacity.

(d) Organic matter (humus) contains abundant carboxyl and phenolic functional groups that deprotonate to create a very high density of negative exchange sites, surpassing all clay minerals.

Final Answer: The component is Organic matter (Humus).

Answer: (D)

Go Back to Question 5

Q6.

Solution

Concept: A phase diagram is a thermodynamic state space graph illustrating the boundaries between solid, liquid, and gaseous forms of a pure component under varying pressure and temperature conditions. The intersection lines indicate equilibrium parameters where phase changes occur.

Solution:

(a) The lines plotted on a phase diagram describe two-phase equilibrium curves, such as the sublimation curve, the melting curve, and the vapor pressure curve.

(b) Point X marks the specific convergence vertex where these three distinct boundary curves meet at a single, unique coordinate.

(c) At this thermodynamic coordinate, the rates of interconversion among all three states of matter balance perfectly to establish mutual equilibrium.

(d) Therefore, point X represents the triple point, where the solid, liquid, and vapor phases coexist in a stable, uniform state of equilibrium.

Final Answer: The point represents the Coexistence of solid, liquid, and vapor phases in equilibrium.

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: The oxidation state of an element within a polyatomic molecule or formula unit reflects the apparent charge it carries when bonding electron pairs are allocated entirely to the more electronegative elements. The sum of these individual oxidation numbers must equal the net electrical charge of the species.

Solution:

(a) In potassium dichromate ($K_2Cr_2O_7$), potassium ions exhibit a fixed oxidation state of +1, while oxygen atoms carry an oxidation state of −2.

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

(c) Formulating a balanced algebraic expression based on the neutral compound yields: $2(+1) + 2(x) + 7(-2) = 0$.

(d) Simplifying the equation gives $2 + 2x - 14 = 0$, which reduces to $2x = 12$, and solving for the variable yields $x = +6$.

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

Answer: (D)

Go Back to Question 7

Q8.

Solution

Concept: Electron gain enthalpy ($\Delta_{eg}H$) represents the enthalpy change that occurs when an electron is added to a gaseous atom. While this value generally becomes less negative moving down a halogen group, small atomic dimensions can introduce significant electron-electron repulsions that modify this periodic trend.

Solution:

(a) Fluorine is a highly electronegative element, but its valence electrons are crowded into a very compact 2p subshell.

(b) This high electron density generates strong electrostatic repulsions that resist the introduction of an incoming electron, making its electron gain enthalpy less negative than expected.

(c) Chlorine has a larger 3p subshell that easily accommodates an extra electron with minimal repulsion, resulting in a highly exothermic electron capture process.

(a) Further down the group, bromine and iodine have larger atomic radii that weaken the attractive force of the nucleus, leading to less negative electron gain enthalpies than chlorine.

Final Answer: The element is Chlorine.

Answer: (B)

Go Back to Question 8

Q4.

Solution

Concept: The dissolution of gaseous molecules into liquid solvents is governed by gas laws that model phase equilibria. These relationships show how changing the temperature or pressure affects the concentration of dissolved gas at equilibrium.

Solution:

(a) Raoult's law describes how the vapor pressure of a solution changes based on the mole fraction of a non-volatile solute added to the liquid phase.

(b) Dalton's law states that the total pressure exerted by a mixture of non-reactive gases is equal to the sum of their individual partial pressures.

(c) Boyle's law is an ideal gas relationship showing that the volume of a gas sample varies inversely with pressure at a constant temperature.

(d) Henry's law states that the solubility of a gas in a liquid is directly proportional to the partial pressure of that gas above the liquid surface ($C = k \cdot P$).

Final Answer: The gas law is Henry's Law.

Answer: (B)

Go Back to Question 9

Q5.

Solution

Concept: The addition of hydrogen halides to unsymmetrical alkenes typically follows Markovnikov's rule. However, introducing organic peroxides changes the reaction path, initiating a radical chain mechanism that reverses the regiochemical outcome.

Solution:

(a) Without peroxides, the reaction proceeds through a carbocation intermediate, placing the bromide ion at the more substituted carbon to yield 2-bromopropane.

(b) Introducing organic peroxides leads to thermal homolysis, generating alkoxy radicals that react with HBr to produce active bromine radicals ($Br^{\bullet}$).

(c) The bromine radical attacks propene at the terminal carbon, forming a more stable secondary carbon radical intermediate.

(d) This secondary radical extracts a hydrogen atom from another HBr molecule, yielding 1-bromopropane as the major anti-Markovnikov product.

Final Answer: The product is 1-Bromopropane.

Answer: (B)

Go Back to Question 10

Q6.

Solution

Concept: Plant nutrients are classified as macro-nutrients or micro-nutrients depending on the quantitative demands required for metabolic operations. Primary and secondary macronutrients are needed in large amounts, whereas micronutrients act mainly as enzymatic cofactors in trace quantities.

Solution:

(a) Urea provides highly concentrated nitrogen, a primary macronutrient vital for structural vegetative development and chlorophyll production.

(b) Single Super Phosphate delivers phosphorus and calcium, which are essential macronutrients required for root architecture and cellular energy pathways.

(c) Muriate of Potash supplies potassium, a critical macronutrient that regulates cellular turgor, enzyme behavior, and stomatal pathways.

(d) Zinc sulphate delivers zinc ions (Zn^{2+}), an essential plant micronutrient that activates specific dehydrogenases and aids tryptophan synthesis.

Final Answer: Zinc sulphate.

Answer: (B)

Go Back to Question 11

Q7.

Solution

Concept: An electrochemical cell generates electrical current from a spontaneous redox reaction. The direction of electron migration through the external wiring depends entirely on the relative standard reduction potentials of the two coupled metallic electrodes.

Solution:

(a) The standard reduction potential for the zinc half-cell is -0.76 V, while the copper half-cell has a value of $+0.34$ V.

(b) Zinc acts as the anode because it has a more negative potential, causing it to undergo oxidation and release electrons.

(c) Copper serves as the cathode due to its more positive potential, where copper ions consume incoming electrons and undergo reduction.

(d) Electrons flow spontaneously away from the oxidized zinc anode toward the reduced copper cathode via the external wire circuit.

Final Answer: From zinc electrode to copper electrode via the external wire.

Answer: (B)

Go Back to Question 12

Q8.

Solution

Concept: Orbital hybridization models how valence atomic orbitals mix to produce equivalent hybrid orbitals optimized for covalent bonding. The geometry around a carbon atom is determined by the total number of localized σ-bonds and unshared electron pairs.

Solution:

(a) Ethyne (C_2H_2) features a linear molecular structure where the two central carbon atoms are linked by a triple bond.

(b) Each carbon atom forms one σ-bond with a hydrogen atom and one σ-bond with the adjacent carbon atom.

(c) The remaining two orbital overlaps create a pair of mutual π-bonds, which are not included in the hybridization count.

(d) Blending one s-orbital and one p-orbital creates two linear hybrid orbitals, assigning each carbon an sp hybridization state.

Final Answer: sp

Answer: (C)

Go Back to Question 13

Q9.

Solution

Concept: The de Broglie hypothesis extends wave-particle duality from light to all moving material particles. It relates the geometric wavelength of a matter wave to the mechanical momentum of the moving particle through Planck's constant.

Solution:

(a) Quantum mechanics treats every moving mass as a wave packet that travels through space with a characteristic wavelength.

(b) The momentum of a moving body is defined as the product of its mass (m) and linear velocity (v).

(c) The de Broglie hypothesis states that this matter wavelength is inversely proportional to the particle's linear momentum.

(d) Introducing Planck's constant (h) as the proportionality factor yields the exact mathematical equation: $\lambda = \frac{h}{mv}$.

Final Answer: $\lambda = \frac{h}{mv}$

Answer: (A)

Go Back to Question 14

Q10.

Solution

Concept: The equilibrium state of a gas-phase reaction can be expressed using either partial pressures (K_p) or molar concentrations (K_c). These constants are related by the ideal gas law, adjusted for the net change in gas molecules.

Solution:

(a) The mathematical relation connecting these gas-phase equilibrium constants is written as $K_p = K_c(RT)^{\Delta n_g}$.

(b) The parameter Δn_g represents the total moles of gaseous products minus the total moles of gaseous reactants.

(c) For the synthesis of ammonia, subtracting the reactant coefficients from the product coefficients gives $\Delta n_g = 2 - (1 + 3) = -2$.

(d) Substituting this value into the equation yields the final relationship for the system: $K_p = K_c(RT)^{-2}$.

Final Answer: $K_p = K_c(RT)^{-2}$

Answer: (C)

Go Back to Question 15

Q11.

Solution

Concept: Tollens' test uses an ammoniacal silver nitrate solution to differentiate between functional groups based on their reducing strength. A positive result is indicated by the formation of a reflective silver mirror on the reaction vessel walls.

Solution:

(a) Alcohols like ethanol and ethers like diethyl ether lack the carbonyl structure needed to reduce the Tollens' reagent.

(b) Ketones like propanone contain a carbonyl group but lack a reactive hydrogen atom, making them resistant to mild oxidation.

(c) Aldehydes possess a highly reactive hydrogen atom attached directly to the carbonyl carbon, allowing them to be oxidized easily.

(d) Ethanal reduces the silver complexes in Tollens' reagent to metallic silver, producing a distinct positive silver mirror test.

Final Answer: Ethanal.

Answer: (B)

Go Back to Question 16

Q12.

Solution

Concept: Water hardness is caused by dissolved mineral cations that prevent soap from lathering. Hardness is classified as temporary or permanent depending on whether the dissolved salts can be removed by simple thermal boiling.

Solution:

(a) Permanent hardness is caused by dissolved chloride or sulphate salts of calcium and magnesium, which do not precipitate upon heating.

(b) Temporary hardness is caused by dissolved calcium bicarbonate and magnesium bicarbonate salts entering the water supply.

(c) Heating temporary hard water decomposes these soluble bicarbonates into insoluble carbonates like calcium carbonate.

(d) This thermal decomposition precipitates the minerals out of solution, effectively softening the water through simple boiling.

Final Answer: Bicarbonates of Calcium and Magnesium.

Answer: (C)

Go Back to Question 17

Q13.

Solution

Concept: An energy profile diagram tracks the potential energy changes of a chemical system along the reaction coordinate. Reactants must overcome a specific energy barrier to form an activated complex before turning into products.

Solution:

(a) The initial baseline on the left side of the profile curve marks the total potential energy of the starting reactants.

(b) The peak of the potential energy curve represents the transition state, where unstable chemical bonds are breaking and forming.

(c) The activation energy (E_a) is the minimum energy input required to lift the reactants up to this transition state.

(d) The vertical interval E_a measures the energy gap from the reactant baseline to the peak, representing the activation energy of the forward reaction.

Final Answer: Activation energy of the forward reaction.

Answer: (B)

Go Back to Question 18

Q14.

Solution

Concept: Valence Shell Electron Pair Repulsion (VSEPR) theory determines molecular geometry by minimizing electrostatic repulsions between electron domains. The final shape depends on the arrangement of both bonding pairs and unshared lone pairs around the central atom.

Solution:

(a) Carbon dioxide (CO_2) has two bonding domains and zero lone pairs, giving it a linear geometry with a 180° bond angle.

(b) Sulfur dioxide (SO_2) contains two bonding domains and one lone pair, which forces the molecule into a bent geometry.

(c) Beryllium chloride ($BeCl_2$) has two single bonding domains and zero lone pairs, forming a symmetric linear geometry.

(d) Comparing these structures shows that $BeCl_2$ and CO_2 both have linear shapes due to their identical electron configurations.

Final Answer: $BeCl_2$ and CO_2

Answer: (D)

Go Back to Question 19

Q15.

Solution

Concept: The second ionization enthalpy is the energy required to remove an electron from a univalent positive cation. This value increases significantly when the electron must be taken from a highly stable, completely filled noble gas core configuration.

Solution:

(a) The configuration $1s^2 2s^2 2p^6 3s^1$ represents a neutral sodium atom. Removing the first electron leaves a stable $1s^2 2s^2 2p^6$ cation.

(b) This resulting sodium cation matches the stable electronic configuration of neon, with a completely filled valence shell.

(c) Removing a second electron requires breaking this stable noble gas shell, which demands an exceptionally large energy input.

(d) Consequently, this configuration exhibits the highest second ionization enthalpy compared to elements that retain valence electrons.

Final Answer: $1s^2 2s^2 2p^6 3s^1$

Answer: (A)

Go Back to Question 20

Q16.

Solution

Concept: The pH of an aqueous solution quantifies its acidity or alkalinity on a logarithmic scale. For strong bases like sodium hydroxide (NaOH), the solute dissociates completely in water, releasing hydroxide ions (OH^-) that directly determine the hydroxide ion concentration and the corresponding pOH of the solution.

Solution:

(a) Sodium hydroxide is a strong monobasic electrolyte that undergoes full ionization, meaning a 1.0×10^{-3} M solution yields exactly 1.0×10^{-3} M of OH^- ions.

(b) The pOH value is calculated by taking the negative logarithm of the hydroxide ion molarity, expressed mathematically as $\text{pOH} = -\log[OH^-]$.

(c) Substituting the concentration value gives $\text{pOH} = -\log(1.0 \times 10^{-3}) = 3$, which represents the alkalinity level on the pOH scale.

(d) Using the fundamental water autoionization constant relationship at 298 K, where pH + pOH = 14, the final value is found by computing $\text{pH} = 14 - 3 = 11$.

Final Answer: 11

Answer: (B)

Go Back to Question 21

Q17.

Solution

Concept: Structural isomers are chemical compounds that share an identical molecular formula but differ significantly in the connectivity and arrangement of their constituent atoms. For alkanes, this variance manifests as skeletal isomerism where the carbon backbone changes from unbranched chains to branched networks.

Solution:

(a) The first structural configuration is a straight, unbranched arrangement of all five carbon units, known systematically as n-pentane.

(b) The second configuration involves shortening the main chain to four carbon atoms and adding a single methyl branch at the second position, yielding 2-methylbutane.

(c) The third configuration shortens the main chain further to three carbon atoms and places two methyl branches on the central carbon atom, yielding 2,2-dimethylpropane.

(d) Attempting any other branching variations simply duplicates these three unique carbon skeletons due to molecular symmetry, establishing that only three structural isomers exist.

Final Answer: 3

Answer: (B)

Go Back to Question 22

Q18.

Solution

Concept: Organic functional groups are classified by the specific structural arrangements of heteroatoms linked to a carbon framework. A carbonyl group consists of a carbon atom doubly bonded to an oxygen atom (C = O), which exhibits different properties depending on its neighboring substituents.

Solution:

(a) In alcohols, a simple hydroxyl unit (−OH) is attached directly to an sp^3 hybridized saturated carbon atom, lacking any adjacent carbonyl group.

(b) In aldehydes, the central carbonyl group is bonded directly to at least one terminal hydrogen atom (−CHO).

(c) In esters, the carbonyl carbon atom is bonded to an alkoxy group (−COOR), creating a distinct linkage configuration.

(d) In carboxylic acids, the carbonyl carbon is joined directly to a hydroxyl unit, forming the characteristic carboxyl group (−COOH).

Final Answer: Carboxylic acid

Answer: (C)

Go Back to Question 23

Q19.

Solution

Concept: The physical and chemical profile of a soil type depends heavily on the mineral composition of its original parent rock material. Weathering breaks down these parent formations over long periods, transferring specific mineral assemblages to the resulting topsoil layer.

Solution:

(a) Granite and sandstone are siliceous, acidic rocks that weather into coarse, sandy soils with low moisture retention properties.

(b) Limestone consists primarily of calcium carbonate, which typically develops into alkaline soils with a distinctly different mineral profile.

(c) Black soil, also known as Regur soil, is highly fertile and rich in clay, making it ideal for agricultural cultivation.

(d) This unique soil profile forms through the long-term weathering of basaltic lava rocks, which are rich in iron and magnesium minerals from ancient volcanic activity.

Final Answer: Basaltic lava rocks

Answer: (A)

Go Back to Question 24

Q20.

Solution

Concept: Volumetric analysis uses controlled titrations to determine the exact concentration of an unknown analyte by reacting it with a standard reagent. The reaction progress is monitored using indicators or instruments to identify when the chemical reaction reaches completion.

Solution:

(a) The point where a chemical indicator undergoes a visible color change is called the end point, which closely matches the theoretical reaction limit.

(b) The initial point simply marks the starting volumetric readings on the burette before any reagent has been added to the flask.

(c) The saturation point describes a state where a solvent can no longer dissolve any additional solute under stable thermal conditions.

(d) The equivalence point is the exact stage where the moles of titrant added are stoichiometrically equal to the moles of analyte present.

Final Answer: Equivalence point

Answer: (C)

Go Back to Question 25

Q21.

Solution

Concept: Thermodynamic properties are classified into two main categories based on how they respond to changes in system size. Extensive properties depend directly on the total quantity of matter present, whereas intensive properties remain constant regardless of sample size.

Solution:

(a) Mass and volume change proportionally with the amount of material in a system, classifying them as classic extensive variables.

(b) Total enthalpy measures the overall thermal energy content of a substance, which scales directly with the sample size and mass.

(c) Density is an intrinsic physical constant defined mathematically as the ratio of mass to volume ($\rho = m/V$).

(d) Because both mass and volume scale identically, their ratio remains constant, making density an intensive property that is independent of sample size.

Final Answer: Density

Answer: (D)

Go Back to Question 26

Q22.

Solution

Concept: The universal gas constant (R) is a fundamental physical constant that appears in ideal gas equations and various thermodynamic state functions. Its numerical value changes depending on the specific units chosen for pressure, volume, temperature, and chemical quantity.

Solution:

(a) When managing gas systems using non-SI units like atmospheres and liters, the gas constant value is expressed as $0.0821\ \text{L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$.

(b) When dealing with thermal energy operations measured in calories, the constant takes a value of approximately $1.987\ \text{cal} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$.

(c) In standard international (SI) units, pressure is measured in Pascals ($\text{N} \cdot \text{m}^{-2}$) and volume is measured in cubic meters (m^3).

(d) Since the product of Pascal and cubic meter equals Joules, the universal gas constant is accurately represented as $8.314\ \text{J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$.

Final Answer: 8.314

Answer: (B)

Go Back to Question 27

Q23.

Solution

Concept: The geometric shape and magnetic behavior of transition metal complexes are governed by crystal field theory. Strong-field ligands create a large d-orbital splitting that forces electrons to pair up, enabling inner-orbital dsp^2 hybridization and square planar configurations.

Solution:

(a) The nickel ion in these complexes exhibits a +2 oxidation state, resulting in a transition metal electron configuration of $[\text{Ar}]3d^8$.

(b) Chloride is a weak-field ligand that cannot force electron pairing, leading to a high-spin state with sp^3 tetrahedral geometry.

(c) Cyanide (CN^-) is a strong-field ligand that forces the two unpaired 3d electrons to pair up, vacating a single inner 3d orbital.

(d) This empty 3d orbital mixes with one 4s and two 4p orbitals, resulting in dsp^2 hybridization and a square planar geometry for $[Ni(CN)_4]^{2-}$.

Final Answer: $[Ni(CN)_4]^{2-}$

Answer: (B)

Go Back to Question 28

Q24.

Solution

Concept: Friedel-Crafts alkylation is an electrophilic aromatic substitution reaction that introduces alkyl groups onto an aromatic ring. The reaction requires a Lewis acid catalyst to polarize the alkyl halide and generate a highly reactive electrophilic intermediate.

Solution:

(a) Anhydrous aluminum chloride ($AlCl_3$) acts as a strong Lewis acid catalyst, abstracting a chloride ion from methyl chloride.

(b) This abstraction polarizes the bond to generate a highly reactive, electrophilic methyl carbocation intermediate (CH_3^+).

(c) The electron-rich π-cloud of the benzene ring attacks this carbocation, forming a temporary arenium ion intermediate that breaks aromaticity.

(d) The system then eliminates a proton to restore its stable aromatic ring structure, yielding methylbenzene, commonly known as toluene.

Final Answer: Toluene

Answer: (B)

Go Back to Question 29

Q25.

Solution

Concept: Alkaline sodic soils contain high levels of exchangeable sodium ions bound to clay surfaces, which degrades soil structure and limits plant growth. Reclaiming these soils requires chemical amendments that replace sodium with divalent calcium ions.

Solution:

(a) Adding calcium carbonate to highly alkaline soils is ineffective because its low solubility prevents it from releasing calcium ions.

(b) Sodium chloride is a neutral salt that increases salinity without altering the undesirable exchangeable sodium percentage.

(c) Ammonium sulphate acts as an acidifying fertilizer but lacks the calcium ions needed to displace exchangeable sodium from clay surfaces.

(d) Gypsum ($CaSO_4 \cdot 2H_2O$) provides soluble calcium ions that displace sodium from the clay complex, converting it into soluble sodium sulphate that can be leached away.

Final Answer: Calcium sulphate dihydrate (Gypsum)

Answer: (B)

Go Back to Question 30

Q26.

Solution

Concept: The coordination number of a sphere in a crystalline lattice refers to the total number of immediate neighboring spheres it touches directly. In a single two-dimensional layer, spheres can be packed in a square configuration or a more efficient close-packed layout that minimizes empty space.

Solution:

(a) In a two-dimensional square close-packed layout, each sphere is surrounded symmetrically by four immediate neighbors, establishing a coordination number of four.

(b) The given schematic shows a highly efficient two-dimensional hexagonal close-packed layer configuration, where rows of spheres are nested tightly within the depressions of adjacent rows.

(c) Selecting any internal reference sphere from this lattice reveals that it is surrounded by a ring of touching spheres.

(d) Counting these adjacent neighbors demonstrates that the reference sphere makes direct contact with exactly six surrounding spheres, giving it a coordination number of six.

Final Answer: The coordination number is 6.

Answer: (B)

Go Back to Question 31

Q27.

Solution

Concept: Equivalent conductance is defined as the conducting power of all the ions produced by dissolving one gram-equivalent of an electrolyte in a solution. This property changes as the volume of the solution shifts because dilution influences ion concentrations and electrostatic interactions.

Solution:

(a) Dilution increases the overall volume of the solution holding a fixed amount of electrolyte, which forces the individual ions farther apart from one another.

(b) For weak electrolytes, adding solvent shifts the chemical equilibrium to favor dissociation according to Ostwald's dilution law, increasing the total fraction of active ions.

(c) For strong electrolytes, dilution separates ions and reduces the interionic attractive forces, allowing them to migrate more freely toward electrodes.

(d) Consequently, the equivalent conductance increases with dilution due to higher dissociation and increased mobility, even though the total number of ions per unit volume decreases.

Final Answer: The degree of dissociation increases.

Answer: (A)

Go Back to Question 32

Q28.

Solution

Concept: A crystalline unit cell is the smallest repeating structural block that forms a full three-dimensional lattice. The total number of net atoms contained within a unit cell depends on the specific lattice positions the atoms occupy and how those positions are shared with neighboring cells.

Solution:

(a) A primitive simple cubic unit cell features a basic layout where atoms or spheres are located exclusively at the eight corners of the cube.

(b) Each corner position is shared among eight adjacent unit cells in a three-dimensional lattice network.

(c) This sharing means that only one-eighth of each corner atom belongs exclusively to any single unit cell.

(d) Multiplying the eight corners by their sharing factor yields the net atom count: $8 \times (1/8) = 1$ atom per unit cell.

Final Answer: The number of atoms is 1.

Answer: (A)

Go Back to Question 33

Q29.

Solution

Concept: Organic reaction intermediates are short-lived, highly reactive species formed during chemical transformations. The geometric structures, hybridization states, and valence shell electron counts of these intermediates depend on the nature of the bond cleavage that produced them.

Solution:

(a) A carbanion is generated via heterolytic cleavage where the carbon retains the bonding pair, leaving it with eight valence electrons and a pyramidal geometry.

(b) A carbon free radical is a neutral species that holds seven valence electrons, containing a single unpaired electron in an unhybridized p-orbital.

(c) A carbene is a neutral intermediate that possesses six valence electrons around a divalent carbon atom, existing in either a singlet or triplet electronic state.

(d) A carbocation is formed when a leaving group departs with the shared electron pair, leaving a positive carbon with six valence electrons. It adopts an sp^2 hybridization state with a planar geometry.

Final Answer: The intermediate is Carbocation.

Answer: (C)

Go Back to Question 34

Q30.

Solution

Concept: Structural isomerism in coordination chemistry arises from different arrangements of ligands around a central metal ion. Linkage isomerism occurs when a ligand can coordinate to the metal center in more than one way.

Solution:

(a) Unidentate neutral ligands like water or ammonia possess only a single donor atom, meaning they cannot form structural linkage isomers.

(b) Chelate and macrocyclic ligands bind to a central metal ion through multiple donor atoms simultaneously to form stable ring structures.

(c) Ambidentate ligands are unidentate ligands that possess two or more different potential donor atoms but coordinate through only one atom at a time.

(d) Examples include the thiocyanate ion, which can bind through nitrogen or sulfur, and the nitrite ion, which can bind through nitrogen or oxygen, leading to linkage isomers.

Final Answer: The ligands are Ambidentate ligands.

Answer: (B)

Go Back to Question 35

Q31.

Solution

Concept: Essential plant nutrients are grouped into macronutrients and micronutrients based on the quantities needed for healthy growth. Each element serves distinct structural or metabolic roles, including forming cellular components, balancing charge, or regulating enzyme activity.

Solution:

(a) Nitrogen is a primary macronutrient built directly into proteins, chlorophyll molecules, and nucleic acid chains.

(b) Phosphorus is an essential element needed for structural nucleic acids, cell membrane phospholipids, and energy transfer molecules like ATP.

(c) Magnesium serves as the central coordinating metal atom in chlorophyll molecules and acts as an activator for many enzymes involved in carbohydrate metabolism.

(d) Potassium (K^+) is an abundant cellular cation that maintains turgor pressure, regulates the opening and closing of stomata, and activates essential metabolic enzymes.

Final Answer: The nutrient is Potassium (K).

Answer: (C)

Go Back to Question 36

Q32.

Solution

Concept: Liquid-liquid extraction separates compounds based on their relative solubilities in two different immiscible liquids. When two immiscible liquids are mixed in a separating funnel, they separate into distinct layers based on their relative mass densities.

Solution:

(a) Water and chloroform are immiscible liquids that separate cleanly into two distinct phases after being shaken together.

(b) The liquid component with the lower mass density floats to the top, while the component with the higher mass density sinks to the bottom.

(c) The density of water is approximately 1.00 g/cm^3, whereas the density of organic chloroform is significantly higher at approximately 1.49 g/cm^3.

(d) Because chloroform is denser than water, it forms the bottom organic layer (Layer B), while the less dense water forms the top aqueous layer (Layer A).

Final Answer: The organic layer containing chloroform.

Answer: (B)

Go Back to Question 37

Q33.

Solution

Concept: Covalent chemical bonds are classified as σ (sigma) or π (pi) bonds based on the overlap of atomic orbitals. A single covalent bond consists of a single σ-bond, while a multiple covalent bond contains one σ-bond along with supplementary π-bonds.

Solution:

(a) Benzene (C_6H_6) consists of six carbon atoms arranged in a planar hexagonal ring, with each carbon bonded to a single hydrogen atom.

(b) The ring framework features alternating single and double bonds between the adjacent carbon atoms, stabilized by resonance.

(c) Counting the single bonds reveals six carbon-hydrogen (C-H) σ-bonds and six carbon-carbon (C-C) σ-bonds, giving a total of twelve σ-bonds.

(d) The three carbon-carbon double bonds consist of one σ-bond and one π-bond each, contributing exactly three π-bonds to the ring system.

Final Answer: 12 σ and 3 π.

Answer: (B)

Go Back to Question 38

Q34.

Solution

Concept: Oxidation and reduction reactions can be defined using electron transfer, changes in oxidation states, or the gain and loss of specific atoms. In organic chemistry, redox processes are typically tracked by looking at changes in hydrogen and oxygen content.

Solution:

(a) Reduction involves gaining electrons, decreasing the positive oxidation state, adding hydrogen atoms, or losing oxygen atoms.

(b) Oxidation is defined as losing electrons or increasing the positive oxidation state of an atom within a chemical species.

(c) In organic reaction mechanisms, oxidation frequently occurs through the addition of an electronegative oxygen atom to a carbon framework.

(d) Alternatively, organic oxidation can occur through the loss of hydrogen atoms, which increases the overall oxidation state of the carbon atom.

Final Answer: Addition of oxygen or loss of hydrogen.

Answer: (B)

Go Back to Question 39

Q35.

Solution

Concept: Silicate clay minerals are layered crystalline structures found in soils, classified by the arrangement of their tetrahedral and octahedral sheets. The structural links between these sheets determine whether a clay mineral expands or resists volume changes when exposed to water.

Solution:

(a) Kaolinite is a 1:1 type silicate clay mineral with strong hydrogen bonds between its layers, which prevents water from entering and makes it non-expanding.

(b) Illite is a 2:1 type clay mineral where potassium ions reside between the layers, locking the structure together and limiting its capacity to expand.

(c) Montmorillonite is a 2:1 type clay mineral with weak van der Waals forces holding its layers together, allowing water molecules to easily enter the interlayer spaces.

(d) This structural spacing causes substantial swelling when wet and shrinking when dry, which is characteristic of the expansive black soils found in regions like India.

Final Answer: Montmorillonite.

Answer: (C)

Go Back to Question 40

Answer Key

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