UPCATET Chemistry Sample Paper-4

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. An organic compound with molecular formula $C_4H_{10}O$ does not react with sodium metal. Upon treatment with excess hot hydroiodic acid (HI), it yields a single alkyl iodide. Identify the organic compound.

(A) Diethyl ether

(B) Methyl propyl ether

(C) 1-Butanol

(D) 2-Butanol

Q2. Arrange the following carbocations in decreasing order of their stability:

(I) $(CH_3)_3C^+$ (II) $(C_6H_5)_2CH^+$ (III) $C_6H_5CH_2^+$ (IV) $CH_3CH_2CH_2^+$

(A) I > II > III > IV

(B) II > I > III > IV

(C) II > III > I > IV

(D) I > III > II > IV

Q3. Consider the following named organic transformation:

$$2\ CH_3CHO \xrightarrow{\text{dil. NaOH}} CH_3CH(OH)CH_2CHO \xrightarrow{\Delta} CH_3CH{=}CHCHO$$

Which intermediate species drives the formation of compound (B) from the starting material?

(A) A carbocation intermediate at the α-carbon

(B) A resonance-stabilized enolate carbanion

(C) A free radical generated by thermal cleavage

(D) An acylium ion formed via dehydration

Q4. Which of the following forms a non-reducing sugar structural component upon undergoing a condensation linkage to form sucrose?

(A) α-D-glucopyranose and β-D-fructofuranose

(B) β-D-glucopyranose and α-D-fructofuranose

(C) α-D-galactopyranose and β-D-fructofuranose

(D) α-D-glucopyranose and α-D-glucopyranose

Q5. During the electrophilic aromatic substitution of chlorobenzene, the chlorine atom acts as an:

(A) Ortho/para-director and activating group

(B) Meta-director and deactivating group

(C) Ortho/para-director and deactivating group

(D) Meta-director and activating group

Q6. What is the major product obtained when 2-bromobutane is heated with concentrated alcoholic KOH?

(A) 1-Butene

(B) trans-2-Butene

(C) cis-2-Butene

(D) 2-Butanol

Q7. Which test can be successfully used to chemically distinguish between benzaldehyde and acetophenone?

(A) Tollen's test

(B) Iodoform test

(C) Both (A) and (B)

(D) Fehling's test

Q8. Identify the main product of the Reimer-Tiemann reaction when phenol reacts with chloroform in the presence of aqueous sodium hydroxide.

(A) Salicylic acid

(B) Salicylaldehyde

(C) Acetophenone

(D) Benzyl alcohol

Q9. The denaturation of proteins leads to the destruction of which of the following structural levels?

(A) Primary structure only

(B) Secondary and tertiary structures only

(C) Primary, secondary, and tertiary structures

(D) Secondary, tertiary, and quaternary structures

Q10. Which sequence correctly represents the ascending order of reactivity of the following acyl derivatives towards nucleophilic acyl substitution?

R–COCl (I), R–COOR' (II), R–$CONH_2$ (III), $(RCO)_2O$ (IV)

(A) III < II < IV < I

(B) I < IV < II < III

(C) III < IV < II < I

(D) II < III < IV < I

Q11. When primary amines are treated with chloroform and ethanolic KOH, a foul-smelling substance is produced. This reaction is known as:

(A) Hofmann bromamide reaction

(B) Carbylamine reaction

(C) Gabriel phthalimide synthesis

(D) Schotten-Baumann reaction

Q12. What will be the major product when propene reacts with HBr in the presence of dibenzoyl peroxide?

(A) 2-Bromopropane

(B) 1-Bromopropane

(C) 1,2-Dibromopropane

(D) 2-Propanol

Q13. Which of the following structures represents the chemical skeleton of the monomer used to synthesize Nylon-6?

Caprolactam

(A) Hexamethylenediamine

(B) Adipic acid

(C) ε-Caprolactam

(D) Ethylene glycol

Q14. The conversion of an optically active alkyl halide into an alcohol via the S_N2 pathway results strictly in:

(A) Complete racemization

(B) 100% inversion of configuration

(C) Partial retention of configuration

(D) Complete retention of configuration

Q15. What is the total number of ions present in 100 mL of a 0.1 M solution of calcium chloride (CaCl2) assuming complete dissociation? ($N_A = 6.022 \times 10^{23}$)

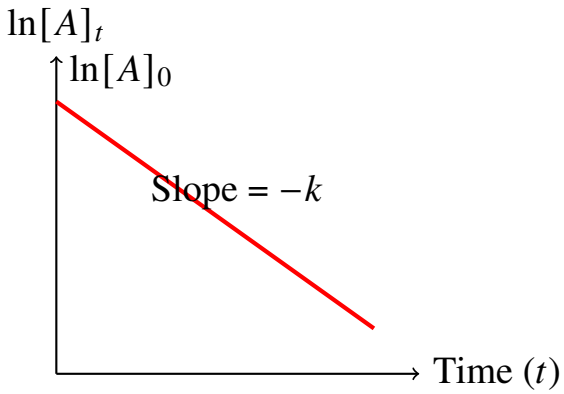
(A) 1.806×10^{22}

(B) 6.022×10^{22}

(C) 1.806×10^{23}

(D) 6.022×10^{21}

Q16. A graph of a certain chemical kinetics run is plotted below:



Based on the graphical representation, what is the order of the corresponding reaction?

(A) Zero-order

(B) First-order

(C) Second-order

(D) Half-order

Q17. The vapor pressure of pure water at 298 K is 23.8 mmHg. Calculate the vapor pressure of a solution containing 30 g of urea (Molar mass = 60 g mol^{-1}) dissolved in 846 g of water.

(A) 23.55 mmHg

(B) 22.75 mmHg

(C) 24.12 mmHg

(D) 23.23 mmHg

Q18. The standard EMF (E°) for the cell reaction Zn(s) + $Cu^2 + (aq) - > Zn^2 + (aq) + Cu(s) is 1.10$ V. $What is the value of equilibrium constant$ (K_c) for this process at 298 K? ($\frac{2.303RT}{F} = 0.0591$ V)

(A) 1.9×10^{37}

(B) 2.4×10^{28}

(C) 1.5×10^{15}

(D) 4.8×10^{32}

Q19. For the chemical equilibrium N2(g) + 3H2(g) <=> 2NH3(g), the value of K_p/K_c is equal to:

(A) $(RT)^2$

(B) $(RT)^{-2}$

(C) $(RT)^{-1}$

(D) $(RT)^1$

Q20. How much charge in Faradays (F) is required to achieve the complete quantitative reduction of one mole of MnO_4^- ions to Mn^{2+} in an acidic medium?

(A) 1 F

(B) 3 F

(C) 5 F

(D) 7 F

Q21. An aqueous solution of a non-volatile solute boils at 100.156°C. Determine its freezing point if the cryoscopic and ebullioscopic constants for water are 1.86 K kg mol^{-1} and 0.52 K kg mol^{-1} respectively.

(A) −0.558°C

(B) −0.156°C

(C) −0.312°C

(D) −0.744°C

Q22. If the rate constant of a first-order thermal decomposition reaction is 4.606×10^{-3} s^{-1}, calculate the time required for the initial reactant concentration to drop down to 10% of its baseline value.

(A) 200 s

(B) 500 s

(C) 1000 s

(D) 100 s

Q23. The solubility product (K_{sp}) of a sparingly soluble salt Al(OH)3 in water at a specific temperature is denoted as K_{sp}. Its molar solubility (S) can be found using the expression:

(A) $S = (K_{sp}/4)^{1/3}$

(B) $S = (K_{sp}/27)^{1/4}$

(C) $S = (K_{sp}/108)^{1/5}$

(D) $S = (K_{sp})^{1/2}$

Q24. The resistance of a 0.05 M electrolyte solution filled in a conductivity cell is found to be 200 Ω. If the cell constant is 1.0 cm^{-1}, the molar conductivity (Λ_m) of the solution in S cm^2 mol^{-1} is:

(A) 100

(B) 50

(C) 200

(D) 1000

Q25. What volume of water must be added to 200 mL of an aqueous 0.5 M HCl solution to exactly change its concentration to 0.1 M?

(A) 1000 mL

(B) 800 mL

(C) 600 mL

(D) 400 mL

Q26. During an isothermal reversible expansion of an ideal gas into a vacuum (free expansion), the values of thermodynamic parameters q, w, and ΔU are:

(A) $q > 0, w < 0, \Delta U = 0$

(B) $q = 0, w = 0, \Delta U = 0$

(C) $q < 0, w > 0, \Delta U > 0$

(D) $q = 0, w < 0, \Delta U < 0$

Q27. The pH of a buffer system prepared by mixing equal volumes of 0.2 M acetic acid ($K_a = 1.8 \times 10^{-5}$) and 0.2 M sodium acetate will be closest to:

(A) 7.00

(B) 4.74

(C) 3.74

(D) 5.74

Q28. The primary valency and secondary valency of the central metal atom in the coordination complex [Co(NH3)5Cl]Cl2 are respectively:

(A) 3 and 6

(B) 2 and 5

(C) 3 and 5

(D) 1 and 6

Q29. Which of the following compounds displays the highest structural stability due to the presence of a chelate ring framework?

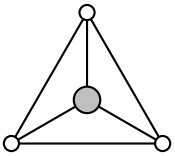
(A) $[Fe(H2O)6]^{3}+$

(A) $[Fe(NH3)6]^{3}+$

(A) $[Fe(ox)3]^{3}-$

(A) $[Fe(Cl)6]^{3}-$

Q30. Consider the basic structural unit layout of a silicate mineral class below:



General Formula: $[SiO_4]^{4-}$

Which crystalline arrangement is produced when exactly two oxygen vertices of each structural unit are shared endlessly in a linear fashion?

(A) Orthosilicates

(B) Sheet silicates

(C) Chain silicates (pyroxenes)

(D) Three-dimensional framework silicates

Q31. The disproportionation reaction of phosphorous acid (H3PO3) on thermal heating yields which of the following sets of phosphorus-containing compounds?

(A) H3PO4 and PH3

(B) HPO3 and PH3

(C) H4P2O7 and P2O5

(D) P4O10 and H2

Q32. Which noble gas configuration is responsible for showing the lowest boiling point among all known elemental substances due to weak dispersion forces?

(A) Argon (Ar)

(B) Helium (He)

(C) Neon (Ne)

(D) Krypton (Kr)

Q33. What is the correct magnetic property assignment and number of unpaired electrons in the high-spin octahedral complex $[CoF_6]^{3-}$? (Atomic number of Co = 27)

(A) Diamagnetic, 0

(B) Paramagnetic, 2

(C) Paramagnetic, 4

(D) Paramagnetic, 5

Q34. During the commercial metallurgical extraction of gold and silver, the crushed ore is leached with a dilute solution of NaCN in the presence of air to form a soluble cyano-complex. The metal is then recovered by a displacement reaction using:

(A) Copper (Cu)

(B) Zinc (Zn)

(C) Iron (Fe)

(D) Sodium (Na)

Q35. Which oxide of nitrogen is a colored blue liquid at low temperatures and exists as an anhydride of nitrous acid?

(A) N2O

(B) NO2

(C) N2O3

(D) N2O5

Q36. The sharp decrease in the atomic and ionic radii along the actinide series, known as actinide contraction, is predominantly caused by:

(A) Poor shielding effect of $5f$ orbitals

(B) Effective shielding of $6d$ orbitals

(C) High shielding ability of $4f$ electrons

(D) Strong penetrating power of $7s$ orbitals

Q37. In the industrial isolation of high-purity iron inside a blast furnace, which chemical substance behaves as the primary slag-forming flux agent to clear away silica impurities?

(A) CaCO3 (decomposing to CaO)

(B) C (Coke)

(C) CO gas

(D) Al2O3

Q38. Which set of structural isomers is illustrated by the pair [Co(NH3)5(SO4)]Br and [Co(NH3)5Br]SO4?

(A) Linkage isomerism

(B) Coordination isomerism

(C) Ionization isomerism

(D) Solvate isomerism

Q39. Which of the following sets of quantum numbers describes an electron residing in a $4d$ subshell orbital?

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

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

(C) $n = 4, l = 3, m_l = +2, m_s = +\frac{1}{2}$

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

Q40. Predict the correct molecular geometry shape and the hybridisation state of the central atom for the sulfur tetrafluoride (SF4) molecule.

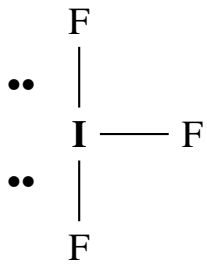
(A) Tetrahedral, sp^3

(B) See-saw, sp^3d

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

(D) Trigonal bipyramidal, sp^3d

Q41. The geometry framework of a specific interhalogen species is diagrammed below:



Identify the molecule corresponding to this T-shaped spatial orientation containing two lone pairs on its central atom.

(A) ClF3

(B) BF3

(C) NF3

(D) PF3

Q42. According to Molecular Orbital Theory (MOT), which of the following homonuclear diatomic species is expected to be diamagnetic with a formal bond order of 2?

(A) O2

(B) B2

(C) C2

(D) $N2^{2}+$

Q43. The correct increasing order of the first ionization enthalpy values for the second-period elements carbon (C), nitrogen (N), oxygen (O), and fluorine (F) is:

(A) C < O < N < F

(B) C < N < O < F

(C) O < C < N < F

(D) C < O < F < N

Q44. Which type of intermolecular attractive forces is primarily responsible for holding molecules together in a molecular solid crystal of Iodine (I2)?

(A) Dipole-dipole interactions

(B) London dispersion forces

(C) Hydrogen bonding

(D) Ion-dipole forces

Q45. The number of radial nodes and angular nodes present in a $3p$ atomic orbital are respectively:

(A) 1 and 1

(B) 2 and 0

(C) 0 and 2

(D) 1 and 2

Q46. Which pair of chemical species is perfectly isostructural and isoelectronic with each other?

(A) $CO3^{2} - andNO3^{-}$

(A) SO2 and CO2

(B) $ClO3^{-}andSO3$

(B) NF3 and BF3

Q47. When a beam of intense light is passed through a colloidal solution, the scattering of light paths becomes visible. This phenomenon is known as the:

(A) Electrophoresis effect

(B) Tyndall effect

(C) Brownian movement

(D) Hardy-Schulze rule

Q48. According to the Freundlich adsorption isotherm equation, the path relationship between the mass of gas adsorbed per gram of adsorbent (x/m) and equilibrium pressure (P) in the intermediate pressure range is written as:

(A) $x/m = kP^1$

(B) $x/m = kP^0$

(C) $x/m = kP^{1/n}$ $(n > 1)$

(D) $x/m = k/P$

Q49. Which atmosphere-polluting chemical compound is primarily responsible for binding tightly with blood hemoglobin to form carboxyhemoglobin, reducing oxygen transport efficiency?

(A) Carbon dioxide (CO2)

(B) Sulfur dioxide (SO2)

(C) Carbon monoxide (CO)

(D) Nitrogen dioxide (NO2)

Q50. Which of the following processes or choices represents a fundamental practice aligned with the core principles of Green Chemistry?

(A) Using volatile organic solvents like CCl4 extensively

(B) Maximizing atom economy in synthetic chemical pathways

(C) Discarding industrial byproducts into nearby water streams

(D) Prioritizing non-biodegradable polymer production

Detailed Solutions

Q1.

Solution

Concept: Ethers do not have active hydrogen and fail to react with sodium metal. Cleavage of ethers with excess hot HI yields alkyl iodides via nucleophilic substitution.

Solution:

(a) The formula $C_4H_{10}O$ corresponds to either an alcohol or an ether. Since it does not react with sodium metal, it must be an ether (ruling out 1-butanol and 2-butanol).

(b) Symmetrical ethers yield a single type of alkyl iodide upon cleavage with excess HI.

(c) Diethyl ether ($CH_3CH_2OCH_2CH_3$) reacts with excess HI to produce two moles of ethyl iodide (CH_3CH_2I) and water:

$$CH_3CH_2OCH_2CH_3 + 2HI \rightarrow 2CH_3CH_2I + H_2O$$

(d) Unsymmetrical methyl propyl ether would yield a mixture of methyl iodide and propyl iodide.

Final Answer:

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: Carbocation stability depends on inductive effects, hyperconjugation, and resonance delocalization. Resonance stabilization by phenyl rings is generally stronger than hyperconjugation.
Solution:

(a) Species (II) $(C_6H_5)_2CH^+$ is stabilized by extensive resonance from two benzene rings, making it highly stable.

(b) Species (I) $(CH_3)_3C^+$ is a tertiary carbocation stabilized by 9 hyperconjugative α-hydrogens and $+I$ effects.

(c) Species (III) $C_6H_5CH_2^+$ is a secondary/benzylic carbocation stabilized by resonance with one phenyl ring. It is less stable than the tertiary carbocation (I) due to the exceptional hyperconjugation in the t-butyl cation.

(d) Species (IV) $CH_3CH_2CH_2^+$ is a primary carbocation with only 2 hyperconjugative hydrogens, making it the least stable.

Final Answer:

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: The self-condensation of aldehydes containing α-hydrogens in the presence of a dilute base is known as the Aldol condensation reaction.
Solution:

(a) Acetaldehyde (CH_3CHO) contains three α-hydrogens which are weakly acidic.

(b) The dilute base (NaOH) abstracts an α-proton from one molecule of acetaldehyde to generate a nucleophilic, resonance-stabilized enolate carbanion intermediate:

$$CH_3CHO + OH^- \rightleftharpoons [H_2CHO \leftrightarrow CH_2{=}CH\text{-}O^-] + H_2O$$

(c) This enolate carbanion attacks the electrophilic carbonyl carbon of a second acetaldehyde molecule to form a β-hydroxyaldehyde (Aldol), driving the transformation.

Final Answer:

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: Sucrose is a non-reducing disaccharide formed by a glycosidic linkage that locks the anomeric carbons of both constituent monosaccharide units.

Solution:

(a) Sucrose is synthesized through a condensation reaction connecting an aldohexose and a ketohexose unit.

(b) The specific linkage occurs between the C − 1 anomeric hydroxyl group of α-D-glucopyranose and the C − 2 anomeric hydroxyl group of β-D-fructofuranose.

(c) Because both reducing centers (anomeric carbons) participate directly in the $\alpha(1 \rightarrow 2)$ glycosidic bond, sucrose lacks a free aldehyde or ketone group and behaves as a non-reducing sugar.

Final Answer:

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: Substituents on a benzene ring influence both the rate of electrophilic aromatic substitution and the regiochemical position of the incoming electrophile.

Solution:

(a) The chlorine atom exhibits a strong electron-withdrawing inductive effect ($-I$) due to its high electronegativity, which decreases the overall electron density of the ring, acting as a deactivating group.

(b) Concurrently, chlorine possesses lone pairs of electrons that can be shared with the aromatic system via resonance ($+R$ effect).

(c) This resonance stabilization specifically increases electron density at the ortho and para positions relative to the meta position, directing substitution to those sites.

Final Answer:

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Heating an alkyl halide with a strong, sterically unhindered base like alcoholic KOH promotes dehydrohalogenation via an E2 elimination mechanism.

Solution:

(a) Elimination of HBr from 2-bromobutane can yield two regioisomers: 1-butene or 2-butene.

(b) According to Saytzeff's rule, the more highly substituted and conjugated alkene is the major product because it is thermodynamically more stable. Thus, 2-butene dominates over 1-butene.

(c) Between the stereoisomers of 2-butene, trans-2-butene is less sterically hindered and lower in energy than cis-2-butene, making it the predominant major product.

Final Answer:

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Chemical tests differentiate functional groups based on distinct structural features like aldehydes versus methyl ketones.

Solution:

(a) Benzaldehyde (C_6H_5CHO) is an aromatic aldehyde. It reduces Tollen's reagent to form a silver mirror but does not contain a methyl ketone group, so it fails the iodoform test.

(b) Acetophenone ($C_6H_5COCH_3$) is a methyl ketone. It contains the -$COCH_3$ group, yielding a yellow precipitate of iodoform (CHI_3), but it fails to reduce Tollen's reagent.

(c) Thus, both Tollen's test and the Iodoform test can successfully distinguish them. Note that Fehling's test cannot be used as it does not reduce aromatic aldehydes.

Final Answer:

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: The Reimer-Tiemann reaction introduces a formyl group (-CHO) onto an activated aromatic ring, specifically targeting the ortho position of phenols.

Solution:

(a) Phenol is treated with chloroform ($CHCl_3$) in an aqueous alkaline medium (NaOH).

(b) The base reacts with chloroform to generate a highly reactive dichlorocarbene intermediate (: CCl_2).

(c) The phenoxide ion undergoes electrophilic attack by the carbene, primarily at the sterically favored and ortho-directed position. Subsequent hydrolysis yields 2-hydroxybenzaldehyde, commonly known as salicylaldehyde.

Final Answer:

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: Denaturation alters the unique three-dimensional conformation of a protein without breaking the strong covalent bonds holding its basic backbone together.

Solution:

(a) Physical factors (like heat) or chemical factors (like pH changes) disrupt hydrogen bonds, disulfide linkages, and hydrophobic interactions.

(b) This disruption unfolds the complex quaternary, tertiary, and secondary structural geometries of the protein.

(c) The primary structure, which is maintained by covalent peptide bonds between amino acids, remains fully intact during standard denaturation processes.

Final Answer:

Answer: (D)

Go Back to Question 9

Q10.

Solution

Concept: The reactivity of carboxylic acid derivatives toward nucleophilic acyl substitution depends heavily on the leaving group ability and resonance stabilization of the carbonyl group.

Solution:

(a) Better leaving groups and weaker electron-donating resonance groups increase the electrophilicity of the carbonyl carbon.

(b) The order of leaving group ability is: $Cl^- > RCOO^- > R'O^- > NH_2^-$.

(c) Conversely, the basicity and resonance donation follow the reverse trend, making amides the least reactive and acyl chlorides the most reactive. The ascending order is: Amide (III) < Ester (II) < Anhydride (IV) < Acyl Chloride (I).

Final Answer:

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: The carbylamine reaction is a specific chemical test for primary amines, characterized by the production of a highly distinct, foul-smelling organic compound.

Solution:

(a) When an aliphatic or aromatic primary amine is heated with chloroform and an ethanolic solution of potassium hydroxide, it undergoes an organic transformation to form an alkyl or aryl isocyanide.

(b) Isocyanides possess a remarkably offensive, repulsive, and pungent odor, which acts as a clear diagnostic indicator for the presence of a primary amino group.

(c) This particular reaction proceeds via the intermediate generation of a highly reactive dichlorocarbene species formed from the chloroform in alkaline conditions.

(d) Secondary and tertiary amines do not undergo this transformation because they lack the necessary number of hydrogen atoms on the nitrogen to form the isocyanide skeleton.

Final Answer: Carbylamine reaction

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The addition of hydrobromic acid to asymmetrical alkenes follows different regiochemical pathways depending on the presence of organic peroxides.

Solution:

(a) In the absence of peroxides, the addition follows Markovnikov's rule, where the electrophilic proton attaches to the carbon with more hydrogen atoms.

(b) However, when dibenzoyl peroxide is introduced, the reaction switches to a free-radical chain mechanism, universally referred to as the anti-Markovnikov addition or the peroxide effect.

(c) The peroxide homolytically cleaves to form radical species that abstract a hydrogen atom from HBr, generating a highly reactive bromine free radical.

(d) This bromine radical attacks propene to form a more stable secondary carbon radical rather than a primary radical, which subsequently abstracts a hydrogen atom to produce 1-bromopropane as the main product.

Final Answer: 1-Bromopropane

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: Nylon-6 is a versatile synthetic polyamide polymer formed through the ring-opening polymerization of a cyclic organic monomer.

Solution:

(a) Unlike Nylon-6,6, which is a copolymer synthesized from hexamethylenediamine and adipic acid, Nylon-6 is a homopolymer derived from a single cyclic monomer containing an amide linkage within its ring structure.

(b) The corresponding structural monomer containing a seven-membered ring with six carbon atoms is known as ε-caprolactam.

(c) Heating ε-caprolactam with water at elevated temperatures induces hydrolytic ring opening, generating ε-aminocaproic acid.

(d) Continuous heating leads to self-condensation polymerization of these linear units, linking them together through strong intermolecular amide covalent bonds to yield the final high-molecular-weight polymer chain.

Final Answer: ε-Caprolactam

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: The bimolecular nucleophilic substitution pathway follows a concerted mechanism that dramatically impacts the spatial stereochemistry of the chiral carbon center.

Solution:

(a) In an S_N2 mechanism, the attacking nucleophile approaches the electrophilic substrate carbon from the direction exactly opposite to the departing leaving group.

(b) This back-side nucleophilic attack minimizes steric hindrance and electrostatic repulsion between the incoming species and the attached leaving atom.

(c) As the new covalent bond simultaneously forms and the old bond breaks, the three non-reacting groups transition through a planar configuration before flipping to the opposite side.

(d) This concerted transition structure behaves like an umbrella blowing inside out in a strong wind, resulting strictly in a complete inversion of stereochemical configuration.

Final Answer: 100

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: The concentration of ions in an electrolyte solution depends directly on its molarity, volume, and stoichiometric dissociation behavior.

Solution:

(a) Calcium chloride behaves as a strong electrolyte and dissociates entirely in aqueous media:

$$CaCl_2(aq) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$$

(b) Each formula unit of calcium chloride yields exactly three structural ions upon complete dissociation (1 Ca^{2+} and 2 Cl^-).

(c) The total number of moles of calcium chloride dissolved is calculated using molarity and volume:

$$n = \text{Molarity} \times \text{Volume in Liters} = 0.1\ \text{M} \times 0.1\ \text{L} = 0.01\ \text{mol}$$

(d) The total number of dissociated ions is found by multiplying the moles of compound by the number of ions per formula unit and Avogadro's constant:

$$\text{Total Ions} = 0.01 \times 3 \times 6.022 \times 10^{23} = 1.806 \times 10^{22}$$

Final Answer: 1.806×10^{22}

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: Integrated rate expressions describe how the concentrations of chemical reactants change linearly with time based on specific reaction orders.

Solution:

(a) The mathematical integrated rate law for a standard first-order chemical process can be formulated as follows:

$$\ln[A]_t = -kt + \ln[A]_0$$

(b) This equation matches the standard slope-intercept algebraic form for a straight line:

$$y = mx + c$$

(c) A plot featuring the natural logarithm of the reactant concentration ($\ln[A]_t$) on the vertical axis against elapsed time (t) on the horizontal axis yields a straight downward-sloping line.

(d) The resulting linear profile features a negative slope equal to $-k$ and a vertical y-intercept corresponding directly to $\ln[A]_0$, validating a first-order chemical process.

Final Answer: First-order

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: Raoult's law correlates the relative lowering of vapor pressure in an ideal solution to the mole fraction of the dissolved non-volatile solute.

Solution:

(a) First, evaluate the absolute number of moles of the non-volatile solute, urea:

$$n_{\text{urea}} = \frac{30\ \text{g}}{60\ \text{g mol}^{-1}} = 0.5\ \text{mol}$$

(b) Next, calculate the exact number of moles of the solvent, water:

$$n_{\text{water}} = \frac{846\ \text{g}}{18\ \text{g mol}^{-1}} = 47\ \text{mol}$$

(c) Determine the structural mole fraction of the pure solvent water within the prepared mixture:

$$\chi_{\text{water}} = \frac{47}{47 + 0.5} = \frac{47}{47.5} = 0.98947$$

(d) According to Raoult's law, the partial vapor pressure of the solution is given by:

$$P = P^{\circ} \times \chi_{\text{water}} = 23.8\ \text{mmHg} \times 0.98947 = 23.55\ \text{mmHg}$$

Final Answer: 23.55 mmHg

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: The Nernst equation correlates the standard electromotive force of a galvanic cell with its chemical equilibrium constant at a specific temperature.

Solution:

(a) The redox process involve the exchange of two electrons, establishing $n = 2$. At chemical equilibrium, the net cell potential drops to zero.

(b) The simplified electrochemical formula relating these variables at 298 K is expressed as:

$$E^\circ = \frac{0.0591}{n} \log K_c$$

(c) Substitute the given quantities directly into the equation to calculate the logarithm:

$$1.10 = \frac{0.0591}{2} \log K_c \implies \log K_c = \frac{2.20}{0.0591} \approx 37.225$$

(d) Taking the base-10 inverse logarithm of this value yields the corresponding numerical value:

$$K_c = 10^{37.225} \approx 1.68 \times 10^{37}$$

(e) Evaluating the options, 1.9×10^{37} represents the closest accurate value.

Final Answer: 1.9×10^{37}

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: The mathematical relationship between the partial pressure equilibrium constant and the molar concentration equilibrium constant relies on the stoichiometric change in gas moles.

Solution:

(a) The general thermodynamic equation linking these two distinct equilibrium constants is defined as:

$$K_p = K_c(RT)^{\Delta n_g}$$

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

(c) For the specific synthetic ammonia equilibrium reaction:

$$\Delta n_g = 2 - (1 + 3) = 2 - 4 = -2$$

(d) Rearranging the equation to solve for the ratio of the two constants gives:

$$\frac{K_p}{K_c} = (RT)^{\Delta n_g} = (RT)^{-2}$$

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

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: Faraday's laws of electrolysis state that the total quantity of electrical charge required for a redox transformation depends on the stoichiometry of electron transfer.

Solution:

(a) Write out the balanced reduction half-reaction occurring for the manganese species in an acidic medium:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

(b) Evaluate the oxidation state of the manganese atom on both sides: it shifts from +7 in the permanganate ion to +2 as a free ion.

(c) The calculated change confirms that exactly five moles of electrons are required to fully reduce one mole of reactant.

(d) Since the electrical charge carried by one mole of single electrons is exactly equal to one Faraday (1 F), the reduction requires five Faradays of charge.

Final Answer: 5 F

Answer: (C)

Go Back to Question 20

Q21.

Solution

Concept: The elevation in boiling point and depression in freezing point are colligative properties that depend directly on the molality of the solution.

Solution:

(a) First, determine the elevation in boiling point (ΔT_b) from the given boiling point of the solution:

$$\Delta T_b = T_b - T_b^\circ = 100.156^\circ\text{C} - 100.000^\circ\text{C} = 0.156\ \text{K}$$

(b) Express the elevation in boiling point using the ebullioscopic constant and molality (m):

$$\Delta T_b = K_b \times m \implies 0.156 = 0.52 \times m$$

(c) Solve for the molality of the aqueous solution:

$$m = \frac{0.156}{0.52} = 0.3\ \text{mol kg}^{-1}$$

(d) Use the calculated molality to find the corresponding depression in freezing point (ΔT_f):

$$\Delta T_f = K_f \times m = 1.86 \times 0.3 = 0.558\ \text{K}$$

(e) Calculate the absolute freezing point (T_f) of the aqueous solution:

$$T_f = T_f^\circ - \Delta T_f = 0.000^\circ\text{C} - 0.558\ \text{K} = -0.558^\circ\text{C}$$

Final Answer: -0.558°C

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: The integrated rate law for a first-order reaction describes the mathematical relationship between time, the rate constant, and reactant concentrations.

Solution:

(a) Let the initial baseline concentration of the reactant be represented as $[A]_0$.

(b) The problem states that the concentration drops down to 10% of its baseline value, which means the final remaining concentration $[A]_t$ is:

$$[A]_t = 0.10 \times [A]_0$$

(c) Write out the standard integrated rate equation for a first-order kinetic process:

$$t = \frac{2.303}{k} \log\left(\frac{[A]_0}{[A]_t}\right)$$

(d) Substitute the given rate constant $k = 4.606 \times 10^{-3}\ \text{s}^{-1}$ and the concentration ratio into the expression:

$$t = \frac{2.303}{4.606 \times 10^{-3}} \log\left(\frac{[A]_0}{0.10 \times [A]_0}\right)$$

(e) Simplify the expression by calculating the numerical quotient and evaluating the base-10 logarithm:

$$t = \frac{1}{2 \times 10^{-3}} \log(10) = 500 \times 1 = 500\ \text{s}$$

Final Answer: 500 s

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: The solubility product constant governs heterogeneous equilibrium configurations for sparingly soluble ionic salts in saturated aqueous solutions.

Solution:

(a) Write out the balanced chemical equation representing the dissolution and dissociation of the sparingly soluble salt:

$$Al(OH)_3(s) \rightleftharpoons Al^{3+}(aq) + 3OH^-(aq)$$

(b) Let the equilibrium molar solubility of the salt in water be denoted as S.

(c) Based on the stoichiometry of the dissociation, the equilibrium concentrations of the constituent ions are:

$$[Al^{3+}] = S \quad \text{and} \quad [OH^-] = 3S$$

(d) Express the equilibrium solubility product equation by substituting these concentration variables:

$$K_{sp} = [Al^{3+}][OH^-]^3 = (S)(3S)^3$$

(e) Simplify the mathematical terms to isolate the solubility variable:

$$K_{sp} = S \times 27S^3 = 27S^4 \implies S^4 = \frac{K_{sp}}{27} \implies S = \left(\frac{K_{sp}}{27}\right)^{1/4}$$

Final Answer: $S = (K_{sp}/27)^{1/4}$

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: Molar conductivity relates the specific electrolytic conductivity of a solution directly to its molar concentration.

Solution:

(a) First, calculate the electrolytic conductivity (κ) using the measured cell resistance (R) and the cell constant (G^*):

$$\kappa = \frac{\text{Cell constant}}{R} = \frac{1.0\ \text{cm}^{-1}}{200\ \Omega} = 0.005\ \text{S cm}^{-1}$$

(b) Write down the standard formula for converting specific conductivity into molar conductivity (Λ_m):

$$\Lambda_m = \frac{\kappa \times 1000}{\text{Molarity}}$$

(c) Substitute the calculated electrolytic conductivity and the given molarity (0.05 M) into the formula:

$$\Lambda_m = \frac{0.005 \times 1000}{0.05}$$

(d) Perform the arithmetic simplification to find the value:

$$\Lambda_m = \frac{5}{0.05} = 100\ \text{S cm}^2\ \text{mol}^{-1}$$

Final Answer: 100

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: The dilution equation preserves the absolute chemical amount of dissolved solute when additional solvent is added to a solution.

Solution:

(a) State the core algebraic relationship representing the conservation of moles during a dilution process:

$$M_1V_1 = M_2V_2$$

(b) Identify the initial parameters from the problem: $M_1 = 0.5$ M and $V_1 = 200$ mL.

(c) Identify the target final molar concentration parameter: $M_2 = 0.1$ M.

(d) Substitute these values into the equation to determine the total final volume (V_2) of the solution:

$$0.5 \times 200 = 0.1 \times V_2 \implies 100 = 0.1 \times V_2 \implies V_2 = 1000 \text{ mL}$$

(e) Calculate the precise net volume of water that must be added to achieve this final volume:

$$V_{\text{added}} = V_2 - V_1 = 1000 \text{ mL} - 200 \text{ mL} = 800 \text{ mL}$$

Final Answer: 800 mL

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept: Free expansion describes the unregulated expansion of a gas into an unresisting vacuum environment, which alters standard thermodynamic pathways.

Solution:

(a) Because the ideal gas expands directly into a vacuum, there is no opposing external pressure ($P_{ext} = 0$).

(b) Since work is mathematically defined as $w = -P_{ext}\Delta V$, the lack of opposing resistance means no mechanical work is performed ($w = 0$).

(c) For an ideal gas, the internal energy change depends exclusively on temperature. Because the process is explicitly specified as isothermal ($\Delta T = 0$), the internal energy change must be zero ($\Delta U = 0$).

(d) According to the first law of thermodynamics, the relationships combine as follows:

$$\Delta U = q + w \implies 0 = q + 0 \implies q = 0$$

(e) Thus, all three thermodynamic values are zero.

Final Answer: q = 0, w = 0, $\Delta U = 0$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept: The Henderson-Hasselbalch equation describes the pH of an acidic buffer system composed of a weak acid and its conjugate salt.

Solution:

(a) First, evaluate the negative logarithm (pK_a) of the given acid dissociation constant:

$$pK_a = -\log K_a = -\log(1.8 \times 10^{-5}) = 5 - \log(1.8) \approx 4.74$$

(b) Equal volumes of the weak acid and its salt are mixed together. Because they dilute equally, their final analytical concentrations remain equal.

(c) Write out the standard Henderson-Hasselbalch equation for an acidic buffer solution:

$$\text{pH} = pK_a + \log\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right)$$

(d) Substitute the equal concentrations into the logarithmic ratio term:

$$\text{pH} = 4.74 + \log\left(\frac{0.1}{0.1}\right) = 4.74 + \log(1)$$

(e) Since the base-10 logarithm of one is zero, the final pH matches the pK_a:

$$\text{pH} = 4.74 + 0 = 4.74$$

Final Answer: 4.74

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept: Werner's coordination theory divides central metal bonds into ionizable primary valencies and non-ionizable secondary directional valencies.

Solution:

(a) The primary valency corresponds directly to the conventional oxidation state of the central transition metal atom.

(b) Let the oxidation state of Cobalt be represented as x. Neutral ammonia ligands and anionic chloride ligands have charges of 0 and -1, respectively:

$$x + 5(0) + 1(-1) + 2(-1) = 0 \implies x - 3 = 0 \implies x = +3$$

(c) This calculation establishes that the primary valency of Cobalt is equal to 3.

(d) The secondary valency corresponds to the coordination number, which is the total number of ligand donor atoms bonded directly within the coordination sphere.

(e) Here, five ammonia molecules and one chloride ion are bonded to the core, yielding a secondary valency of $5 + 1 = 6$.

Final Answer: 3 and 6

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: The chelate effect significantly enhances the thermodynamic stability of a coordination complex through the formation of stable ring frameworks.

Solution:

(a) Monodentate ligands like H_2O, NH_3, and Cl^- form single coordinate bonds with the central metal ion without closing a ring.

(b) The oxalate ion (ox^{2-}, $C_2O_4^{2-}$) behaves as a bidentate ligand, binding to the metal center through two oxygen donor atoms simultaneously.

(c) This bidentate binding mode encapsulates the central Fe^{3+} ion within five-membered chelate ring architectures.

(d) The formation of these rings introduces favorable entropic and enthalpy changes, ensuring that $[Fe(ox)3]^3-$ displays the highest structural stability among the choices.

Final Answer: $[Fe(ox)3]^3-$

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept: The structural classification of silicate minerals depends on how individual tetrahedral $[SiO_4]^{4-}$ units share oxygen vertices.

Solution:

(a) Each fundamental orthosilicate unit forms a standalone silicon-centered oxygen tetrahedron.

(b) When exactly two oxygen vertices of every individual tetrahedron are shared continuously with adjacent units, it forms a repeating chain structure.

(c) This endless linear concatenation results in a specific silicate class known as chain silicates or pyroxenes.

(d) The shared stoichiometry changes the empirical formula of the repeating backbone from $[SiO_4]^{4-}$ to a simplified unit formula of $(SiO_3)_n^{2n-}$.

Final Answer: Chain silicates (pyroxenes)

Answer: (C)

Go Back to Question 30

Q31.

Solution

Concept: Disproportionation represents a specific class of redox processes where a single chemical element undergoes simultaneous oxidation and reduction to yield distinct high and low oxidation state compounds.

Solution:

(a) In phosphorous acid (H_3PO_3), the central phosphorus atom exhibits an intermediate oxidation state of +3.

(b) When subjected to thermal heating, this acid undergoes self-oxidation and reduction because the intermediate state is unstable relative to other oxidation combinations.

(c) The phosphorus atom increases its oxidation number to +5 to form orthophosphoric acid (H_3PO_4) and simultaneously decreases its oxidation number to -3 to produce phosphine gas (PH_3).

(d) The stoichiometrically balanced chemical equation for this thermal transformation is represented as follows:

$$4H_3PO_3 \xrightarrow{\Delta} 3H_3PO_4 + PH_3$$

(e) This confirmation demonstrates that the pyrolytic breakdown of the starting material yields orthophosphoric acid and phosphine.

Final Answer: H3PO4 and PH3

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: The boiling point of elemental substances depends directly on the relative strength of the intermolecular attractive forces holding the atoms together in the liquid phase.

Solution:

(a) Noble gases exist exclusively as isolated monatomic entities because they possess completely filled valence electronic shells that prevent standard covalent bonding.

(b) The only forces holding these monatomic gas entities together in a condensed liquid state are extremely weak, transient London dispersion forces.

(c) The magnitude of these instantaneous induced dipole interactions scales directly with the total number of electrons and the overall surface polarizability of the atom.

(d) Helium contains only two tightly bound core electrons, giving it the smallest atomic radius and the lowest polarizability of any element in the periodic table.

(e) Consequently, Helium exhibits the weakest intermolecular attractions and possesses the lowest boiling point (4.2 K) among all known physical substances.

Final Answer: Helium (He)

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: Crystal field theory describes how the geometric arrangement of surrounding ligands influences the electronic orbital configuration and magnetic behavior of transition metal complexes.

Solution:

(a) Evaluate the oxidation state of the central transition metal in the coordination complex:

$$\mathrm{Co}^{x} + 6(-1) = -3 \implies x = +3$$

(b) Cobalt possesses an atomic number of 27, giving the trivalent ion (Co^{3+}) a valence electronic configuration of $[\mathrm{Ar}]3d^6$.

(c) The fluoride ion (F^-) behaves as a classic weak-field ligand according to the spectrochemical series, meaning its crystal field splitting energy is smaller than the spin-pairing energy.

(d) Consequently, the five $3d$ atomic orbitals split into a lower t_{2g} set and an upper e_g set without forcing the pairing of electrons.

(e) Distributing the six valence electrons across these high-spin orbitals yields the electronic configuration $t_{2g}^4 e_g^2$, which contains exactly four unpaired electrons and renders the complex paramagnetic.

Final Answer: Paramagnetic, 4

Answer: (C)

Go Back to Question 33

Q34.

Solution

Concept: The recovery of precious transition metals from soluble coordination complexes relies on the principles of displacement reactions using more reactive reducing agents.

Solution:

(a) During the hydrometallurgical Macarthur-Forrest process, crushed gold or silver ore is treated with an aerated dilute solution of sodium cyanide to form a stable, soluble dicyano-complex:

$$4Au + 8NaCN + 2H_2O + O_2 \rightarrow 4Na[Au(CN)_2] + 4NaOH$$

(b) To isolate and recover the native precious metal from this aqueous complex solution, a highly electropositive and chemically reactive metal must be introduced.

(c) Zinc possesses a significantly lower reduction potential than gold or silver, making it a powerful reducing agent capable of displacing them from the solution.

(d) Zinc undergoes an oxidation reaction to form a tetrahedral tetracyanozincate(II) complex, precipitating the native gold out of solution:

$$2Na[Au(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Au$$

Final Answer: Zinc (Zn)

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept: Acid anhydrides represent chemical compounds derived by formally removing water molecules from their corresponding parent oxoacid structures.

Solution:

(a) Nitrous acid is represented by the empirical formula HNO_2, where the central nitrogen atom displays a formal oxidation state of +3.

(b) To determine its corresponding acid anhydride, double the empirical formula of the oxoacid and subtract one molecule of water:

$$2HNO_2 - H_2O \rightarrow N_2O_3$$

(c) This mathematical derivation confirms that dinitrogen trioxide (N_2O_3) is the formal chemical anhydride of nitrous acid.

(d) Physically, dinitrogen trioxide exists as an intensely colored blue liquid at low temperatures, which dissociates into nitric oxide (NO) and nitrogen dioxide (NO_2) at room temperature.

(e) Other options like N_2O or N_2O_5 represent anhydrides of different acids or exhibit different physical properties.

Final Answer: N2O3

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept: The progressive contraction of atomic and ionic dimensions along the internal inner transition series stems from the unique spatial geometry of f orbitals.

Solution:

(a) Actinide contraction describes the steady, monotonic decrease in atomic and ionic radii observed across the actinide elements from thorium to lawrencium.

(b) As the nuclear charge increases by one unit at each successive element, a corresponding electron enters the inner $5f$ subshell.

(c) The $5f$ atomic orbitals possess highly diffused shapes and complex spatial orientations, which makes them exceptionally poor at shielding outer electrons from the nucleus.

(d) Due to this inadequate shielding, the valence electrons experience a steadily increasing effective nuclear charge.

(e) This strong, unbalanced electrostatic attraction pulls the electron cloud tighter toward the atomic core, producing a sharp contraction in radius.

Final Answer: Poor shielding effect of 5f orbitals

Answer: (A)

Go Back to Question 36

Q37.

Solution

Concept: Pyrometallurgical extraction processes utilize specific mineral fluxes to react with infusible impurities, converting them into a low-density, fusible liquid slag.

Solution:

(a) The primary raw iron ore fed into an industrial blast furnace contains a substantial amount of acidic silicon dioxide (SiO_2, sand) as an impurity.

(b) To remove this high-melting-point silica contamination, a basic fluxing agent must be added to the furnace charge.

(c) Limestone ($CaCO_3$) is added for this purpose, decomposing thermally in the high-temperature zone of the furnace to produce calcium oxide (CaO):

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

(d) The resulting basic calcium oxide flux reacts directly with the acidic silica impurities via an acid-base neutralization to form liquid calcium silicate slag:

$$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$$

Final Answer: CaCO3 (decomposing to CaO)

Answer: (A)

Go Back to Question 37

Q38.

Solution

Concept: Structural isomerism in coordination chemistry arises when identical chemical formulas yield different ionic species when dissolved in an aqueous medium.

Solution:

(a) Ionization isomerism occurs when the counter-ion in the outer coordination sphere exchanges positions with a ligand bound inside the inner coordination sphere.

(b) Consider the first coordination complex, $[Co(NH3)5(SO4)]Br$, which dissolves in water to release a bromide ion (Br^-) as its counter-ion.

(c) Dissolving this isomer and treating it with aqueous silver nitrate produces a distinct cream-colored precipitate of silver bromide (AgBr).

(d) The second coordination complex, $[Co(NH3)5Br]SO4$, dissolves to release a free sulfate ion ($SO4^{2-}$) into the solution.

Final Answer: Ionization isomerism

Answer: (C)

Go Back to Question 38

Q39.

Solution

Concept: Quantum numbers establish the mathematical constraints that define the energy, size, shape, and spatial orientation of an atomic orbital.

Solution:

(a) The principal quantum number (n) defines the main electronic shell or energy level, which for a $4d$ orbital requires $n = 4$.

(b) The azimuthal quantum number (l) defines the subshell type and orbital shape, with specific integer assignments: $s = 0$, $p = 1$, $d = 2$, and $f = 3$. Therefore, a $4d$ subshell requires $l = 2$.

(c) The magnetic quantum number (m_l) specifies the spatial orientation of the orbital and must fall within the range from $-l$ to $+l$. For $l = 2$, the permissible values are $-2, -1, 0, +1, +2$.

(d) The spin quantum number (m_s) represents the intrinsic spin of the electron and can be either $+\frac{1}{2}$ or $-\frac{1}{2}$.

(e) Evaluating the choices, the set $n = 4, l = 2, m_l = -1, m_s = -\frac{1}{2}$ fits these criteria perfectly.

Final Answer: n = 4, l = 2, $m_l = -1, m_s = -\frac{1}{2}$

Answer: (B)

Go Back to Question 39

Q40.

Solution

Concept: The valence shell electron pair repulsion (VSEPR) model predicts the geometric shape of molecules based on minimizing electrostatic repulsion around a central atom.

Solution:

(a) Identify the central atom as sulfur, which belongs to group 16 and possesses six valence electrons.

(b) Sulfur forms four single covalent bonds with the four surrounding fluorine atoms, using four of its valence electrons.

(c) The remaining two valence electrons form a single non-bonding lone pair, giving a total of five electron domains (4 bonding pairs + 1 lone pair).

(d) Five electron domains arrange themselves in a trigonal bipyramidal steric geometry to minimize electron repulsion, requiring sp^3d hybridization.

(e) Placing the lone pair in an equatorial position to reduce steric strain results in a distorted tetrahedral geometry, commonly referred to as a see-saw molecular shape.

Final Answer: See-saw, sp^3d

Answer: (B)

Go Back to Question 40

Q41.

Solution

Concept: Interhalogen compounds are molecules formed by the direct chemical combination of two or more distinct halogen atoms. Their spatial frameworks and valence configurations can be reliably predicted using valence shell electron pair repulsion logic.

Solution:

(a) The given spatial layout illustrates a T-shaped geometric configuration containing two lone pairs of electrons localized on the central atom.

(b) Calculating the total valence electron count for a neutral interhalogen molecule of type XX'_3 involves evaluating the halogen atoms, which contribute seven valence electrons each.

(c) The central halogen atom shares three of its valence electrons to form three single covalent bonds with the surrounding halogen ligands.

(d) The remaining four valence electrons group together to create two distinct non-bonding lone pairs on the central atom, yielding five total electron domains.

(e) According to electronic domain constraints, five domains adopt a trigonal bipyramidal steric geometry with sp^3d hybridization. Placing the two lone pairs in equatorial positions minimizes structural repulsion, producing a T-shaped spatial orientation as exemplified by chlorine trifluoride (ClF_3).

Final Answer: ClF3

Answer: (A)

Go Back to Question 41

Q42.

Solution

Concept: Molecular Orbital Theory offers a description of homonuclear diatomic systems by distributing valence electrons into bonding and antibonding molecular orbitals.

Solution:

(a) Carbon (C_2) possesses a total of 12 valence electrons. Writing its ground-state molecular orbital sequence yields:

$$\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \pi_{2p_x}^2 \pi_{2p_y}^2$$

(b) Calculate the formal bond order by taking half the difference between bonding and antibonding electrons:

$$\text{Bond Order} = \frac{N_b - N_a}{2} = \frac{8-4}{2} = 2$$

(c) Since all electrons in the filled π_{2p} orbitals are fully paired, the molecule is diamagnetic.

(d) For comparison, dioxygen (O_2) has a bond order of 2 but contains two unpaired electrons in its antibonding orbitals, making it paramagnetic.

(e) Therefore, the homonuclear diatomic carbon molecule fulfills both conditions of being completely diamagnetic while maintaining a bond order of 2.

Final Answer: C2

Answer: (C)

Go Back to Question 42

Q43.

Solution

Concept: The first ionization enthalpy represents the energy required to remove the most loosely bound valence electron from an isolated gaseous atom in its ground state.

Solution:

(a) Across a period from left to right, the first ionization enthalpy generally increases due to a steady rise in effective nuclear charge and a concomitant decrease in atomic radius.

(b) This periodic trend exhibits a notable anomaly between group 15 nitrogen (N) and group 16 oxygen (O).

(c) Nitrogen features a valence configuration of $2s^2 2p^3$, meaning its $2p$ subshell is exactly half-filled, providing extra thermodynamic stability due to symmetric charge distribution and high exchange energy.

(d) Oxygen possesses a valence configuration of $2s^2 2p^4$, where removing one electron relieves inter-electronic repulsion within the paired orbital and yields a stable half-filled subshell.

(e) Consequently, the first ionization enthalpy of oxygen is lower than that of nitrogen, making the overall ascending periodic sequence Carbon < Oxygen < Nitrogen < Fluorine.

Final Answer: C < O < N < F

Answer: (A)

Go Back to Question 43

Q44.

Solution

Concept: The macroscopic properties of crystalline solids, such as melting point and structural rigidity, depend on the specific nature of the intermolecular forces holding the units together.

Solution:

(a) Iodine exists as a non-polar homonuclear diatomic molecule (I_2) where the shared bonding electrons are distributed symmetrically between the two iodine nuclei.

(b) Because there is no difference in electronegativity between the bonded atoms, the molecule lacks a permanent dipole moment.

(c) In a crystalline molecular solid, separate non-polar iodine molecules pack closely together in a well-defined geometric lattice framework.

(d) The only forces holding these discrete non-polar molecules together are weak, short-range London dispersion forces.

(e) These transient forces arise from temporary, instantaneous fluctuations in electronic density that induce corresponding temporary dipoles in adjacent molecules, defining the property of a molecular solid crystal.

Final Answer: London dispersion forces

Answer: (B)

Go Back to Question 44

Q45.

Solution

Concept: Nodes represent regions in an electronic wave function where the probability density of finding an electron drops to absolute zero.

Solution:

(a) The spatial topography of any atomic orbital is characterized by two distinct types of nodes: radial nodes and angular nodes.

(b) Angular nodes are planar or conical regions determined by the azimuthal quantum number (l), where the total count of angular nodes is simply equal to l.

(c) For a $3p$ atomic orbital, the principal quantum number n equals 3, and the azimuthal quantum number l equals 1, meaning it contains exactly 1 angular node.

(d) Radial nodes are spherical shells within the orbital framework, calculated using the standard mathematical formula:

$$\text{Radial Nodes} = n - l - 1$$

(e) Substituting the values for a $3p$ orbital yields:

$$\text{Radial Nodes} = 3 - 1 - 1 = 1$$

(f) This confirms that the orbital possesses exactly 1 radial node and 1 angular node.

Final Answer: 1 and 1

Answer: (A)

Go Back to Question 45

Q46.

Solution

Concept: Chemical species are classified as isoelectronic if they share the same number of valence electrons, and isostructural if they possess identical molecular geometries.

Solution:

(a) Calculate the total valence electron count for the carbonate ion (CO_3^{2-}), where carbon provides 4, each oxygen provides 6, and the negative charge adds 2:

$$\text{Valence Electrons} = 4 + 3(6) + 2 = 24$$

(b) Calculate the valence electron count for the nitrate ion (NO_3^-), where nitrogen provides 5, each oxygen provides 6, and the negative charge adds 1:

$$\text{Valence Electrons} = 5 + 3(6) + 1 = 24$$

(c) Both central atoms have three bonding domains and zero lone pairs, giving a steric number of 3, which corresponds to sp^2 hybridization.

(d) This electronic configuration forces both chemical structures to adopt an identical trigonal planar molecular geometry.

(e) Because they possess both matching electron counts and matching geometries, they are perfectly isoelectronic and isostructural.

Final Answer: $CO3^2 - and NO3^-$

Answer: (A)

Go Back to Question 46

Q47.

Solution

Concept: Colloidal dispersions exhibit unique optical phenomena due to the physical size of the dispersed phase particles relative to the wavelength of incident light.

Solution:

(a) True solutions contain dissolved solute particles smaller than 1 nm, which allow light to pass through without scattering.

(b) Colloidal systems contain dispersed particles with dimensions ranging between 1 nm and 1000 nm.

(c) When an intense beam of light passes through a colloid, these larger dispersed particles intercept and scatter the individual light rays in all directions.

(d) This illumination of the light path makes the trajectory visible as a bright, glowing cone when viewed from a perpendicular angle.

(e) This optical scattering phenomenon is defined as the Tyndall effect, and the visible luminous pathway is called the Tyndall cone, which serves to distinguish colloids from true solutions.

Final Answer: Tyndall effect

Answer: (B)

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Q48.

Solution

Concept: The Freundlich adsorption isotherm provides an empirical mathematical model that describes how the quantity of gas adsorbed onto a solid surface varies with pressure.

Solution:

(a) Let x represent the mass of gas adsorbed, and m represent the mass of the solid adsorbent, making x/m the mass of gas adsorbed per gram.

(b) At exceptionally low pressures, adsorption scales linearly with pressure, changing in direct proportion to the concentration:

$$x/m = kP^1$$

(c) At exceptionally high pressures, the surface reaches complete saturation, making the rate independent of pressure:

$$x/m = kP^0$$

(d) In the intermediate pressure range, adsorption depends on fractional powers of pressure, expressed by the Freundlich equation:

$$x/m = kP^{1/n}$$

(e) Here, n is an empirical constant greater than one, reflecting a non-linear relationship where adsorption increases less rapidly as pressure rises.

Final Answer: x/m = k $P^{1/n} (n > 1)$

Answer: (C)

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Q49.

Solution

Concept: The physiological toxicity of specific atmospheric pollutants stems from their ability to undergo competitive coordination chemistry with metal centers in biomolecules.

Solution:

(a) Hemoglobin functions as an iron-centered transport protein designed to bind oxygen reversibly in the lungs and deliver it throughout the human body.

(b) Carbon monoxide (CO) is a colorless, odorless gas that behaves as an exceptionally strong ligand toward the ferrous iron (Fe^{2+}) center of hemoglobin.

(c) Carbon monoxide binds to hemoglobin with an affinity approximately 200 times greater than that of molecular oxygen.

(d) This highly thermodynamically favorable binding reaction forms a stable, fully coordinated complex known as carboxyhemoglobin.

(e) The stability of carboxyhemoglobin prevents oxygen from binding to the protein, reducing the oxygen-carrying capacity of the blood and causing cellular asphyxiation.

Final Answer: Carbon monoxide (CO)

Answer: (C)

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Q50.

Solution

Concept: Green Chemistry encompasses a systematic framework of twelve core principles engineered to minimize the environmental impact of chemical manufacturing processes.

Solution:

(a) Maximizing atom economy stands as a core principle of sustainable chemical synthesis.

(b) Atom economy is an analytical metric that measures the efficiency of a chemical reaction by calculating the percentage of starting material mass incorporated into the final target product:

$$\text{Atom Economy} = \left(\frac{\text{Molar Mass of Desired Product}}{\text{Total Molar Mass of All Reactants}} \right) \times 100\%$$

(c) Designing synthetic pathways with a high atom economy ensures that most of the raw reactant mass ends up in the desired product rather than generating hazardous byproducts.

(d) Other practices, such as using volatile solvents like carbon tetrachloride, releasing waste into water streams, or producing non-biodegradable materials, directly contradict these green design criteria.

Final Answer: Maximizing atom economy in synthetic chemical pathways

Answer: (B)

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Answer Key

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