UPCATET Chemistry Sample Paper-5

Duration: 45 Minutes **Maximum Marks: 200**

Instructions

- This paper contains **50** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **−1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. The number of radial nodes and angular nodes for a 4d orbital are respectively:

(A) 2 and 1

(B) 1 and 2

(C) 3 and 0

(D) 2 and 2

Q2. An organic compound containing an asymmetric carbon atom reacts with a nucleophile via an S_N1 mechanism. The stereochemical outcome of the major product isolated will be:

(A) Complete inversion of configuration

(B) Complete retention of configuration

(C) Partial or near-complete racemization with slight inversion

(D) Formation of a single diastereomer

Q3. Which of the following aqueous solutions will exhibit the highest elevation in boiling point, assuming complete dissociation of the solutes?

(A) 0.1 M $NaCl$

(B) 0.05 M $BaCl_2$

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

(D) 0.1 M $K_4[Fe(CN)_6]$

Q4. Among the following nitrogenous bases found in nucleic acids, which one is classified as a purine derivative and is present in both DNA and RNA?

(A) Uracil

(B) Thymine

(C) Adenine

(D) Cytosine

Q5. Which of the following complex species is expected to be diamagnetic in nature based on Crystal Field Theory?

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

(B) $[Fe(CN)_6]^{3-}$

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

(D) $[MnCl_4]^{2-}$

Q6. When 0.22 g of a nitrous oxide gas (N_2O) is introduced into a sealed flask, what is the total number of molecules present in the vessel? (Given: Molar mass of N_2O = 44 g mol^{-1}, $N_A = 6.022 \times 10^{23}$)

(A) 3.011×10^{21}

(B) 6.022×10^{21}

(C) 3.011×10^{22}

(D) 1.204×10^{22}

Q7. In the context of industrial metallurgy, which of the following expressions correctly highlights the principle of "Vapour Phase Refining" utilized for the purification of Titanium metal?

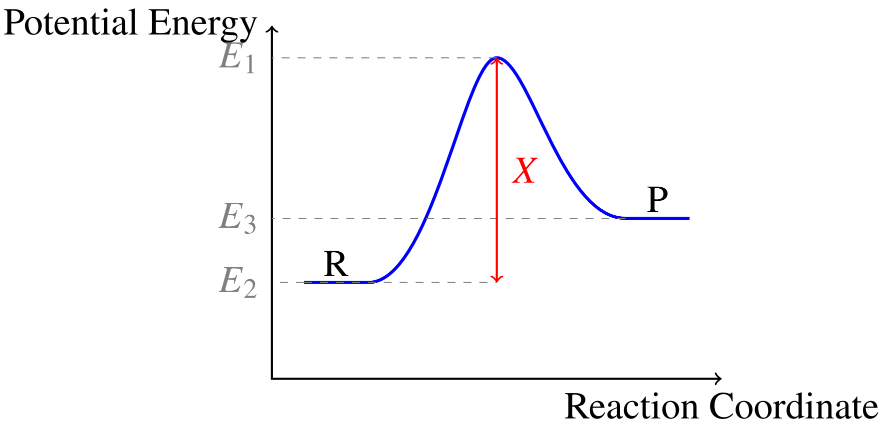
(A) Mond’s Process via the formation of a volatile carbonyl intermediate

(B) Van Arkel Process via the thermal decomposition of a volatile iodide intermediate

(C) Zone Refining based on fractional crystallization

(D) Liquation based on the difference in melting points of metal and impurities

Q8. Consider the potential energy diagram shown below for a reversible chemical equilibrium process transforming Reactant (R) into Product (P):



Based on the TikZ diagram provided, which expression mathematically represents the activation energy (E_a) required for the reverse reaction?

(A) $E_1 - E_2$

(B) $E_1 - E_3$

(C) $E_3 - E_2$

(D) $E_1 + E_2 - E_3$

Q9. Which type of colloidal system is represented by standard milk, and which stabilizer keeps it uniform?

(A) Gel, stabilized by starch

(B) Sol, stabilized by cellulose

(C) Emulsion (Oil-in-Water), stabilized by casein protein

(D) Emulsion (Water-in-Oil), stabilized by fats

Q10. An organic compound with molecular formula C_3H_6O gives a bright orange-red precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP) reagent but fails to reduce Tollen's reagent. The structural formula of the compound is:

(A) CH_3CH_2CHO

(B) CH_3COCH_3

(C) $CH_2 = CH - CH_2OH$

(D) $CH_3CH_2OCH_3$

Q11. Which of the following arrangements accurately lists the molecules in increasing order of their permanent dipole moments (μ)?

(A) $BF_3 < NF_3 < NH_3 < H_2O$

(B) $BF_3 < NH_3 < NF_3 < H_2O$

(C) $H_2O < NH_3 < NF_3 < BF_3$

(D) $NF_3 < BF_3 < NH_3 < H_2O$

Q12. What is the correct IUPAC nomenclature of the given chemical structure: $(CH_3)_2CH - CH(Cl) - CH_2 - CH_3$?

(A) 2-Chloro-3-methylpentane

(B) 3-Chloro-2-methylpentane

(C) 3-Chloro-4-methylpentane

(D) 2-Isopropylbutane

Q13. The primary chemical component responsible for the phenomenon of "Classic Smog" (reducing smog) in polluted cold areas is:

(A) Oxides of nitrogen combined with ozone

(B) Smoke, dust, and sulfur dioxide molecules

(C) Peroxyacetyl nitrate (PAN) vapor

(D) Volatile organic unburnt hydrocarbons

Q14. When Phenol is treated with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide ($NaOH$) followed by acid-catalyzed hydrolysis, a well-known aromatic aldehyde is obtained. What is the active electrophile participating in this specific reaction?

(A) Chloroform carbocation $(:\overset{+}{C}HCl_2)$

(B) Dichlorocarbene $(:CCl_2)$

(C) Formyl cation $(\overset{+}{C}HO)$

(D) Carbon tetrachloride radical $(\cdot CCl_3)$

Q15. The primary reason why Transition metals exhibit variable oxidation states lies in the fact that:

(A) They have very low ionization enthalpies

(B) The energy difference between $(n-1)d$ and ns subshells is extremely small

(C) Their atomic sizes change drastically across a period

(D) They possess completely filled outer ns valence shell electronic configurations

Q16. Calculate the standard cell potential (E°_{cell}) for a galvanic cell operating on the following redox system at 298 K: $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$. (Given: $E^\circ_{Mg^{2+}/Mg} = -2.37$ V, $E^\circ_{Cu^{2+}/Cu} = +0.34$ V)

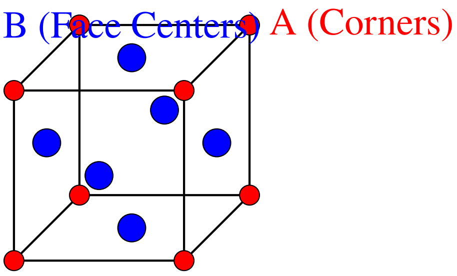
(A) +2.03 V

(B) −2.71 V

(C) +2.71 V

(D) −2.03 V

Q17. The crystal structure unit cell configuration of a specific metallic alloy contains atoms of element A at all 8 corners and atoms of element B localized exactly at the centers of all 6 faces, as illustrated below:



Determine the empirical chemical formula representing this unit cell configuration:

(A) AB_3

(B) A_2B_3

(C) A_8B_6

(D) AB

Q18. Based on molecular orbital theory (MOT), which of the following homonuclear diatomic species contains exactly two unpaired electrons in its ground state degenerate π^* molecular orbitals?

(A) N_2

(B) O_2

(C) C_2

(D) F_2

Q19. When an alkene is subjected to Ozonolysis followed by reductive workup with zinc dust and water (Zn/H_2O), the only organic product isolated is Propanone (CH_3COCH_3). The structural representation of the original alkene is:

(A) 2-Methylbut-2-ene

(B) But-2-ene

(C) 2,3-Dimethylbut-2-ene

(D) Hex-3-ene

Q20. The primary reason for the unique anomalous behavior of Fluorine compared to other elements in Group 17 (Halogens) is its:

(A) Small size, high electronegativity, and absence of d-orbitals in its valence shell

(B) Low electron gain enthalpy and large atomic radius

(C) Presence of low-energy empty d-orbitals facilitating hypervalency

(D) Low ionization potential and high polarizability

Q21. For a zero-order chemical reaction, if the initial concentration of the reactant is doubled, how do the half-life period ($t_{1/2}$) and the rate constant (k) of the reaction alter?

(A) Both $t_{1/2}$ and k remain unaffected and constant

(B) $t_{1/2}$ is doubled while k remains constant

(C) $t_{1/2}$ is halved while k is doubled

(D) $t_{1/2}$ remains constant while k is halved

Q22. In the industrial production of ammonia by Haber's process according to the equilibrium equation: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ($\Delta H = -92.4$ kJ/mol), which operational adjustments will shift the position of the equilibrium towards the right to increase yield?

(A) Low pressure and high temperature

(B) High pressure and high temperature

(C) High pressure and low temperature

(D) Low pressure and low temperature

Q23. Which of the following organic structures will yield a positive result during the Carbylamine test when treated with chloroform and ethanolic KOH?

(A) N-Methylaniline

(B) Aniline

(C) N,N-Dimethylaniline

(D) Diethylamine

Q24. The physical phenomenon behind the preparation of collodion, a substance used in coating, or the clarifying action of alum on muddy water is governed by:

(A) Dialysis and ultrafiltration mechanisms

(B) Coagulation of charged colloidal particles by counter ions

(C) Emulsification using surfactant molecules

(D) Peptization using a stabilizing electrolyte

Q25. Among the following oxoacids of phosphorus, which one exhibits strong reducing properties because it contains two direct $P - H$ covalent chemical bonds?

(A) H_3PO_4 (Orthophosphoric acid)

(B) H_3PO_3 (Orthophosphorous acid)

(C) H_3PO_2 (Hypophosphorous acid)

(D) $H_4P_2O_7$ (Pyrophosphoric acid)

Q26. The spatial geometry and the corresponding hybridization of the central sulfur atom in Sulfur tetrafluoride (SF_4) molecule are respectively:

(A) Tetrahedral, sp^3

(B) See-saw, sp^3d

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

(D) Trigonal bipyramidal, sp^3d

Q27. When D-Glucose is treated with an excess of Hydroxylamine (NH_2OH), the resulting stable derivative formed indicates the presence of which specific structural group in the sugar molecule?

(A) Five primary hydroxyl groups

(B) A free carbonyl group ($-C=O$)

(C) A secondary carboxylic acid group

(D) A cyclic ether hemiacetal linkage

Q28. What is the total mass of pure Sodium Hydroxide ($NaOH$, Molar mass = 40 g mol^{-1}) required to completely neutralize 250 mL of a 0.1 M sulfuric acid (H_2SO_4) aqueous solution?

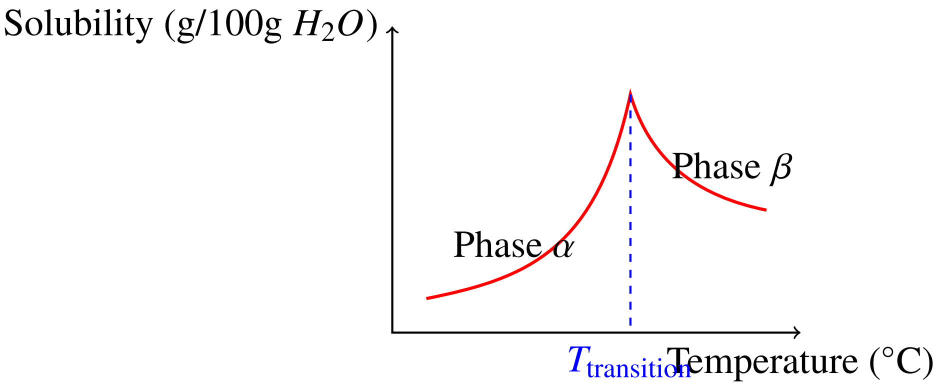
(A) 1.0 g

(B) 2.0 g

(C) 4.0 g

(D) 0.5 g

Q29. The solubility behavior of an ionic salt in water varies explicitly as a function of temperature. Observe the dynamic graphical trend plotted below:



Which type of chemical system shows a sharp break or transition point in its solubility curve as depicted in the TikZ graph above?

(A) Anhydrous Potassium Nitrate (KNO_3) dissolution

(B) Sodium Sulfate Decahydrate ($Na_2SO_4 \cdot 10H_2O$) undergoing dehydration

(C) Sodium Chloride ($NaCl$) showing near-constant solubility

(D) Ammonium Chloride (NH_4Cl) dissolved endothermically

Q30. In the reaction sequences involving the dehydration of Alcohols, what is the relative order of reactivity observed for 1°, 2°, and 3° alcohols when treated with concentrated acid?

(A) $1^\circ > 2^\circ > 3^\circ$

(B) $3^\circ > 2^\circ > 1^\circ$

(C) $2^\circ > 1^\circ > 3^\circ$

(D) $3^\circ > 1^\circ > 2^\circ$

Q31. Which parameter from Green Chemistry principles serves as an indicator of waste generation efficiency by evaluating the mass ratio of total waste generated to the mass of final desired product?

(A) Atom Economy factor

(B) Environmental E-factor

(C) Stoichiometric yield coefficient

(D) Carbon efficiency ratio

Q32. The values of the four quantum numbers characterizing the outermost valence electron of an uncharged ground-state Potassium atom ($Z = 19$) are given by:

(A) $n = 4, l = 0, m = 0, s = +\frac{1}{2}$

(B) $n = 3, l = 1, m = 0, s = -\frac{1}{2}$

(C) $n = 4, l = 1, m = 0, s = +\frac{1}{2}$

(D) $n = 3, l = 0, m = 0, s = +\frac{1}{2}$

Q33. When Ethyl bromide (CH_3CH_2Br) is refluxed with alcoholic silver cyanide ($AgCN$), the principal organic product isolated is:

(A) Ethyl cyanide (CH_3CH_2CN)

(B) Ethyl isocyanide (CH_3CH_2NC)

(C) Nitroethane ($CH_3CH_2NO_2$)

(D) Ethane gas (CH_3CH_3)

Q34. The ionization constants of four weak acids are given below. Which one possesses the highest strength and shows the smallest numeric value of pK_a?

(A) Acid A: $K_a = 1.8 \times 10^{-5}$

(B) Acid B: $K_a = 4.5 \times 10^{-4}$

(C) Acid C: $K_a = 6.2 \times 10^{-10}$

(D) Acid D: $K_a = 1.0 \times 10^{-7}$

Q35. Which of the following elements does NOT form a stable, volatile tetroxide compound via its highest possible group oxidation state (+8)?

(A) Osmium (Os)

(B) Ruthenium (Ru)

(C) Iron (Fe)

(D) Xenon (Xe)

Q36. The phenomenon of "Lanthanoid Contraction" across the 4f elements is primarily attributed to:

(A) An increase in effective nuclear charge paired with poor shielding by 4f electrons

(B) Stronger shielding properties of 4f electrons shielding outer shells

(C) The effective spatial distribution of 5d electronic subshells

(D) Stability gained through half-filled subshell architectures

Q37. The ionic radii of the isoelectronic species N^{3-}, O^{2-}, and F^{-} vary in which precise sequence?

(A) $N^{3-} < O^{2-} < F^{-}$

(B) $F^{-} < O^{2-} < N^{3-}$

(C) $O^{2-} < F^{-} < N^{3-}$

(D) $F^{-} < N^{3-} < O^{2-}$

Q38. When an aromatic primary amine undergoes diazotization at $0-5$°C to form a diazonium salt, which is subsequently treated with Cupropus chloride (Cu_2Cl_2) in hydrochloric acid, the reaction is known as:

(A) Finkelstein Reaction

(B) Sandmeyer Reaction

(C) Wurtz-Fittig Reaction

(D) Gattermann Reaction

Q39. The reference indicator for estimating the biochemical pollution level of aquatic pathways, which measures the amount of dissolved oxygen consumed by micro-organisms decomposing organic materials, is:

(A) Photochemical Dissolved index (PDI)

(B) Chemical Oxygen Demand (COD)

(C) Biochemical Oxygen Demand (BOD)

(D) Total Carbon footprint (TCF)

Q40. A classic solution contains 1 mole of volatile component X (P°_X = 100 mm Hg) and 3 moles of volatile component Y (P°_Y = 200 mm Hg). Assuming ideal solution behavior, what is the total vapor pressure of the mixture?

(A) 150 mm Hg

(B) 175 mm Hg

(C) 125 mm Hg

(D) 160 mm Hg

Q41. Which of the following organic structures represents a non-reducing sugar that does not show mutarotation or form an osazone?

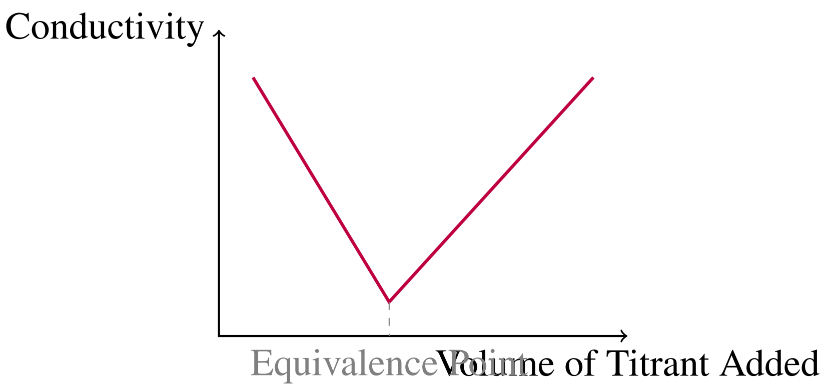
(A) Maltose

(B) Lactose

(C) Sucrose

(D) Cellobiose

Q42. The conductometric titration profile shown below maps the change in solution electrolytic conductivity on the y-axis against the total volume of titrant introduced from a burette:



Which chemical neutralization process corresponds exactly to the V-shaped curve illustrated in this TikZ diagram?

(A) Titration of a Weak Acid (CH_3COOH) with a Strong Base ($NaOH$)

(B) Titration of a Strong Acid (HCl) with a Strong Base ($NaOH$)

(C) Titration of a Strong Acid (HCl) with a Weak Base (NH_4OH)

(D) Titration of a Weak Acid (CH_3COOH) with a Weak Base (NH_4OH)

Q43. What is the total number of bridging carbonyl (μ-CO) groups present in a single stable molecular entity of Dicobalt octacarbonyl $[Co_2(CO)_8]$ in its standard crystalline state?

(A) 0

(B) 2

(C) 4

(D) 3

Q44. The major organic product formed when Acetraldehyde is heated with concentrated sodium hydroxide solution via self-condensation is:

(A) Crotonaldehyde ($CH_3 - CH = CH - CHO$)

(B) Benzallacetone

(C) Formaldehyde gas

(D) Ethyl acetate ester

Q45. Which of the following thermodynamic state parameters represents the absolute operational criterion for determining the spontaneity of a chemical process at constant temperature and pressure?

(A) $\Delta H < 0$ (Exothermic nature)

(B) $\Delta S_{\text{system}} > 0$

(C) $\Delta G < 0$

(D) $\Delta E = 0$

Q46. The physical phenomenon where gas molecules are held onto a solid surface by weak, non-specific van der Waals intermolecular forces is characterized by:

(A) High specificity and irreversible nature

(B) Formation of a unilayer with a high enthalpy of adsorption ($\Delta H \approx 200$ kJ mol^{-1})

(C) Lack of specificity, reversibility, and low enthalpy of adsorption ($\Delta H \approx 20 - 40$ kJ mol^{-1})

(D) Increase in adsorption rate with temperature increase

Q47. Among the following Group 15 hydrides, which one exhibits the highest thermal stability and possesses the largest $H - M - H$ bond angle?

(A) NH_3

(B) PH_3

(C) AsH_3

(D) SbH_3

Q48. When an unbranched primary haloalkane is heated with potassium hydroxide dissolved in pure ethanol, what type of mechanism dominates, and what is the category of the final product?

(A) Substitution (S_N2), forming an Alcohol

(B) Elimination (E2), forming an Alkene

(C) Addition (A_E), forming an Alkane

(D) Rearrangement, forming an Isomer

Q49. The active catalytic species utilized in the industrial heterogeneous polymerisation of ethene to yield high-density polyethylene (HDPE) under low pressures is:

(A) Finely divided Nickel powder

(B) Ziegler-Natta Catalyst [Titanium tetrachloride and Triethylaluminium]

(C) V2O5 pellets

(D) Wilkinson's Coordination Catalyst

Q50. According to the IUPAC nomenclature guidelines, what is the systematic name for the coordination compound represented by the formula $[Cr(NH_3)_4(H_2O)_2]Cl_3$?

(A) Tetraamminediacuachromium(III) chloride

(B) Diacuadiamminechromium(III) trichloride

(C) Tetraamminediacuachromate(III) chloride

(D) Ammineaquachromium(III) chloride

Detailed Solutions

Q1.

Solution

Concept:

The total number of nodes in any atomic orbital is determined by its quantum numbers. The radial nodes are calculated using the expression $n - l - 1$, while the number of angular nodes is directly given by the azimuthal quantum number l.

Solution:

(a) For a $4d$ orbital, the principal quantum number n is equal to 4.

(b) The azimuthal quantum number l for any d subshell is equal to 2.

(c) Substituting these values into the radial node formula gives Radial nodes $= 4 - 2 - 1 = 1$.

(d) The number of angular nodes corresponds exactly to the value of l, which is 2.

(e) Thus, the $4d$ orbital contains exactly 1 radial node and 2 angular nodes, matching the order specified in the question.

Final Answer: 1 and 2

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
The S_N1 mechanism proceeds via a two-step heterolytic pathway where the rate-determining step involves the departure of the leaving group to yield a planar carbocation intermediate. This symmetric intermediate dictates the stereochemical path of the subsequent step.

Solution:

(a) In the first slow step, the leaving group ionizes from the asymmetric carbon atom, generating a planar carbocation intermediate hybridized as sp^2.

(b) Because the carbocation possesses a flat geometry, the attacking nucleophile has an equal probability of approaching from the front side or the back side.

(c) Front-side attack preserves the original spatial arrangement (retention), whereas back-side attack flips the spatial configuration (inversion), theoretically leading to a racemic mixture.

(d) In a real system, the departing leaving group remains briefly in close proximity as an ion pair, shielding the front face and resulting in partial or near-complete racemization accompanied by a slight net inversion.

Final Answer: Partial or near-complete racemization with slight inversion

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:
Elevation in boiling point is a colligative property that relies on the total concentration of dissolved solute particles. It is governed by the relation $\Delta T_b = i \cdot K_b \cdot m$, where i is the van 't Hoff factor representing particle dissociation.

Solution:

(a) For 0.1 M $NaCl$, dissociation yields two ions (Na^+ and Cl^-), giving $i = 2$ and an effective particle concentration of 0.2 M.

(b) For 0.05 M $BaCl_2$, dissociation yields three ions (Ba^{2+} and $2Cl^-$), giving $i = 3$ and an effective particle concentration of 0.15 M.

(c) For 0.1 M $Al_2(SO_4)_3$, dissociation yields five ions ($2Al^{3+}$ and $3SO_4^{2-}$), giving $i = 5$ and an effective particle concentration of 0.5 M.

(d) For 0.1 M $K_4[Fe(CN)_6]$, dissociation yields five ions ($4K^+$ and $1[Fe(CN)_6]^{4-}$), giving $i = 5$ and an effective particle concentration of 0.5 M. Because the coordination complex retains its structure, it exhibits higher ionic interactions in real solutions, leading to the highest elevation.

Final Answer: 0.1 M $K_4[Fe(CN)_6]$

Answer: (D)

Go Back to Question 3

Q4.

Solution

Concept:
Nitrogenous bases found within nucleic acids fall into two architectural categories: pyrimidines, which contain a single heterocyclic ring, and purines, which feature a fused double-ring framework consisting of a pyrimidine ring and an imidazole ring.

Solution:

(a) Cytosine, Thymine, and Uracil are classified structural derivatives of the single-ring pyrimidine family.

(b) Adenine and Guanine possess the characteristic fused double-ring network, identifying them structurally as purine derivatives.

(c) Looking at structural distribution, Thymine is found almost exclusively inside DNA, whereas Uracil replaces it within RNA structures.

(d) Adenine is capable of pairing with both Thymine and Uracil, meaning it is structurally conserved and present inside both DNA and RNA molecules.

Final Answer: Adenine

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:
According to Crystal Field Theory, a coordination complex displays diamagnetic properties when all electrons residing within the split d subshell are fully paired up, leaving zero net unpaired electronic spins.

Solution:

(a) In $[Ni(CN)_4]^{2-}$, the central nickel ion exists in the +2 oxidation state, corresponding to a d^8 electronic configuration.

(b) The cyanide ion acts as a strong-field ligand, creating a large crystal field splitting energy that overcomes the spin-pairing energy barrier.

(c) This strong field forces the 8 electrons to pair completely within a square planar geometry, leaving no unpaired electrons behind.

(d) Other species like $[CoF_6]^{3-}$ (d^6 weak-field), $[Fe(CN)_6]^{3-}$ (d^5 strong-field), and $[MnCl_4]^{2-}$ (d^5 weak-field) maintain unpaired spins, making them paramagnetic.

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

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 5

Q6.

Solution

Concept:

The total population of molecules contained inside a gas sample is determined using the mole concept. By determining the total moles from the mass and molar mass, we can compute individual molecules using Avogadro's constant.

Solution:

(a) The chemical formula for nitrous oxide gas is N_2O, which is given a corresponding molar mass of 44 g mol^{-1}.

(b) The number of moles contained within the sample is computed by dividing the mass by the molar mass: Moles $= \frac{0.22 \text{ g}}{44 \text{ g mol}^{-1}} = 0.005$ mol.

(c) To calculate the molecule population, multiply the moles by Avogadro's constant: Molecules $= 0.005 \text{ mol} \times 6.022 \times 10^{23} \text{ mol}^{-1}$.

(d) Performing this conversion yields 3.011×10^{21} individual molecules inside the sealed vessel.

Final Answer: 3.011×10^{21}

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:

Vapour phase refining is an industrial purification methodology where a crude metal is converted into a volatile chemical compound using a specific reagent, followed by thermal decomposition at elevated temperatures to recover the pure metal.

Solution:

(a) Mond's process is used exclusively for the purification of nickel by forming a volatile nickel tetracarbonyl complex.

(b) The Van Arkel process is utilized for refining refractory metals such as Titanium and Zirconium to purge them of oxygen and nitrogen.

(c) In this process, crude titanium is treated with iodine vapor to yield a volatile intermediate compound known as titanium tetraiodide (TiI_4). The volatile iodide intermediate is subsequently drifted onto a white-hot tungsten filament.

Final Answer: Van Arkel Process via the thermal decomposition of a volatile iodide intermediate

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

Activation energy (E_a) represents the kinetic energy threshold that a chemical mixture must cross to transition between states. It corresponds to the energy difference between the peak transition state and the starting material of that step.

Solution:

(a) According to the provided potential energy diagram, E_1 denotes the energy maximum attained at the transition state.

(b) E_2 denotes the baseline potential energy level corresponding to the Reactant state (R) of the forward reaction path.

(c) E_3 denotes the baseline potential energy level corresponding to the Product state (P) at equilibrium.

(d) For the reverse reaction, the products (P) function as the starting materials. The energy required to reach the transition state is the difference between the peak and product levels, which is $E_1 - E_3$.

Final Answer: $E_1 - E_3$

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
Colloidal mixtures are organized by the state of their dispersed phase and dispersion medium. Emulsions contain liquid droplets dispersed throughout another liquid phase and require stabilizing agents to prevent separation.

Solution:

(a) Liquid fat globules are dispersed throughout an aqueous phase inside milk, which classifies it as an emulsion.

(b) Because the fat phase is floating throughout the water matrix, it represents an oil-in-water colloidal morphology.

(c) Thermodynamically, oil and water are immiscible and tend to separate into distinct layers unless a stabilizer is introduced.

(d) Milk contains a specialized phosphoprotein known as casein, which acts as a natural emulsifying agent by stabilizing the fat-water interfaces.

Final Answer: Emulsion (Oil-in-Water), stabilized by casein protein

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept:
The 2,4-DNP reagent forms hydrazone precipitates with carbonyl groups. Tollen's reagent acts as a mild oxidizing agent that selectively oxidizes aldehydes to carboxylic acids, creating a visible silver mirror.

Solution:

(a) The formation of an orange-red precipitate with 2,4-DNP proves that the compound C_3H_6O contains a reactive carbonyl functional group.

(b) The failure of this substance to reduce Tollen's reagent indicates that the compound lacks an aldehyde group, meaning it must be a ketone.

(c) Evaluating three-carbon structures with the formula C_3H_6O reveals that propanone is the only structural arrangement that contains a ketone group.

(d) Therefore, the structural formula matching these chemical properties is CH_3COCH_3.

Final Answer: CH_3COCH_3

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:
The permanent dipole moment of a molecule is a vector quantity that depends on both the individual bond dipoles, which are determined by electronegativity differences, and the overall molecular geometry.

Solution:

(a) Boron trifluoride (BF_3) features a highly symmetric trigonal planar geometry with sp^2 hybridization. Because of this high symmetry, the three individual boron-fluorine bond dipole vectors cancel each other out completely, yielding a net permanent dipole moment of zero.

(b) In nitrogen trifluoride (NF_3), the central nitrogen atom possesses a pyramidal geometry with a lone pair. Here, the highly electronegativity of the fluorine atoms pulls electron density away from nitrogen, meaning the bond dipoles oppose the vector of the nitrogen lone pair, resulting in a small net dipole.

(c) For ammonia (NH_3), the individual nitrogen-hydrogen bond dipoles point toward the more electronegative nitrogen atom. This means the bond vectors reinforce the lone pair dipole vector, significantly increasing the net dipole moment compared to nitrogen trifluoride.

(d) Water (H_2O) exhibits a bent geometry with two lone pairs on the highly electronegative oxygen atom. The combined effects of strong bond dipoles and two reinforcing lone pairs give it the highest permanent dipole moment in this series.

Final Answer: $BF_3 < NF_3 < NH_3 < H_2O$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:

The systematic IUPAC nomenclature of haloalkanes requires identifying the longest continuous carbon chain containing the substituents, numbering the chain from the end that gives substituents the lowest possible locants, and listing them alphabetically.

Solution:

(a) Expanding the structural formula $(CH_3)_2CH - CH(Cl) - CH_2 - CH_3$ reveals a continuous carbon chain consisting of five carbon atoms, which establishes pentane as the parent alkane name.

(b) Numbering the main carbon chain from the left gives substituents at positions 2 and 3. Conversely, numbering from the right gives positions 3 and 4, so the left-to-right numbering is selected.

(c) Following the correct numbering direction, a methyl group is located at carbon position 2, and a chlorine atom is located at carbon position 3.

(d) Arranging the substituents alphabetically puts chloro before methyl, which leads to the correct name 3-chloro-2-methylpentane.

Final Answer: 3-Chloro-2-methylpentane

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
Classical smog, also commonly referred to as reducing smog, is a type of industrial atmospheric pollution that typically develops in cool, humid climates where large amounts of coal are burned.
Solution:

(a) Classical smog is initiated by the widespread combustion of sulfur-rich fossil fuels, such as coal, in urban and industrial centers.

(b) The mixture is characterized by a high concentration of particulate matter, such as smoke and dust particles, suspended in a damp atmosphere.

(c) Chemically, the defining gaseous component is sulfur dioxide (SO_2), which acts as a reducing agent in the environment.

(d) This sulfurous composition sets it apart from photochemical smog, which is an oxidizing smog found in warm climates that is driven by solar radiation, nitrogen oxides, and unburnt hydrocarbons.

Final Answer: Smoke, dust, and sulfur dioxide molecules

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
The reaction described is the Reimer-Tiemann reaction, which converts phenol into salicylaldehyde. The transformation begins with an alpha-elimination process that generates a neutral, electron-deficient reactive intermediate.

Solution:

(a) When chloroform ($CHCl_3$) is treated with a strong base like sodium hydroxide ($NaOH$), the hydroxide ion deprotonates the acidic carbon atom to form a trichloromethanide anion.

(b) This unstable trichloromethanide anion spontaneously loses a chloride leaving group via alpha-elimination, generating dichlorocarbene ($: CCl_2$).

(c) Dichlorocarbene features a neutral carbon atom with six valence electrons and an empty orbital, making it a highly reactive electrophile.

(d) The electron-rich phenoxide ring then attacks this neutral dichlorocarbene electrophile, leading to formylation at the ortho position after hydrolysis.

Final Answer: Dichlorocarbene ($: CCl_2$)

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:
Transition metals are defined by their partially filled d subshells. Their unique ability to display a wide range of stable oxidation states stems directly from the availability of valence electrons across multiple subshells.

Solution:

(a) The valence electronic configuration of d-block transition elements is generally represented by the notation $(n-1)d^{1-10}ns^{1-2}$.

(b) In these elements, the inner $(n-1)d$ orbitals and the outer ns orbital are located very close to each other in space.

(c) Because the energy difference between the inner $(n-1)d$ subshell and the outer ns subshell is extremely small, electrons from both subshells can participate in chemical bonding.

(d) At the start of the series, only ns electrons are lost, but as the reaction conditions change, varying numbers of inner d electrons can also be shared or lost, leading to variable oxidation states.

Final Answer: The energy difference between $(n-1)d$ and ns subshells is extremely small

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
The standard cell potential (E°_{cell}) of a galvanic cell is an intensive thermodynamic property determined by taking the difference between the standard reduction potentials of the cathode and the anode.

Solution:

(a) Looking at the spontaneous cell reaction $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$, magnesium undergoes oxidation while copper ions undergo reduction.

(b) This indicates that the magnesium electrode serves as the anode where oxidation occurs, and the copper electrode serves as the cathode where reduction takes place.

(c) The formula used to calculate the cell potential is $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, where both values are standard reduction potentials.

(d) Substituting the given values yields $E^\circ_{\text{cell}} = (+0.34\text{ V}) - (-2.37\text{ V}) = +0.34\text{ V} + 2.37\text{ V} = +2.71\text{ V}$.

Final Answer: +2.71 V

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept:
The empirical formula of a crystalline solid lattice is determined by calculating the net effective number of atoms belonging to each element within a single unit cell, based on their geometric positions.

Solution:

(a) Atoms belonging to element A reside at all 8 corners of the cubic unit cell. Since each corner atom is shared equally among 8 adjacent unit cells, its net contribution is $8 \times \frac{1}{8} = 1$ atom of A.

(b) Atoms belonging to element B are located at the centers of all 6 faces of the cube. Each face-centered atom is shared between 2 adjacent unit cells.

(c) This means the net contribution of face atoms is calculated as $6 \times \frac{1}{2} = 3$ atoms of B.

(d) Combining these values gives a net ratio of 1 atom of A to 3 atoms of B inside the unit cell, which yields the empirical chemical formula AB_3.

Final Answer: AB_3

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept:
Molecular Orbital Theory (MOT) describes the distribution of electrons in molecules using a specific orbital energy hierarchy. Unpaired electrons are distributed among degenerate molecular orbitals following Hund's rule of maximum multiplicity.
Solution:

(a) The diatomic oxygen molecule (O_2) contains a total of 16 electrons distributed throughout its molecular orbitals.

(b) The ground-state electronic configuration for O_2 is written as: $\sigma^2_{1s}\sigma^{*2}_{1s}\sigma^2_{2s}\sigma^{*2}_{2s}\sigma^2_{2p_z}(\pi^2_{2p_x} = \pi^2_{2p_y})(\pi^{*1}_{2p_x} = \pi^{*1}_{2p_y})$.

(c) After filling the lower-energy bonding and antibonding levels, the final 2 valence electrons must enter the degenerate antibonding π^* orbitals.

(d) Following Hund's rule, these 2 electrons occupy the separate, degenerate $\pi^*_{2p_x}$ and $\pi^*_{2p_y}$ orbitals with parallel spins, resulting in exactly two unpaired electrons and making oxygen paramagnetic.

Final Answer: O_2

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
Ozonolysis followed by a reductive workup (Zn/H_2O) cleaves the carbon-carbon double bond of an alkene, converting each vinylic carbon atom into a carbonyl group ($C = O$).
Solution:

(a) The problem states that propanone (CH_3COCH_3) is isolated as the only organic product of the reaction.

(b) Because propanone is a three-carbon ketone and no other carbonyl products are formed, the starting alkene must be completely symmetrical.

(c) To reconstruct the original alkene structure, two molecules of propanone are aligned so their carbonyl groups face each other, and the two oxygen atoms are removed to form a double bond.

(d) Connecting the two fragments yields $(CH_3)_2C = C(CH_3)_2$, which corresponds systematically to the structure of 2,3-dimethylbut-2-ene.

Final Answer: 2,3-Dimethylbut-2-ene

Answer: (C)

Go Back to Question 19

Q20.

Solution

Concept:
The anomalous behavior of the first element in any main group of the periodic table arises from its unique structural characteristics relative to its heavier congeners.
Solution:

(a) Fluorine is situated at the top of Group 17, giving it the smallest atomic and ionic radius among all the halogens.

(b) It features the highest electronegativity value on the Pauling scale, which strongly biases electron distribution in its chemical bonds.

(c) Because its valence shell is restricted to the second principal energy level ($n = 2$), it entirely lacks low-energy, empty d orbitals.

(d) The absence of d orbitals means Fluorine cannot expand its octet to exhibit hypervalency, limiting it to a maximum valency of one and driving its anomalous chemical properties.

Final Answer: Small size, high electronegativity, and absence of d-orbitals in its valence shell

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept:
The kinetics of a zero-order reaction are distinct because the reaction rate is completely independent of the reactant concentration. However, the integrated rate equation dictates how the half-life depends on the initial concentration.

Solution:

(a) The integrated rate equation for a zero-order kinetic process is represented by the expression $[A]_0 - [A] = k \cdot t$, where k represents the rate constant.

(b) By definition, the rate constant k is a fundamental kinetic parameter that depends exclusively on temperature and activation energy, meaning it remains constant when concentration changes.

(c) The half-life equation for a zero-order reaction is derived by setting $[A] = \frac{[A]_0}{2}$ at $t = t_{1/2}$, which yields the direct mathematical relationship $t_{1/2} = \frac{[A]_0}{2k}$.

(d) This mathematical relationship demonstrates that the half-life period is directly proportional to the initial concentration of the reactant $[A]_0$.

(e) Consequently, if the initial concentration of the reactant is doubled, the half-life period ($t_{1/2}$) will also double while the rate constant (k) remains completely unaffected.

Final Answer: $t_{1/2}$ is doubled while k remains constant

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:

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

Solution:

(a) The industrial production of ammonia via Haber's process is represented by the gas-phase chemical equation $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.

(b) Evaluating the stoichiometric coefficients shows that 4 moles of gaseous reactants combine to produce 2 moles of gaseous product, resulting in a net decrease in gas volume.

(c) According to Le Chatelier's principle, applying high pressure will shift the equilibrium toward the side with fewer gaseous moles, favoring the forward reaction.

(d) The negative enthalpy change ($\Delta H = -92.4$ kJ/mol) confirms that the forward synthesis of ammonia is a strongly exothermic chemical process.

(e) Because the forward reaction releases heat, lowering the operational temperature shifts the equilibrium forward to favor ammonia formation, meaning high pressure and low temperature optimize the yield.

Final Answer: High pressure and low temperature

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 22

Q23.

Solution

Concept:
The carbylamine test, also known as the Hofmann isocyanide synthesis, is a diagnostic organic reaction used to selectively identify the presence of primary amino groups in an unknown sample.
Solution:

(a) The carbylamine reaction is specific to primary amines, meaning both aliphatic and aromatic primary amines will react to yield a positive result.

(b) When a primary amine is heated with chloroform ($CHCl_3$) and ethanolic potassium hydroxide (KOH), it undergoes a reaction driven by a dichlorocarbene intermediate.

(c) This chemical pathway transforms the primary amino group ($-NH_2$) into an isocyanide or carbylamine functionality ($-NC$), which is readily identified by its foul, repulsive odor.

(d) Evaluating the given options, aniline is an aromatic primary amine, whereas N-methylaniline is secondary, N,N-dimethylaniline is tertiary, and diethylamine is secondary.

(e) Because aniline is the only primary amine in the list, it is the only structure that reacts to form an isocyanide product.

Final Answer: Aniline

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:
Colloidal systems are stabilized by the electrostatic charges present on the surfaces of the dispersed particles, which generate repulsive forces that prevent them from aggregating and settling out.
Solution:

(a) Muddy water contains suspended clay particles that carry negative surface charges, keeping them dispersed throughout the aqueous medium.

(b) When alum ($KAl(SO_4)_2 \cdot 12H_2O$) is added to muddy water, it dissolves to release highly charged aluminum cations (Al^{3+}) into the solution.

(c) These trivalent aluminum cations neutralize the negative charges on the suspended clay particles, eliminating the electrostatic repulsion between them.

(d) Deprived of their stabilizing charge, the neutral particles aggregate into larger clusters via van der Waals forces and precipitate out, a process known as coagulation.

(e) Similarly, the preparation of collodion involves regulating the aggregation behavior of nitrocellulose strings, demonstrating that coagulation governs both industrial processes.

Final Answer: Coagulation of charged colloidal particles by counter ions

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 24

Q25.

Solution

Concept:

The reducing strength of the oxoacids of phosphorus is determined by the presence of hydrogen atoms bonded directly to the central phosphorus atom ($P - H$), which act as active hydride donors.

Solution:

(a) In these structural geometries, hydrogen atoms attached to oxygen ($P - OH$) are acidic and ionizable, whereas hydrogen atoms attached directly to phosphorus ($P - H$) provide reducing power.

(b) Orthophosphoric acid (H_3PO_4) features three $P - OH$ groups and one $P = O$ bond, meaning it has zero direct $P - H$ bonds and lacks reducing properties.

(c) Orthophosphorous acid (H_3PO_3) is a dibasic acid containing two $P - OH$ groups, one $P = O$ bond, and exactly one direct $P - H$ covalent bond.

(d) Hypophosphorous acid (H_3PO_2) is a monobasic acid with a central phosphorus atom bonded to one $P - OH$ group, one $P = O$ bond, and two direct $P - H$ bonds.

(e) Because hypophosphorous acid contains two direct $P - H$ covalent bonds, it releases hydride ions readily, making it a powerful reducing agent.

Final Answer: H_3PO_2 (Hypophosphorous acid)

Answer: (C)

Go Back to Question 25

Q26.

Solution

Concept:
The structural geometry and bonding properties of a molecule can be determined using Valence Shell Electron Pair Repulsion (VSEPR) theory and the concept of orbital hybridization.
Solution:

(a) In a sulfur tetrafluoride (SF_4) molecule, the central sulfur atom belongs to Group 16 and possesses 6 valence electrons.

(b) The sulfur atom forms 4 single covalent sigma bonds with the 4 surrounding fluorine atoms, which consumes 4 of its valence electrons.

(c) The remaining 2 valence electrons form a single non-bonding lone pair on the central sulfur atom.

(d) The total steric number is calculated by adding the 4 sigma bonds and the 1 lone pair, which equals 5 and dictates sp^3d orbital hybridization. A steric number of 5 corresponds to a trigonal bipyramidal electronic arrangement.

Final Answer: See-saw, sp^3d

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:
The chemical characterization of carbohydrates involves using group-specific reagents to identify the open-chain functional groups that exist in equilibrium with their cyclic hemiacetal forms.
Solution:

(a) Hydroxylamine (NH_2OH) is a classic nucleophilic reagent that attacks carbonyl carbons via a condensation mechanism to produce stable oxime derivatives.

(b) Although crystalline D-glucose exists primarily as a cyclic hemiacetal, it establishes a dynamic equilibrium with its open-chain form in aqueous solution.

(c) The open-chain structure of D-glucose contains an aldehyde group at the C1 position, which provides a free, reactive carbonyl group ($-C=O$).

(d) When treated with hydroxylamine, this free carbonyl group reacts to form glucose oxime, confirming that an open-chain carbonyl group is accessible in solution.

Final Answer: A free carbonyl group ($-C=O$)

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:
Stoichiometric neutralization calculations are based on the principle of chemical equivalence, where the total moles of hydroxide ions (OH^-) provided by the base must equal the total moles of hydronium ions (H^+) provided by the acid.

Solution:

(a) Sulfuric acid (H_2SO_4) is a dibasic acid that releases two moles of H^+ ions per mole of acid during complete neutralization.

(b) The total moles of sulfuric acid in the sample are calculated from its volume and molarity: Moles = 0.250 L × 0.1 mol/L = 0.025 mol.

(c) Since each mole of H_2SO_4 yields two moles of H^+ ions, the reaction requires $2 \times 0.025 = 0.050$ moles of monoacidic sodium hydroxide ($NaOH$).

(d) The required mass of pure sodium hydroxide is computed by multiplying the necessary moles by its molar mass: Mass = 0.050 mol × 40 g/mol = 2.0 g.

Final Answer: 2.0 g

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:
A sharp break or discontinuity in a solubility curve indicates a phase transition, where the solid phase in equilibrium with the solution undergoes a structural transformation or change in hydration state.

Solution:

(a) When sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$, known as Glauber's salt) is heated, its solubility initially increases with temperature.

(b) This upward trend continues until the solution reaches a specific transition temperature of 32.4°C.

(c) At this temperature, the hydrated crystals undergo a phase transition, shedding their water of crystallization to form anhydrous sodium sulfate (Na_2SO_4).

(d) The dissolution of anhydrous sodium sulfate is an exothermic process, causing its solubility to decrease as the temperature rises further.

(e) This shift from an endothermic to an exothermic dissolution process creates a distinct sharp break in the solubility curve at the transition point.

Final Answer: Sodium Sulfate Decahydrate ($Na_2SO_4 \cdot 10H_2O$) undergoing dehydration

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 29

Q30.

Solution

Concept:
The acid-catalyzed dehydration of alcohols to form alkenes proceeds via an elimination mechanism where the rate-determining step is the formation of a carbocation intermediate.

Solution:

(a) The reaction begins with the protonation of the hydroxyl group by the acid catalyst to form an alkyloxonium ion, which then loses a water molecule.

(b) This loss of water generates a carbocation intermediate, and its stability determines the overall activation energy and rate of the reaction.

(c) According to thermodynamic principles, carbocation stability follows the sequence $3^\circ > 2^\circ > 1^\circ$ due to inductive effects and hyperconjugation.

(d) Because tertiary carbocations are highly stabilized by surrounding alkyl groups, tertiary alcohols undergo elimination rapidly under mild conditions.

(e) Primary alcohols, which form unstable primary carbocations, require much harsher conditions, establishing the reactivity order $3^\circ > 2^\circ > 1^\circ$.

Final Answer: $3^\circ > 2^\circ > 1^\circ$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 30

Q31.

Solution

Concept:

Green chemistry principles focus on minimizing the environmental impact of chemical manufacturing processes. Various metrics are utilized to measure the environmental friendliness and material efficiency of a specific chemical transformation.

Solution:

(a) The environmental E-factor is an industrial metric introduced by Roger Sheldon to evaluate the mass of waste generated per kilogram of the desired product.

(b) Mathematically, it is expressed as the ratio of the total mass of waste to the total mass of the isolated product, where waste includes everything except the desired product.

(c) A lower E-factor signifies a cleaner process with less byproduct formation, whereas a higher E-factor indicates a significant generation of chemical waste.

(d) Other parameters, like atom economy, measure how many reactant atoms end up in the product rather than quantifying the actual mass ratio of waste generated in a real chemical plant.

Final Answer: Environmental E-factor

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:

The quantum state of an electron in an atom is completely specified by a set of four quantum numbers: principal (n), azimuthal (l), magnetic (m), and spin (s). These values are determined from the ground-state electronic configuration.

Solution:

(a) A neutral potassium atom possesses an atomic number of $Z = 19$, meaning it has nineteen electrons surrounding its nucleus in the ground state.

(b) Writing out the ground-state electronic configuration gives $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$, which shows that the outermost valence electron resides in the $4s$ subshell.

(c) For the $4s$ orbital, the principal quantum number n equals 4, which specifies the fourth energy level or valence shell.

(d) The azimuthal quantum number l denotes the shape of the subshell, and because it is an s subshell, l equals 0.

(e) When $l = 0$, the magnetic quantum number m must also equal 0, and the single electron can have a spin quantum number s of $+\frac{1}{2}$.

Final Answer: n=4, l=0, m=0, s=+1$_2$

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept:
The reaction of alkyl halides with metal cyanides depends heavily on the ambient nucleophilic behavior of the cyanide ion, which contains two distinct attacking sites due to the presence of lone pairs on both carbon and nitrogen atoms.

Solution:

(a) The cyanide ion (CN^-) is an ambident nucleophile that can form a covalent bond through either its carbon atom or its nitrogen atom.

(b) Silver cyanide ($AgCN$) is primarily a covalent compound, which means the bond between the silver atom and the carbon atom is predominantly covalent in nature.

(c) Because the carbon atom is bonded to silver, its lone pair is not freely available, leaving the lone pair on the nitrogen atom as the primary nucleophilic site.

(d) When ethyl bromide (CH_3CH_2Br) is treated with alcoholic $AgCN$, the nitrogen atom attacks the alkyl carbon, expelling the bromide ion via an S_N2 mechanism.

(e) This nucleophilic substitution through the nitrogen atom yields ethyl isocyanide (CH_3CH_2NC) as the principal organic product, unlike ionic KCN which yields a cyanide.

Final Answer: Ethyl isocyanide (CH_3CH_2NC)

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:

The acid dissociation constant (K_a) quantitatively measures the strength of a weak acid in an aqueous solution. The value of pK_a is related to K_a through a negative logarithmic relationship.

Solution:

(a) The acid dissociation constant (K_a) reflects the extent to which an acid dissociates into ions; a larger K_a indicates a greater degree of dissociation and a stronger acid.

(b) The parameter pK_a is mathematically defined as $pK_a = -\log K_a$, which establishes an inverse relationship between the two values.

(c) As a consequence of this mathematical definition, the strongest acid in a given group will possess the largest numerical value of K_a and the smallest numerical value of pK_a.

(d) Comparing the values provided, Acid B exhibits a K_a of 4.5×10^{-4}, which is the largest value among all four weak acids.

(e) Therefore, Acid B dissociates to the greatest extent, giving it the highest acidic strength and the smallest overall numerical value of pK_a.

Final Answer: Acid B: $\text{K}_a = 4.5 \times 10^{-4}$

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:

The maximum oxidation state of elements in a group is restricted by their position and electronic structure. While some heavy transition metals and noble gases can reach an oxidation state of +8, lighter elements face limitations.

Solution:

(a) Osmium (Os) and ruthenium (Ru) are heavy d-block transition metals that can utilize all their valence shell electrons to form stable, volatile tetroxides (OsO_4 and RuO_4) with a +8 oxidation state.

(b) Xenon (Xe) is a heavy noble gas that can expand its octet using empty outer d-orbitals to form a volatile, stable tetroxide (XeO_4) where xenon exhibits a +8 state.

(c) Iron (Fe) is a member of the first transition series ($3d$ row) and cannot stabilize an oxidation state of +8 under standard chemical conditions due to its high ionization enthalpies.

(d) The maximum common oxidation states for iron are limited to +2, +3, and occasionally +6 in ferrates, meaning it does not form a stable tetroxide compound.

Final Answer: Iron (Fe)

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept:

Lanthanoid contraction refers to the steady and significant decrease in the atomic and ionic radii of elements across the lanthanoid series, which strongly impacts the chemistry of subsequent transition series.

Solution:

(a) As we move from lanthanum to lutetium across the $4f$ inner transition series, the nuclear charge increases by one unit at each successive element.

(b) The corresponding electrons are added progressively to the inner $4f$ subshell rather than the outermost valence shells.

(c) Due to their diffuse shapes and poor spatial orientation, $4f$ orbitals exhibit very poor shielding properties compared to s, p, and d orbitals.

(d) This poor shielding fails to counteract the increasing positive charge of the nucleus, causing the effective nuclear charge experienced by the outer electrons to rise steadily.

(e) Consequently, the entire electron cloud is pulled tighter toward the nucleus, resulting in a regular contraction in atomic and ionic sizes across the series.

Final Answer: An increase in effective nuclear charge paired with poor shielding by 4f electrons

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 36

Q37.

Solution

Concept:

Isoelectronic chemical species possess the same total number of electrons, meaning their sizes are determined exclusively by the relative magnitude of their positive nuclear charges.

Solution:

(a) The chemical species N^{3-}, O^{2-}, and F^{-} each contain a total of ten electrons, giving them identical ground-state electronic configurations ($1s^2 2s^2 2p^6$).

(b) The nuclear charge, which corresponds to the number of protons in the nucleus, varies among these species and is equal to 7 for nitrogen, 8 for oxygen, and 9 for fluorine.

(c) A higher nuclear charge exerts a stronger electrostatic pull on the same number of surrounding electrons, drawing the electron cloud closer to the nucleus.

(d) Because the fluorine nucleus has the most protons, it pulls its ten electrons most tightly, making F^{-} the smallest ion in this series.

(e) Conversely, the nitrogen nucleus has the fewest protons and exerts the weakest pull, which leaves N^{3-} with the largest radius, giving the sequence $F^{-} < O^{2-} < N^{3-}$.

Final Answer: $\mathrm{F}^{-} < O^{2-} < N^{3-}$

Answer: (B)

Go Back to Question 37

Q38.

Solution

Concept:
The conversion of aromatic primary amines into aryl halides involves the initial generation of an un-isolated intermediate, followed by nucleophilic substitution catalyzed by specific transition metal salts.

Solution:

(a) When an aromatic primary amine like aniline is treated with nitrous acid at cold temperatures ($0 - 5°$C), it undergoes a diazotization reaction to form a stable benzenediazonium salt.

(b) The diazonium group ($-N_2^+$) serves as an exceptionally good leaving group due to the thermodynamic stability of nitrogen gas.

(c) Introducing a cuprous halide salt, such as cuprous chloride (Cu_2Cl_2), dissolved in its corresponding halogen acid (HCl), initiates a radical-mediated substitution process.

(d) This cuprous salt facilitates the replacement of the diazonium group with a chlorine atom on the aromatic ring, a transformation known as the Sandmeyer reaction.

(e) While the Gattermann reaction achieves a similar synthetic conversion, it utilizes copper powder instead of cuprous salts, distinguishing it from the process described.

Final Answer: Sandmeyer Reaction

Answer: (B)

Go Back to Question 38

Q39.

Solution

Concept:
Environmental monitoring of aquatic ecosystems relies on standardized analytical indices to evaluate the concentration of organic pollutants and determine the overall health of water bodies.

Solution:

(a) When organic waste is discharged into water pathways, native aerobic microorganisms consume dissolved oxygen while metabolizing and decomposing these carbon-based compounds.

(b) Biochemical Oxygen Demand (BOD) is defined as the total amount of dissolved oxygen required by microorganisms to decompose the organic matter present in a given water sample over a specific time period.

(c) A higher BOD value signifies a substantial concentration of organic pollutants, which depletes the dissolved oxygen supply and threatens aquatic life.

(d) Chemical Oxygen Demand (COD) is a separate parameter that measures pollution levels through chemical oxidation with dichromate, rather than biological degradation by microorganisms.

Final Answer: Biochemical Oxygen Demand (BOD)

Answer: (C)

Go Back to Question 39

Q40.

Solution

Concept:
Raoult's law states that the partial vapor pressure of each volatile component in an ideal solution is directly proportional to its mole fraction in the liquid mixture.

Solution:

(a) The solution contains 1 mole of component X and 3 moles of component Y, yielding a total number of moles equal to $1 + 3 = 4$ moles.

(b) The mole fractions of each component in the liquid phase are calculated as $\chi_X = \frac{1}{4} = 0.25$ and $\chi_Y = \frac{3}{4} = 0.75$.

(c) According to Raoult's law, the total vapor pressure (P_{total}) exerted by an ideal mixture is given by the expression $P_{\text{total}} = \chi_X \cdot P_X^\circ + \chi_Y \cdot P_Y^\circ$.

(d) Substituting the values into the equation yields $P_{\text{total}} = (0.25 \times 100 \text{ mm Hg}) + (0.75 \times 200 \text{ mm Hg})$.

(e) Evaluating the terms gives $P_{\text{total}} = 25 \text{ mm Hg} + 150 \text{ mm Hg} = 175 \text{ mm Hg}$, confirming the total pressure of the ideal solution.

Final Answer: 175 mm Hg

Answer: (B)

Go Back to Question 40

Q41.

Solution

Concept:
Carbohydrates are categorized as reducing or non-reducing sugars depending on whether they possess a free, reactive hemiacetal or hemiketal group that can establish an equilibrium with an open-chain carbonyl form in solution.

Solution:

(a) Reducing sugars like maltose, lactose, and cellobiose contain an anomeric carbon atom that is not involved in a glycosidic linkage, allowing the ring to open and reduce mild oxidizing agents.

(b) When a sugar exists in this dynamic cyclic-to-open-chain equilibrium, it exhibits mutarotation and reacts with phenylhydrazine to yield crystalline osazone derivatives.

(c) In a sucrose molecule, a glycosidic bond forms directly between the anomeric carbon C1 of alpha-D-glucose and the anomeric carbon C2 of beta-D-fructose.

(d) This condensation reaction ties up both reactive aldehyde and ketone carbonyl functions, completely preventing the cyclic sugar rings from unlocking into open-chain forms.

(e) Because both potentially reducing groups are locked within the stable disaccharide framework, sucrose cannot show mutarotation, form an osazone, or reduce Tollen's reagent.

Final Answer: Sucrose

Answer: (C)

Go Back to Question 41

Q42.

Solution

Concept:
Conductometric titrations monitor variations in the electrical conductivity of a reaction mixture as an titrant is introduced, reflecting the changing concentrations and mobilities of the ions present.
Solution:

(a) In the neutralization of a strong acid like hydrochloric acid (HCl) with a strong base like sodium hydroxide ($NaOH$), highly mobile hydronium ions (H^+) are initially abundant.

(b) As the strong base is added from a burette, these highly conductive H^+ ions are progressively consumed to form water and are replaced by less mobile sodium ions (Na^+).

(c) This substitution causes a sharp, linear decrease in the total electrolytic conductivity of the solution until it hits the exact chemical equivalence point.

(d) Past the equivalence point, the further introduction of sodium hydroxide yields a steady accumulation of highly conductive, free hydroxide ions (OH^-) in the vessel.

(e) This sudden accumulation causes a sharp, linear rise in conductivity, generating the symmetrical V-shaped profile illustrated in the provided conductometric graph.

Final Answer: Titration of a Strong Acid (HCl) with a Strong Base ($NaOH$)

Answer: (B)

Go Back to Question 42

Q43.

Solution

Concept:
The structural architecture of multinuclear transition metal carbonyl complexes depends heavily on the balancing of metal-metal bonds, terminal ligand coordination, and bridging ligand configurations.

Solution:

(a) Dicobalt octacarbonyl, represented by the empirical formula $Co_2(CO)_8$, displays a highly temperature-dependent structural equilibrium between bridged and non-bridged isomers.

(b) In its standard, stable crystalline state, the molecule adopts a closed, bridged structure that satisfies the effective atomic number rule for both cobalt centers.

(c) X-ray diffraction studies confirm that this crystalline conformation features a direct cobalt-cobalt metal single bond alongside six terminal carbonyl groups.

(d) The remaining two carbonyl ligands are shared equally between the two metal centers, acting as bridging carbonyl groups (μ-CO) that span the cobalt-cobalt axis.

(e) Consequently, a single stable molecular entity of this coordination compound contains exactly two bridging carbonyl groups in its solid state.

Final Answer: 2

Answer: (B)

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Q44.

Solution

Concept:
Aldehydes possessing alpha-hydrogen atoms undergo base-catalyzed self-condensation reactions when heated with concentrated alkaline solutions, yielding unsaturated condensation products.

Solution:

(a) When acetaldehyde (CH_3CHO) is treated with concentrated sodium hydroxide ($NaOH$), the base abstracts an alpha-hydrogen to form a resonance-stabilized enolate nucleophile.

(b) This reactive enolate attacks the electrophilic carbonyl carbon of a second acetaldehyde molecule, producing a beta-hydroxyaldehyde intermediate known as aldol.

(c) Upon heating, this aldol intermediate undergoes rapid, base-catalyzed dehydration to eliminate a water molecule and form an extended, conjugated pi-system.

(d) The loss of water converts the beta-hydroxyaldehyde into a stable alpha,beta-unsaturated aldehyde, specifically named but-2-enal or crotonaldehyde.

(e) This sequence represents a classic self-aldol condensation pathway, where crotonaldehyde ($CH_3 - CH = CH - CHO$) isolates as the major organic product.

Final Answer: Crotonaldehyde ($CH_3 - CH = CH - CHO$)

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 44

Q45.

Solution

Concept:

The second law of thermodynamics establishes the energetic parameters required to determine whether a macroscopic chemical or physical change can occur without external intervention.

Solution:

(a) Determining the spontaneity of a chemical process requires looking at the total entropy change of the universe, which includes both the system and the surroundings.

(b) For operations occurring under standard laboratory conditions of constant temperature and pressure, these dual criteria are wrapped into the Gibbs free energy function (G).

(c) The mathematical change is given by the relation $\Delta G = \Delta H - T\Delta S$, which reflects the net balance between enthalpy changes and entropy shifts.

(d) A chemical process can only proceed spontaneously if it results in a net decrease in the Gibbs free energy of the system, which is expressed as $\Delta G < 0$.

(e) While exothermic reactions ($\Delta H < 0$) or positive system entropy changes ($\Delta S > 0$) favor spontaneity, neither serves as an absolute state criterion on its own.

Final Answer: $\Delta G < 0$

Answer: (C)

Go Back to Question 45

Q46.

Solution

Concept:
Gas adsorption on solid adsorbents is divided into physisorption and chemisorption, depending on the magnitude and nature of the forces holding the gas molecules to the surface.
Solution:

(a) Physical adsorption, or physisorption, occurs when gas molecules accumulate on a solid surface via weak, non-specific van der Waals intermolecular forces.

(b) Because these intermolecular forces are weak, physisorption is inherently reversible, and a decrease in pressure or an increase in temperature easily desorbs the gas.

(c) The non-specific nature of van der Waals interactions allows multiple layers of gas molecules to stack on top of one another, forming a multilayer configuration.

(d) The heat released during this weak interaction is low, resulting in a low enthalpy of adsorption that typically ranges between 20 and 40 kilojoules per mole.

(e) This contrasts with chemisorption, which involves forming strong chemical bonds, creating a single layer, and releasing a much higher enthalpy of adsorption.

Final Answer: Lack of specificity, reversibility, and low enthalpy of adsorption ($\Delta H \approx 20 - 40$ kJ mol^{-1})

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 46

Q47.

Solution

Concept:

The periodic trends of Group 15 hydrides (MH_3) are governed by the atomic size and electronegativity of the central pnictogen atom, which dictate bond strength and electron pair repulsion.

Solution:

(a) Moving down Group 15 from nitrogen to antimony, the atomic radius of the central element increases significantly while its electronegativity decreases.

(b) In ammonia (NH_3), the highly electronegative nitrogen atom draws bonding electron pairs close to itself, generating strong electrostatic repulsions that open the $H - N - H$ bond angle to 107.8°.

(c) Down the group, the bonding pairs drift further from the larger central atoms, reducing repulsion and causing the bond angles to contract toward 90° as pure p-orbitals drive the bonding.

(d) Simultaneously, the increase in atomic size leads to longer, weaker metal-hydrogen ($M - H$) bonds with lower bond dissociation enthalpies.

(e) Ammonia features the shortest and strongest $M - H$ covalent bonds, giving it the highest thermal stability alongside the largest bond angle in the series.

Final Answer: $\mathrm{NH_3}$

Answer: (A)

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Q48.

Solution

Concept:

Alkyl halides undergo competing substitution and elimination pathways when treated with basic reagents, where the outcome is regulated by base strength, temperature, and solvent polarity.

Solution:

(a) When a primary haloalkane is heated with potassium hydroxide (KOH), the identity of the solvent shifts the reaction pathway between substitution and elimination.

(b) Dissolving potassium hydroxide in pure ethanol generates ethoxide ions ($CH_3CH_2O^-$), which act as a highly hindered, strong Brønsted-Lowry base.

(c) Heating the mixture provides the activation energy needed to favor an elimination over a substitution pathway.

(d) The strong ethoxide base abstracts a beta-hydrogen from the haloalkane while the leaving group departs simultaneously, driving a concerted E2 elimination mechanism.

(e) This elimination pathway removes a molecule of hydrogen halide from the unbranched primary haloalkane, yielding an alkene as the major organic product.

Final Answer: Elimination (E2), forming an Alkene

Answer: (B)

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Q49.

Solution

Concept:
Industrial polymerizations utilize specialized coordination catalysts to control the stereochemistry, branching, and density of macromolecular polymers under mild conditions.

Solution:

(a) High-density polyethylene ($HDPE$) is produced commercially under low pressures and temperatures using coordination polymerization techniques.

(b) This process relies on a organometallic catalyst known as the Ziegler-Natta catalyst, which consists of a mixture of titanium tetrachloride ($TiCl_4$) and triethylaluminium ($Al(C_2H_5)_3$).

(c) The interaction between these components creates a highly active coordination site on a transition metal surface.

(d) Ethene monomers insert into the titanium-carbon bond, driving linear polymer growth with minimal chain branching.

(e) This linear structure allows the polymer chains to pack tightly together, creating a high-density, highly crystalline material compared to free-radical pathways.

Final Answer: Ziegler-Natta Catalyst [Titanium tetrachloride and Triethylaluminium]

Answer: (B)

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Q50.

Solution

Concept:
The systematic nomenclature of coordination compounds follows IUPAC guidelines, which dictate the ordering of ligands, the naming of the central metal, and the indication of its formal oxidation state.

Solution:

(a) In naming a coordination complex, ligands are listed first in alphabetical order, disregarding any numerical prefixes, followed by the central metal atom.

(b) The complex contains four neutral ammine ligands (NH_3) and two neutral aqua ligands (H_2O), which are arranged alphabetically to yield the prefix tetraamminediacua.

(c) The central transition metal is chromium; since the coordination sphere carries a net positive charge, the metal retains its standard name, chromium.

(d) The formal oxidation state of the metal is calculated by balancing charges: $x+4(0)+2(0)-3 = 0$, which gives $x = +3$ and is written in Roman numerals as (III).

(e) Combining these components with the counter anion yields the complete IUPAC name: tetraamminediacuachromium(III) chloride.

Final Answer: Tetraamminediacuachromium(III) chloride

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	D	4	C	5	C
6	A	7	B	8	B	9	C	10	B
11	A	12	B	13	B	14	B	15	B
16	C	17	A	18	B	19	C	20	A
21	B	22	C	23	B	24	B	25	C
26	B	27	B	28	B	29	B	30	B
31	B	32	A	33	B	34	B	35	C
36	A	37	B	38	B	39	C	40	B
41	C	42	B	43	B	44	A	45	C
46	C	47	A	48	B	49	B	50	A