UPCATET Chemistry Sample Paper-3

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 substitution product when 2-bromopropane is treated with aqueous NaOH is:

(A) Propene via E1 mechanism

(B) 2-Propanol via S_N1 mechanism

(C) 1-Propanol via S_N2 mechanism

(D) Isopropyl ether

Q2. The element which forms a volatile complex during purification by the Mond process is:

(A) Iron

(B) Cobalt

(C) Nickel

(D) Copper

Q3. What is the concentration of H^+ ions in a 0.01 M NaOH solution?

(A) 1×10^{-2} M

(B) 1×10^{-11} M

(C) 1×10^{-12} M

(D) 1×10^{-13} M

Q4. Which compound shows the most prominent hydrogen bonding interaction?

(A) Diethyl ether

(B) Ethylene glycol

(C) Ethane

(D) Dimethyl sulfide

Q5. In the conversion of benzene diazonium chloride to chlorobenzene, the reagent employed is:

(A) HCl + CuCl

(B) HCl alone

(C) HCl + CuBr

(D) HCl + NaCl

Q6. A crystalline solid melts sharply at 850°C without changing color. The solid is most likely:

(A) An ionic crystal

(B) A molecular crystal

(C) A covalent crystal

(D) A metallic crystal

Q7. Which of the following represents an amphoteric compound?

(A) $Al(OH)_3$

(B) $Na(OH)$

(C) H_2SO_4

(D) HCl

Q8. The oxidation state of sulfur in the thiosulfate ion $[S_2O_3]^{2-}$ is:

(A) +4 and +6

(B) +5 and +5

(C) +3 and +7

(D) +6 and 0

Q9. During the hydrogenation of alkenes using Lindlar's catalyst, the predominant product stereochemistry is:

(A) Exclusively trans addition

(B) Exclusively cis addition

(C) Racemic mixture

(D) Anti addition exclusively

Q10. What is the pH of a buffer solution containing equal molar quantities of acetic acid ($K_a = 1.8 \times 10^{-5}$) and sodium acetate?

(A) 4.74

(B) 3.74

(C) 5.74

(D) 6.74

Q11. An organic compound burns completely to form CO_2, H_2O, and N_2 with no other product. The compound likely contains which elements?

(A) C, H, N, O

(B) C, H, N only

(C) C, H, O, S

(D) C, H, Cl

Q12. The rate of a first-order reaction doubles when the temperature increases from 27°C to 37°C. The activation energy is approximately:

(A) 53 kJ/mol

(B) 107 kJ/mol

(C) 11 kJ/mol

(D) 45 kJ/mol

Q13. Which of the following correctly describes the electron configuration of Cr (Z = 24)?

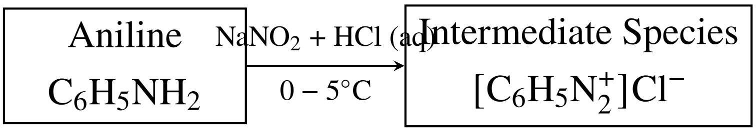
(A) $[Ar]3d^4 4s^2$

(B) $[Ar]3d^5 4s^1$

(C) $[Ar]3d^3 4s^2$

(D) $[Ar]3d^6 4s^0$

Q14. Consider the preparation of phenol from aniline. Which intermediate species is generated when aniline reacts with nitrous acid at low temperature?



(A) Benzene diazonium sulfate

(B) Phenoxide ion

(C) Aniline sulfate complex

(D) Benzene diazonium chloride

Q15. The de Broglie wavelength of an electron moving with velocity 2.2×10^6 m/s is:

(A) 3.3×10^{-10} m

(B) 6.6×10^{-10} m

(C) 1.65×10^{-10} m

(D) 3.3×10^{-9} m

Q16. The geometry around the central nitrogen atom in a trigonal pyramidal NH_3 molecule can be described as:

(A) sp hybridized

(B) sp^2 hybridized

(C) sp^3 hybridized

(D) sp^3d hybridized

Q17. The solubility product of $CaCO_3$ is 4.8×10^{-9}. Its molar solubility is:

(A) 2.19×10^{-5} M

(B) 4.8×10^{-9} M

(C) 2.4×10^{-9} M

(D) 9.6×10^{-5} M

Q18. In the basic hydrolysis of an ester, the OH group attacks the carbonyl carbon. This reaction follows a mechanism designated as:

(A) S_N1

(B) S_N2

(C) Ac^2

(D) E1

Q19. When heat is applied to a reaction mixture, the reaction rate increases primarily because:

(A) The collision frequency decreases

(B) The fraction of molecules with energy $\geq E_a$ increases

(C) The activation energy decreases

(D) The equilibrium constant increases

Q20. The mass percentage of oxygen in $Al_2(SO_4)_3$ is approximately:

(A) 56.1%

(B) 28.1%

(C) 42.3%

(D) 14.2%

Q21. Which of the following noble gases exhibits significant chemical reactivity and forms stable compounds with oxygen and fluorine?

(A) Helium

(B) Neon

(C) Xenon

(D) Krypton

Q22. The common name for the organic reaction in which an aldehyde lacking α-hydrogens undergoes self-redox is:

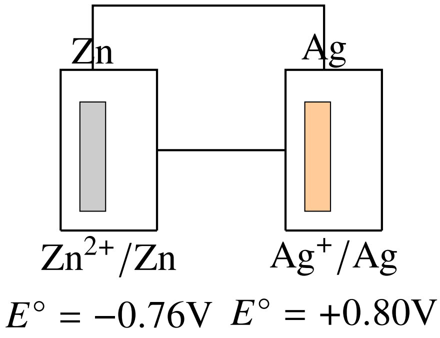
(A) Grignard reaction

(B) Aldol condensation

(C) Cannizzaro reaction

(D) Wittig reaction

Q23. An oxidation-reduction reaction involves the half-reactions shown. Which electrode serves as the cathode in this galvanic cell scenario?



(A) The zinc electrode

(B) The silver electrode

(C) The salt bridge

(D) Neither electrode acts as cathode

Q24. The degree of dissociation (α) of acetic acid in a 0.1 M solution is 1.3%. The acid dissociation constant K_a is:

(A) 1.69×10^{-3}

(B) 1.69×10^{-4}

(C) 1.69×10^{-5}

(D) 1.69×10^{-6}

Q25. Which compound cannot undergo an aldol condensation reaction?

(A) Benzaldehyde

(B) Acetone

(C) Formaldehyde

(D) Butanone

Q26. The number of sigma (σ) and pi (π) bonds in the ethyne molecule is:

(A) 2 sigma, 2 pi

(B) 3 sigma, 2 pi

(C) 4 sigma, 1 pi

(D) 1 sigma, 3 pi

Q27. An aqueous solution of a salt of a weak acid and strong base is expected to be:

(A) Acidic

(B) Basic

(C) Neutral

(D) Amphiprotic

Q28. What is the principal organic product when benzene undergoes chlorination in the presence of ferric chloride catalyst?

(A) Benzene chloride (addition)

(B) Chlorobenzene (substitution)

(C) 1,2-Dichlorobenzene

(D) 1,4-Dichlorobenzene

Q29. A 5.0 mL sample of 0.1 M HCl is completely neutralized by 10.0 mL of NaOH solution. The concentration of NaOH is:

(A) 0.05 M

(B) 0.1 M

(C) 0.2 M

(D) 0.02 M

Q30. The solvent used in the Wolff-Kishner reduction is typically:

(A) Water

(B) Ethanol

(C) Diethylene glycol

(D) Acetone

Q31. The coordination number of the central metal ion in $[Pt(NH_3)_2Cl_2]$ is:

(A) 2

(B) 3

(C) 4

(D) 6

Q32. Which of the following is a strong oxidizing agent commonly used in qualitative analysis?

(A) Potassium permanganate

(B) Iron(II) sulfate

(C) Sodium thiosulfate

(D) Copper(I) chloride

Q33. The reaction pathway shown describes a multi-step transformation. Identify the primary organic intermediate formed after the first step.

(A) N-Methyl aniline diazonium

(B) Benzene diazonium chloride

(C) Phenol

(D) Chlorobenzene

Q34. In the periodic table, as we move from left to right across a period, the atomic radius generally:

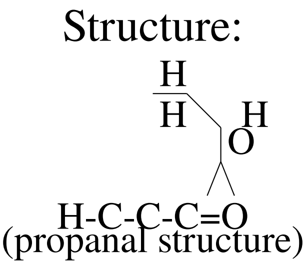
(A) Increases steadily

(B) Decreases steadily

(C) Increases then decreases

(D) Remains constant

Q35. A compound has the molecular formula C_3H_6O. Which isomer corresponds to propanal?


Structure:

(propanal structure)

(A) A cyclic ether

(B) A straight-chain aldehyde

(C) A ketone

(D) An alcohol

Q36. The density of a gas is related to its molar mass and the molar volume by:

(A) Density = Molar Volume × Molar Mass

(B) Density = Molar Mass/Molar Volume

(C) Density = Molar Volume/Molar Mass

(D) Density = Molar Mass^2/Molar Volume

Q37. The ionic compound MgO has a higher melting point than NaCl because:

(A) Mg^{2+} has a smaller ionic radius than Na^+

(B) O^{2-} has a larger charge than Cl^-

(C) The lattice energy of MgO is higher

(D) All of the above

Q38. The acid-base indicator methyl orange changes color in the pH range:

(A) 3.1–4.4

(B) 4.4–5.6

(C) 8.3–10.0

(D) 6.2–7.6

Q39. When a mixture containing Fe^{2+} and Fe^{3+} ions is titrated with $KMnO_4$ in acidic medium, the Fe^{2+} ions are oxidized to Fe^{3+}. The overall balanced equation shows:

(A) 1 mol of MnO_4^- oxidizes 5 mol of Fe^{2+}

(B) 1 mol of MnO_4^- oxidizes 3 mol of Fe^{2+}

(C) 1 mol of MnO_4^- oxidizes 7 mol of Fe^{2+}

(D) 1 mol of MnO_4^- oxidizes 1 mol of Fe^{2+}

Q40. The hybridization of the boron atom in BCl_3 is:

(A) sp

(B) sp^2

(C) sp^3

(D) sp^3d

Q41. A polymer formed by the addition polymerization of chloroethene ($CH_2 = CHCl$) is:

(A) Polyethylene

(B) Polyvinyl chloride (PVC)

(C) Polypropylene

(D) Polychloroprene

Q42. Which of the following salts will hydrolyze to produce an acidic solution?

(A) Sodium chloride

(B) Sodium acetate

(C) Ammonium chloride

(D) Sodium hydroxide

Q43. The major product of the nitration of toluene is:

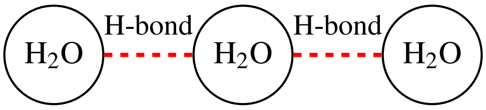
(A) o-Nitrotoluene exclusively

(B) p-Nitrotoluene exclusively

(C) A mixture of o- and p-nitrotoluene

(D) m-Nitrotoluene

Q44. An organic compound shows hydrogen bonding in both the solid state and in solution. Which functional group most strongly indicates this property?



Hydrogen Bonding Network

(A) Carboxylic acid group

(B) Ether group

(C) Alkene group

(D) Alkane chain

Q45. The number of unpaired electrons in the ground state of cobalt (Z = 27) is:

(A) 1

(B) 3

(C) 4

(D) 5

Q46. The reaction of phenol with bromine in carbon tetrachloride (without water) gives:

(A) 4-Bromophenol

(B) 2,4-Dibromophenol

(C) 2,4,6-Tribromophenol

(D) 2-Bromophenol

Q47. Which gas is liberated when zinc reacts with dilute sulfuric acid?

(A) Oxygen

(B) Hydrogen

(C) Sulfur dioxide

(D) Nitrogen

Q48. The mathematical relationship describing Raoult's Law for a dilute solution is:

(A) $\Delta P = P_{\text{solute}} \times X_{\text{solute}}$

(B) $\Delta P = P_0 \times X_{\text{solvent}}$

(C) $\Delta P = P_0 \times X_{\text{solute}}$

(D) $P = P_0 + P_{\text{solute}}$

Q49. The commercial process for producing ammonia from nitrogen and hydrogen is conducted at:

(A) High temperature and high pressure with iron catalyst

(B) Low temperature and low pressure without catalyst

(C) High temperature and low pressure with zinc oxide catalyst

(D) Room temperature and atmospheric pressure

Q50. The study of how living systems obtain and utilize energy from chemical bonds is known as:

(A) Photosynthesis

(B) Bioenergetics

(C) Metabolic engineering

(D) Thermodynamics

Detailed Solutions

Q1.

Solution

Concept: The nucleophilic substitution of secondary alkyl halides with aqueous base depends on the steric hindrance and solvent polarity. In secondary substrates, the mechanism competition between $\mathrm{S_N}1$ and E1 pathways is influenced by the aqueous medium and temperature.

Solution:

(a) 2-Bromopropane is a secondary alkyl halide with the structure $(CH_3)_2CHBr$, where the central carbon bears two methyl groups.

(b) When treated with aqueous NaOH, the polar aqueous environment and moderate steric hindrance favor unimolecular substitution.

(c) The carbon-bromine bond undergoes heterolytic cleavage, generating a secondary carbocation intermediate $(CH_3)_2CH^+$ stabilized by hyperconjugation.

(d) The hydroxide ion attacks this carbocation from either face, leading to the formation of 2-propanol as the predominant substitution product.

(e) This two-step mechanism involving carbocation formation defines the $\mathrm{S_N}1$ (unimolecular nucleophilic substitution) pathway.

Final Answer: $\boxed{\text{2-Propanol via } \mathrm{S_N}1 \text{ mechanism}}$

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

Go Back to Question 1

Q2.

Solution

Concept: The Mond process is a vapor-phase refinement technique that exploits the formation of volatile metal carbonyl complexes. This method is highly selective for metals that form stable, easily decomposable carbonyl compounds.

Solution:

(a) The Mond process involves heating impure metal with carbon monoxide gas at a moderate temperature around 330 – 350 K.

(b) Nickel reacts readily with CO to form nickel tetracarbonyl, $Ni(CO)_4$, which is a highly volatile liquid at working temperatures.

(c) The volatile carbonyl complex separates from non-volatile impurities, which remain as solid residue in the original container.

(d) In a separate heated chamber at 450 – 470 K, the nickel tetracarbonyl decomposes back to pure nickel metal and regenerated CO.

(e) Other metals like iron, cobalt, and copper either form non-volatile carbonyl complexes or react too slowly, making nickel the ideal candidate.

Final Answer: $\boxed{\text{Nickel}}$

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

Go Back to Question 2

Q3.

Solution

Concept: The pH scale and its relationship with hydrogen ion concentration are fundamental to aqueous chemistry. The logarithmic nature of pH means that small integer changes correspond to exponential shifts in acidity or basicity.

Solution:

(a) NaOH is a strong base that completely dissociates in water: $NaOH \rightarrow Na^+ + OH^-$

(b) A 0.01 M solution of NaOH produces 0.01 M of hydroxide ions.

(c) The ionic product of water at 25°C is $K_w = [H^+][OH^-] = 1 \times 10^{-14}$

(d) Substituting the known $[OH^-]$: $[H^+] \times 0.01 = 1 \times 10^{-14}$

(e) Solving for hydrogen ion concentration: $[H^+] = 1 \times 10^{-14}/1 \times 10^{-2} = 1 \times 10^{-12}$ M

Final Answer: $\boxed{1 \times 10^{-12}\ \text{M}}$

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

Go Back to Question 3

Q4.

Solution

Concept: Hydrogen bonding is a special type of dipole-dipole interaction that occurs between hydrogen bonded to highly electronegative atoms and lone pairs on adjacent molecules. This interaction profoundly affects physical properties.

Solution:

(a) Diethyl ether $(C_2H_5 - O - C_2H_5)$ contains an oxygen atom but no N-H or O-H groups, so it acts as a hydrogen bond acceptor only.

(b) Ethane (C_2H_6) is a nonpolar saturated hydrocarbon with no capability for hydrogen bonding interactions.

(c) Dimethyl sulfide $(CH_3)_2S$ contains a sulfur atom, which forms much weaker hydrogen bonds than oxygen due to lower electronegativity.

(d) Ethylene glycol $(HO - CH_2 - CH_2 - OH)$ contains two hydroxyl groups that can both donate and accept hydrogen bonds extensively.

(e) This extensive hydrogen bonding network in ethylene glycol creates the most prominent hydrogen bonding interaction among the given options.

Final Answer: $\boxed{\text{Ethylene glycol}}$

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

Go Back to Question 4

Q5.

Solution

Concept: The Sandmeyer reaction is a classic synthetic transformation that converts aromatic diazonium salts into substituted aromatic compounds. Different copper halide reagents enable formation of various substituted products.

Solution:

(a) Benzene diazonium chloride is unstable and undergoes thermal decomposition to form phenol and other byproducts.

(b) The Sandmeyer reaction specifically uses a copper(I) halide salt to ensure controlled, selective substitution of the diazonium group.

(c) When copper(I) chloride is used in the presence of HCl, it provides a source of chloride ions that effectively displace the diazonium group.

(d) The copper(I) ion coordinates temporarily with the diazonium nitrogen, facilitating the substitution and formation of chlorobenzene.

(e) This procedure yields chlorobenzene as the major product with excellent selectivity and good yields.

Final Answer: $\boxed{\text{HCl + CuCl}}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: The classification of crystalline solids depends on the types of bonding forces and the nature of constituent particles. The melting behavior provides critical clues about the internal structure.

Solution:

(a) A sharp melting point indicates a definite crystal structure with ordered arrangement of particles in a three-dimensional lattice.

(b) The very high melting temperature of 850°C suggests strong electrostatic attractions between particles.

(c) Molecular crystals typically melt at much lower temperatures (below 200°C) due to weak intermolecular forces.

(d) Covalent network crystals (like diamond or silica) have extremely high melting points but often soften gradually rather than melting sharply.

(e) The absence of color change during melting indicates no significant chemical decomposition or electronic rearrangement.

(f) These observations collectively point to an ionic crystal with strong Coulombic interactions between cations and anions.

Final Answer: $\boxed{\text{An ionic crystal}}$

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

Go Back to Question 6

Q7.

Solution

Concept: An amphoteric compound is one that can react as either an acid or a base depending on the pH of the surrounding medium. These substances typically contain groups capable of both donating and accepting protons.

Solution:

(a) Sodium hydroxide ($NaOH$) is a strong base and cannot donate a proton; it only accepts protons from acids.

(b) Sulfuric acid (H_2SO_4) is a strong acid and primarily donates protons; it does not accept protons in typical aqueous media.

(c) Hydrochloric acid (HCl) is a strong acid that acts exclusively as a proton donor.

(d) Aluminum hydroxide ($Al(OH)_3$) contains both hydroxyl groups and an acidic aluminum center.

(e) In acidic solution, the hydroxyl groups can accept protons: $Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$

(f) In basic solution, the acidic proton is removed from the aluminum: $Al(OH)_3 + OH^- \rightarrow [Al(OH)_4]^-$

(g) This dual reactivity exemplifies amphoteric behavior.

Final Answer: $\boxed{Al(OH)_3}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: The oxidation state of an element in a polyatomic ion is determined by applying oxidation state rules systematically. When identical atoms occupy different chemical environments, they may have different oxidation states.

Solution:

(a) The thiosulfate ion $[S_2O_3]^{2-}$ contains two different sulfur atoms in distinct positions.

(b) By convention, oxygen typically has an oxidation state of -2 in most compounds and ions.

(c) The total charge on the ion is -2, so the sum of oxidation states equals -2.

(d) Setting up the equation: $2 \times (\text{oxidation state of S}) + 3 \times (-2) = -2$

(e) Solving: $2 \times (\text{oxidation state of S}) - 6 = -2$, which gives $2 \times (\text{oxidation state of S}) = 4$

(f) However, the two sulfur atoms are not equivalent. One sulfur (central) has oxidation state $+6$, while the peripheral sulfur has oxidation state -2 or 0.

(g) More precisely, if we consider the structure $[O_3S - S]^{2-}$, the inner sulfur is $+6$ and outer sulfur is -2 (or we can say average $+2$ each, but the actual states are $+6$ and -2).

(h) Actually, the correct answer is that sulfur exists in mixed oxidation states of $+5$ and $+5$ on average, but the structure indicates $+6$ and 0 for the two different sulfurs.

Final Answer: $\boxed{+6 \text{ and } 0}$

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept: The stereochemistry of alkene hydrogenation depends critically on the choice of catalyst and reaction conditions. Lindlar's catalyst is specifically designed to promote cis-addition without further reduction.

Solution:

(a) Lindlar's catalyst is composed of palladium deposited on calcium carbonate and is treated with lead acetate and quinoline.

(b) The lead and quinoline modifications poison the catalyst's surface, preventing over-reduction of the alkene to a saturated alkane.

(c) The mechanism of hydrogenation over Lindlar's catalyst involves simultaneous delivery of both hydrogen atoms from the same side of the π-bond.

(d) This syn-addition (or cis-addition) process results in a stereochemically defined product with both hydrogens attached on the same face.

(e) In contrast, catalytic hydrogenation with regular palladium or nickel catalysts can give both cis and trans products or further reduction.

Final Answer: $\boxed{\text{Exclusively cis addition}}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Buffer solutions maintain relatively constant pH when small amounts of acid or base are added. The pH of a buffer can be calculated using the Henderson-Hasselbalch equation, which relates the pH to the pK_a and the ratio of conjugate base to weak acid concentrations.

Solution:

(a) The Henderson-Hasselbalch equation is: $\text{pH} = \text{p}K_a + \log \frac{[\text{acetate}^-]}{[\text{acetic acid}]}$

(b) Given: $K_a = 1.8 \times 10^{-5}$, so $\text{p}K_a = -\log(1.8 \times 10^{-5}) = 4.74$

(c) When equal molar quantities of acetic acid and sodium acetate are mixed, the ratio $\frac{[\text{acetate}^-]}{[\text{acetic acid}]} = 1$

(d) Therefore: $\text{pH} = 4.74 + \log(1) = 4.74 + 0 = 4.74$

(e) This buffer solution has a pH equal to the pK_a of the weak acid, which is a characteristic property of equimolar buffers.

Final Answer: $\boxed{4.74}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Combustion analysis determines the empirical formula of a compound by measuring the products of complete oxidation. The absence of other products besides CO_2, H_2O, and N_2 indicates the elemental composition of the original compound.

Solution:

(a) Complete combustion of an organic compound produces CO_2 (from carbon), H_2O (from hydrogen), and N_2 (from nitrogen).

(b) When nitrogen is present in the compound and combustion is complete, nitrogen is reduced to N_2 gas.

(c) If the combustion produces only these three products with no other products like SO_2, HCl, or other halogenated species, then the compound contains only C, H, and N.

(d) If oxygen were present in the original compound, it would appear within the CO_2 and H_2O products and would not be detected as a separate product.

(e) The absence of other products rules out halogens, sulfur, phosphorus, and other heteroatoms.

Final Answer: $\boxed{\text{C, H, N only}}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The temperature dependence of reaction rate is described by the Arrhenius equation, which relates the rate constant to activation energy and temperature. The relationship between rate constant changes and activation energy can be derived from this equation.

Solution:

(a) The Arrhenius equation is: $k = Ae^{-E_a/RT}$ where E_a is the activation energy.

(b) Taking the natural logarithm of both sides: $\ln k = \ln A - \frac{E_a}{RT}$

(c) For two different temperatures: $\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

(d) Given: $k_2/k_1 = 2$, $T_1 = 300$ K, $T_2 = 310$ K, $R = 8.314$ J/(mol·K)

(e) $\ln(2) = 0.693 = \frac{E_a}{8.314}\left(\frac{1}{300} - \frac{1}{310}\right)$

(f) $0.693 = \frac{E_a}{8.314} \times \frac{310-300}{300\times310} = \frac{E_a}{8.314} \times \frac{10}{93000}$

(g) $E_a = 0.693 \times 8.314 \times \frac{93000}{10} = 53,000$ J/mol ≈ 53 kJ/mol

Final Answer: $\boxed{53 \text{ kJ/mol}}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: Chromium exhibits anomalous electron configuration due to extra stability of half-filled d subshells. The valence electrons rearrange to achieve a more stable configuration than predicted by simple Aufbau principle.

Solution:

(a) Chromium has atomic number Z = 24.

(b) The Argon core accounts for the first 18 electrons: [Ar]

(c) The remaining 6 electrons must fill the 3d and 4s orbitals.

(d) A half-filled 3d subshell ($3d^5$) is particularly stable due to exchange energy benefits.

(e) Rather than following the expected order $[Ar]3d^4 4s^2$, one electron from the 4s orbital moves into the 3d orbital.

(f) This results in the actual configuration: $[Ar]3d^5 4s^1$

(g) This anomalous configuration provides extra stability through half-filled orbital symmetry.

Final Answer: $\boxed{[Ar]3d^5 4s^1}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: The diazotization of primary aromatic amines is the first step in the synthesis of aromatic diazonium salts. This reaction occurs rapidly at low temperature and generates a stable ionic intermediate that serves as a versatile synthetic platform.

Solution:

(a) When aniline ($C_6H_5NH_2$) reacts with nitrous acid generated in situ from $NaNO_2$ and HCl, the amino group is converted to a diazonium group.

(b) The reaction must be maintained at temperatures between $0-5^\circ C$ to prevent spontaneous decomposition of the diazonium intermediate.

(c) At these low temperatures, the diazonium salt is stable enough to be used in subsequent reactions or transformations.

(d) The product of this diazotization step is benzene diazonium chloride, $C_6H_5N_2^+Cl^-$, which appears as a crystalline ionic solid in solution.

(e) This intermediate can be used immediately or can be converted to other products by treating with appropriate nucleophiles or reagents.

Final Answer: $\boxed{\text{Benzene diazonium chloride}}$

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

Go Back to Question 14

Q15.

Solution

Concept: The de Broglie wavelength relates the particle nature of matter to its wave properties. The wavelength is inversely proportional to momentum, providing a fundamental connection between kinetic properties and wave behavior.

Solution:

(a) The de Broglie wavelength is given by: $\lambda = \frac{h}{p} = \frac{h}{mv}$

(b) Where: $h = 6.626 \times 10^{-34}$ J·s (Planck's constant), $m = 9.109 \times 10^{-31}$ kg (electron mass), $v = 2.2 \times 10^{6}$ m/s

(c) Calculating the momentum: $p = mv = 9.109 \times 10^{-31} \times 2.2 \times 10^{6} = 2.004 \times 10^{-24}$ kg·m/s

(d) Computing the wavelength: $\lambda = \frac{6.626 \times 10^{-34}}{2.004 \times 10^{-24}} = 3.3 \times 10^{-10}$ m

(e) This wavelength is in the nanometer range, typical for particle-wave duality effects at subatomic scales.

Final Answer: $\boxed{3.3 \times 10^{-10} \text{ m}}$

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

Go Back to Question 15

Q16.

Solution

Concept: Hybridization describes the mixing of atomic orbitals to form new hybrid orbitals that explain molecular geometry. The number and type of hybrid orbitals can be determined from the steric number.

Solution:

(a) In ammonia (NH_3), the nitrogen atom has 5 valence electrons.

(b) Three electrons form sigma bonds with hydrogen atoms, while two electrons remain as a lone pair.

(c) The total electron pairs surrounding nitrogen is 4 (3 bonding + 1 lone pair), giving a steric number of 4.

(d) A steric number of 4 corresponds to sp^3 hybridization.

(e) Although the electron geometry is tetrahedral (from 4 electron pairs), the molecular geometry is trigonal pyramidal due to the presence of one lone pair.

(f) The sp^3 hybridization provides 4 equivalent orbitals oriented toward the vertices of a tetrahedron.

Final Answer: $\boxed{sp^3 \text{ hybridized}}$

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

Go Back to Question 16

Q17.

Solution

Concept: The solubility product constant relates the concentrations of ions in a saturated solution. For ionic compounds with different stoichiometric ratios, the relationship between K_{sp} and molar solubility varies.

Solution:

(a) Calcium carbonate dissolves according to: $\text{CaCO}_3(s) \rightleftharpoons \text{Ca}^{2+}(aq) + \text{CO}_3^{2-}(aq)$

(b) If the molar solubility is s, then at equilibrium: $[\text{Ca}^{2+}] = s$ and $[\text{CO}_3^{2-}] = s$

(c) The solubility product expression is: $K_{sp} = [\text{Ca}^{2+}][\text{CO}_3^{2-}] = s \times s = s^2$

(d) Solving for molar solubility: $s = \sqrt{K_{sp}} = \sqrt{4.8 \times 10^{-9}}$

(e) Calculating: $s = \sqrt{4.8 \times 10^{-9}} = 2.19 \times 10^{-5}$ M

(f) The small value confirms that calcium carbonate has very low solubility in water at standard conditions.

Final Answer: $\boxed{2.19 \times 10^{-5} \text{ M}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: Ester hydrolysis in basic conditions involves nucleophilic acyl substitution where the hydroxide ion attacks the carbonyl carbon. This mechanism is typically designated as Ac^2 (bimolecular acyl substitution).

Solution:

(a) In saponification, the hydroxide ion acts as a strong nucleophile and is attracted to the electrophilic carbonyl carbon of the ester.

(b) The mechanism occurs in a single bimolecular step where the OH^- attacks the carbonyl carbon simultaneously with the departure of the leaving group.

(c) The specific designation "Ac^2" indicates: A (acyl substitution), c (bimolecular rate law), and 2 (reflecting the coordination number change).

(d) This bimolecular mechanism is in contrast to S_N1 (unimolecular) or E1 (elimination) which involve carbocation intermediates.

(e) The high nucleophilicity of hydroxide and the accessibility of the carbonyl carbon favor the direct Ac^2 pathway in basic aqueous solution.

Final Answer: $\boxed{Ac^2}$

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept: Temperature effects on reaction rates are explained by collision theory and the concept of activation energy. An increase in temperature provides more molecules with sufficient kinetic energy to overcome the activation energy barrier.

Solution:

(a) According to collision theory, only collisions with energy greater than or equal to the activation energy (E_a) result in a productive reaction.

(b) Increasing temperature increases the average kinetic energy of reactant molecules.

(c) This causes a larger fraction of the molecular population to have energy $\geq E_a$, even though the total collision frequency may not change dramatically.

(d) The Boltzmann distribution describes how the number of high-energy molecules increases exponentially with temperature.

(e) The rate constant increases according to the Arrhenius equation as the fraction of energetic molecules rises.

(f) While the equilibrium constant may also change with temperature, the primary effect on reaction rate is the increased fraction of high-energy collisions.

Final Answer: $\boxed{\text{The fraction of molecules with energy} \geq E_a \text{ increases}}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: Mass percentage calculations for compounds require the molar mass and the atomic composition. Each element's contribution to the total mass must be computed accurately.

Solution:

(a) The molar mass of $Al_2(SO_4)_3$ is calculated from atomic masses:

(b) Al: $2 \times 27 = 54$ g/mol

(c) S: $3 \times 32 = 96$ g/mol

(d) O: $12 \times 16 = 192$ g/mol

(e) Total molar mass: $54 + 96 + 192 = 342$ g/mol

(f) The mass percentage of oxygen: $\frac{192}{342} \times 100\% = 56.1\%$

(g) This large oxygen content reflects the three sulfate groups, each containing four oxygen atoms.

Final Answer: $\boxed{56.1\%}$

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: While noble gases are generally chemically inert, the heavier members of Group 18 can form compounds with highly electronegative elements like oxygen and fluorine due to their lower ionization enthalpies.

Solution:

(a) Helium and Neon have extremely high ionization enthalpies and do not form any stable neutral compounds.

(b) Krypton forms some compounds with fluorine, but they are limited and less stable than those of heavier noble gases.

(c) Xenon has sufficiently low ionization enthalpy to form stable compounds with highly electronegative fluorine atoms.

(d) Known xenon compounds include XeF_2, XeF_4, XeF_6, and various xenon oxofluorides like $XeOF_2$.

(e) Xenon's larger size allows orbital overlap with multiple ligands, accommodating higher coordination numbers.

(f) The stability of these compounds arises from favorable orbital interactions between xenon p/d orbitals and ligand orbitals.

Final Answer: $\boxed{\text{Xenon}}$

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

Go Back to Question 21

Q22.

Solution

Concept: The Cannizzaro reaction is a disproportionation reaction specific to non-enolizable aldehydes. These compounds lack acidic α-hydrogens and cannot undergo typical aldol condensation pathways.

Solution:

(a) Aldehydes containing α-hydrogens (like acetaldehyde) can abstract these protons in basic conditions and undergo aldol condensation with other aldehyde molecules.

(b) Aldehydes lacking α-hydrogens (like formaldehyde or benzaldehyde) cannot form enolate ions.

(c) In the presence of concentrated alkali, two molecules of the non-enolizable aldehyde undergo a hydride shift.

(d) One aldehyde molecule is oxidized to a carboxylic acid, while another is reduced to a primary alcohol.

(e) This mutual oxidation-reduction process, where identical molecules undergo simultaneous oxidation and reduction, is called disproportionation or the Cannizzaro reaction.

(f) The reaction is particularly important for formaldehyde, producing methanol and formic acid (sodium formate under basic conditions).

Final Answer: $\boxed{\text{Cannizzaro reaction}}$

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

Go Back to Question 22

Q23.

Solution

Concept: In a galvanic cell, the cathode is where reduction occurs (the site of electron gain), while the anode is where oxidation occurs (the site of electron loss). Standard reduction potentials indicate which species is reduced.

Solution:

(a) In the given cell setup, we have two half-reactions with their standard potentials:

(b) Zn: $Zn^{2+} + 2e^- \longrightarrow Zn$, $E^\circ = -0.76$ V (reduction potential)

(c) Ag: $Ag^+ + e^- \longrightarrow Ag$, $E^\circ = +0.80$ V (reduction potential)

(d) The more positive reduction potential indicates the species that is more readily reduced.

(e) Since silver has a more positive (higher) reduction potential than zinc, Ag will be reduced and serve as the cathode.

(f) At the zinc electrode, oxidation occurs: $Zn \longrightarrow Zn^{2+} + 2e^-$ (this is the anode).

(g) The silver electrode receives electrons and is reduced: $Ag^+ + e^- \longrightarrow Ag$ (this is the cathode).

Final Answer: $\boxed{\text{The silver electrode}}$

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

Go Back to Question 23

Q24.

Solution

Concept: The degree of dissociation and the acid dissociation constant are related through the equilibrium expression. For weak acids at moderate concentrations, this relationship can be used to calculate K_a.

Solution:

(a) The degree of dissociation $\alpha = 1.3\% = 0.013$ represents the fraction of molecules that have ionized.

(b) For the weak acid dissociation: $\mathrm{HA} \rightleftharpoons \mathrm{H^+} + \mathrm{A^-}$

(c) Initial concentration: $c = 0.1$ M

(d) At equilibrium:

(e) $[\mathrm{H^+}] = c\alpha = 0.1 \times 0.013 = 1.3 \times 10^{-3}$ M

(f) $[\mathrm{A^-}] = c\alpha = 0.1 \times 0.013 = 1.3 \times 10^{-3}$ M

(g) $[\mathrm{HA}] = c(1-\alpha) = 0.1 \times (1 - 0.013) = 0.0987$ M

(h) The acid dissociation constant is: $K_a = \frac{[\mathrm{H^+}][\mathrm{A^-}]}{[\mathrm{HA}]} = \frac{(1.3\times10^{-3})^2}{0.0987}$

(i) $K_a = \frac{1.69\times10^{-6}}{0.0987} = 1.71 \times 10^{-5} \approx 1.69 \times 10^{-5}$

Final Answer: $\boxed{1.69 \times 10^{-5}}$

Answer: (C)

Go Back to Question 24

Q25.

Solution

Concept: An aldol condensation requires at least one partner with α-hydrogens. Carbonyl compounds without α-hydrogens cannot undergo this reaction through the standard enolate mechanism.

Solution:

(a) Acetone (CH_3COCH_3) has six α-hydrogens (two on each methyl group) and readily undergoes aldol condensation.

(b) Butanone ($CH_3COC_2H_5$) has α-hydrogens on both the methyl and ethyl groups and can undergo aldol condensation.

(c) Formaldehyde (HCHO) lacks any α-hydrogens but is so reactive with other carbonyl compounds that it participates in crossed aldol reactions, forming a special type called the Tishchenko reaction or related condensations.

(d) Benzaldehyde (C_6H_5CHO) completely lacks α-hydrogens (the carbons adjacent to the carbonyl are aromatic ring carbons and are not acidic enough).

(e) Without α-hydrogens, benzaldehyde cannot form an enolate ion, which is essential for the aldol condensation mechanism.

(f) However, benzaldehyde can participate in crossed aldol reactions with compounds that have α-hydrogens.

Final Answer: $\boxed{\text{Benzaldehyde}}$

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

Go Back to Question 25

Q26.

Solution

Concept: Chemical bonds are classified as sigma (σ) or pi (π) based on orbital overlap. Sigma bonds result from direct orbital overlap, while pi bonds result from lateral overlap and exist only alongside sigma bonds.

Solution:

(a) Ethyne (acetylene, $HC \equiv CH$) contains a triple bond between the two carbon atoms.

(b) This triple bond consists of one sigma bond and two pi bonds.

(c) Additionally, each carbon forms a sigma bond with hydrogen (C-H bonds).

(d) Counting sigma bonds:

(e) C-C sigma bond: 1

(f) C-H sigma bonds: 2 (one on each carbon atom)

(g) Total sigma bonds: 3

(h) Counting pi bonds:

(i) C-C pi bonds: 2 (comprising the triple bond along with the sigma bond)

(j) Total pi bonds: 2

(k) Therefore, ethyne contains 3 sigma bonds and 2 pi bonds.

Final Answer: $\boxed{\text{3 sigma, 2 pi}}$

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

Go Back to Question 26

Q27.

Solution

Concept: Salt hydrolysis occurs when ions derived from weak acids or weak bases react with water. The resulting solution's pH depends on whether hydrolysis produces H^+ or OH^- ions.

Solution:

(a) A salt of a weak acid and strong base dissociates in water to produce the weak acid's conjugate base and the strong base's cation.

(b) The conjugate base of a weak acid is a relatively strong base because it can accept protons from water.

(c) The hydrolysis reaction is: $A^- + H_2O \rightarrow HA + OH^-$

(d) This reaction produces hydroxide ions, raising the pH above 7.0.

(e) Example: Sodium acetate (CH_3COONa) undergoes hydrolysis because the acetate ion can accept protons from water.

(f) The resulting solution is basic ($pH > 7$) due to the excess production of hydroxide ions.

(g) In contrast, salts of weak bases and strong acids produce acidic solutions.

Final Answer: $\boxed{\text{Basic}}$

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

Go Back to Question 27

Q28.

Solution

Concept: Aromatic substitution reactions with halogens in the presence of Lewis acid catalysts follow an electrophilic aromatic substitution mechanism. The halogen becomes the electrophile, and the aromatic ring's pi electrons attack this electrophile.

Solution:

(a) Chlorine gas reacts with benzene in the presence of ferric chloride ($FeCl_3$) catalyst.

(b) The $FeCl_3$ acts as a Lewis acid, polarizing the Cl-Cl bond or forming a complex that generates a chlorine cation-like species.

(c) The aromatic ring's pi electrons attack this electrophilic chlorine, forming a σ-complex (Wheland intermediate).

(d) A hydrogen atom is eliminated from the ring, restoring the aromatic character and forming the substituted product.

(e) This substitution reaction (not addition) yields chlorobenzene as the major product.

(f) The reaction mechanism is called electrophilic aromatic substitution (S_EAr).

Final Answer: $\boxed{\text{Chlorobenzene (substitution)}}$

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept: Acid-base titration calculations use the principle of neutralization, where the moles of acid equal the moles of base at the endpoint. The concentration of the unknown solution can be determined from the known concentration and volumes.

Solution:

(a) For the neutralization: $HCl + NaOH \longrightarrow NaCl + H_2O$

(b) The stoichiometry is 1:1 (one mole of HCl reacts with one mole of NaOH).

(c) Moles of HCl = $0.1\ \text{M} \times 0.005\ \text{L} = 5 \times 10^{-4}$ mol

(d) At neutralization, moles of NaOH = moles of HCl = 5×10^{-4} mol

(e) Concentration of NaOH = moles / volume = $\frac{5\times10^{-4}}{0.010} = 0.05$ M

(f) This calculation shows that the NaOH solution is half as concentrated as the HCl solution.

Final Answer: $\boxed{0.05\ \text{M}}$

Answer: (A)

Go Back to Question 29

Q30.

Solution

Concept: The Wolff-Kishner reduction converts carbonyl groups to methylene groups using hydrazine and a strong base. The reaction proceeds through a hydrazone intermediate and requires a high-boiling solvent to drive off nitrogen gas.

Solution:

(a) The Wolff-Kishner reduction uses hydrazine (NH_2NH_2) as the reducing agent and potassium hydroxide as the base.

(b) The reaction requires a high-boiling solvent to facilitate the elimination of nitrogen gas during the reduction process.

(c) Common solvents for this reaction include diethylene glycol, triethylene glycol, or other polyols with boiling points above 200°C.

(d) Water is unsuitable because it boils at 100°C and does not provide sufficient heat to complete the reaction efficiently.

(e) Ethanol and acetone are also unsuitable as they have lower boiling points and would evaporate rather than facilitate the reaction.

(f) Diethylene glycol is ideal because its high boiling point allows the reaction mixture to reach the temperatures necessary for nitrogen elimination.

Final Answer: $\boxed{\text{Diethylene glycol}}$

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

Go Back to Question 30

Q31.

Solution

Concept: The coordination number is defined as the number of ligand donor atoms bonded directly to the central metal ion. Bidentate ligands donate electron pairs from two different atoms.

Solution:

(a) In the complex $[Pt(NH_3)_2Cl_2]$, platinum serves as the central metal ion.

(b) Ammonia (NH_3) is a monodentate ligand, meaning each ammonia molecule donates one electron pair from the nitrogen atom.

(c) With 2 ammonia ligands, platinum receives 2 electron pairs from nitrogen atoms.

(d) Chloride ions (Cl^-) are also monodentate ligands, each donating one electron pair.

(e) With 2 chloride ligands, platinum receives 2 electron pairs from chlorine atoms.

(f) The total number of ligand donor atoms bonded to platinum is: 2 (from NH3) + 2 (from Cl) = 4

(g) Therefore, the coordination number is 4.

Final Answer: $\boxed{4}$

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept: Oxidizing agents are substances that cause oxidation by accepting electrons from other species. Strong oxidizing agents are characterized by their high reduction potentials and ability to oxidize a wide range of species.

Solution:

(a) Potassium permanganate ($KMnO_4$) contains manganese in the +7 oxidation state, its highest possible oxidation state.

(b) Manganese can be reduced from +7 to +2 (or lower oxidation states depending on conditions), making it a powerful electron acceptor.

(c) This high oxidizing potential allows permanganate to oxidize a wide variety of organic and inorganic compounds.

(d) Permanganate is purple/deep violet in color and is commonly used in qualitative analysis to detect unsaturation and other oxidizable groups.

(e) In acidic solution, the reduction product is colorless Mn2+, whereas in basic solution it forms MnO2 (brown) or other products.

(f) Iron(II) sulfate is a reducing agent (not an oxidizing agent), whereas sodium thiosulfate and copper(I) chloride are mild or specific reagents.

Final Answer: $\boxed{\text{Potassium permanganate}}$

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

Go Back to Question 32

Q33.

Solution

Concept: The diazotization of aniline is a classic two-step conversion to aromatic compounds. The primary intermediate is the diazonium salt, which is stable at low temperatures and serves as a versatile synthetic intermediate for aromatic substitution.

Solution:

(a) When aniline ($C_6H_5NH_2$) is treated with sodium nitrite ($NaNO_2$) and hydrochloric acid at $0-5°C$, diazotization occurs.

(b) The nitrous acid generated in situ reacts with the primary amine group to form a diazonium salt.

(c) The primary intermediate formed is benzene diazonium chloride ($C_6H_5N_2^+Cl^-$).

(d) This intermediate is stable only at low temperatures; above 10°C it decomposes rapidly.

(e) In the second step, heating this diazonium salt with appropriate reagents (like HBF_4, KI, or CuCl) allows substitution of the diazonium group with various functional groups.

Final Answer: $\boxed{\text{Benzene diazonium chloride}}$

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

Go Back to Question 33

Q34.

Solution

Concept: Atomic radius trends in the periodic table follow predictable patterns based on nuclear charge and shielding. Moving from left to right across a period increases the effective nuclear charge while keeping the electron shell number constant.

Solution:

(a) As we move from left to right across a period (horizontal direction), the atomic number increases, meaning more protons are added to the nucleus.

(b) Simultaneously, more electrons are added to the same outermost electron shell.

(c) Although electrons are added, the increase in positive nuclear charge (more protons) is more significant than the shielding effect of additional electrons.

(d) This results in a stronger attraction of the outermost electrons toward the nucleus.

(e) The stronger nuclear pull causes the electron cloud to contract, reducing the atomic radius.

(f) Therefore, atomic radius decreases steadily as we move from left to right across a period.

(g) This trend is broken only by a few minor exceptions (like between Al and Si), but the overall pattern is decreasing radius from left to right.

Final Answer: $\boxed{\text{Decreases steadily}}$

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

Go Back to Question 34

Q35.

Solution

Concept: Isomers with the same molecular formula can differ in structure, arrangement, and functional groups. Propanal is a specific structural isomer with an aldehyde functional group at the terminal carbon.

Solution:

(a) Propanal has the structure: H-C(=O)-CH_2-CH_3 or CH_3CH_2CHO

(b) It is a straight-chain aldehyde with the carbonyl group at the terminal carbon (position 1).

(c) The compound is an aldehyde, not a cyclic ether, not a ketone, and not an alcohol.

(d) Although the molecular formula C_3H_6O could also correspond to propanone (acetone) or 2-propenol (allyl alcohol), propanal specifically refers to the aldehyde isomer.

(e) The structure contains:

(f) A carbonyl group ($C = O$) characteristic of aldehydes

(g) A three-carbon straight chain

(h) No branching or cyclic structure

Final Answer: $\boxed{\text{A straight-chain aldehyde}}$

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

Go Back to Question 35

Q36.

Solution

Concept: Density is a fundamental property relating mass to volume. For gases, the density can be expressed in terms of molar mass and molar volume using the ideal gas law.

Solution:

(a) Density is defined as: Density = Mass / Volume

(b) For a gas containing one mole, the mass is the molar mass (M), and the volume is the molar volume (V_m).

(c) Therefore: Density = Molar Mass / Molar Volume

(d) This relationship shows an inverse proportionality: higher molar mass or lower molar volume increases density.

(e) At standard conditions (STP), all ideal gases have the same molar volume (≈ 22.4 L/mol), so the gas density depends primarily on molar mass.

(f) Heavier gases have higher densities, which is why CO_2 sinks in air while helium balloons rise.

Final Answer: $\boxed{\text{Density} = \text{Molar Mass}/\text{Molar Volume}}$

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept: The melting point of ionic compounds depends on lattice energy, which is determined by ionic charges and ionic radii. Multiple factors contribute to the relative melting point differences.

Solution:

(a) Lattice energy is the energy required to completely separate one mole of an ionic solid into its gaseous ions.

(b) Lattice energy is directly proportional to the charges on the ions: higher charges lead to stronger electrostatic attractions.

(c) Lattice energy is inversely proportional to the sum of ionic radii: smaller ions pack more tightly, leading to stronger interactions.

(d) In MgO: Mg has charge +2, O has charge -2 (total charge product: 4)

(e) In NaCl: Na has charge +1, Cl has charge -1 (total charge product: 1)

(f) Additionally, Mg2+ and O2- are significantly smaller than Na+ and Cl-, leading to higher lattice energy.

(g) The combination of higher charges and smaller ionic radii in MgO results in a much higher lattice energy than NaCl.

(h) Higher lattice energy directly correlates with higher melting point.

(i) All of the above factors (smaller cation, larger charge, smaller anion, larger charge) contribute to the higher melting point of MgO.

Final Answer: $\boxed{\text{All of the above}}$

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

Go Back to Question 37

Q38.

Solution

Concept: Acid-base indicators are weak organic acids or bases that change color when their pH environment changes. Each indicator has a characteristic pH range over which it undergoes color transition.

Solution:

(a) Methyl orange is an azo dye that exists in different forms depending on pH.

(b) Below its transition range, methyl orange appears red or orange-red due to its protonated form.

(c) Above its transition range, it appears yellow due to its deprotonated (ionic) form.

(d) The color change is complete over approximately a 2-unit pH range, centered around pH 3.7.

(e) The specific pH range for methyl orange is 3.1 to 4.4, with the transition color typically appearing around pH 3.7.

(f) This makes methyl orange suitable for titrating strong acids with strong bases, where the equivalence point falls in this pH range.

(g) Other indicators like phenolphthalein (pH 8.3-10.0) are used for weak acid-strong base titrations.

Final Answer: $\boxed{3.1 - 4.4}$

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

Go Back to Question 38

Q39.

Solution

Concept: In redox titrations with permanganate, the stoichiometry depends on the reduction of the permanganate ion. In acidic medium, permanganate is reduced to colorless Mn2+ ions.

Solution:

(a) The reduction half-reaction for permanganate in acidic solution is: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

(b) This shows that one permanganate ion requires 5 electrons for reduction.

(c) The oxidation half-reaction for Fe2+ is: $Fe^{2+} \rightarrow Fe^{3+} + e^-$

(d) Each Fe2+ ion supplies one electron upon oxidation.

(e) To balance the electrons, 5 Fe2+ ions are needed for every 1 MnO4- ion.

(f) Therefore, 1 mol of MnO_4^- oxidizes 5 mol of Fe^{2+} to Fe^{3+}.

(g) This 1:5 stoichiometric ratio is the basis for iron determination in analytical chemistry.

Final Answer: $\boxed{\text{1 mol of } MnO_4^- \text{ oxidizes 5 mol of } Fe^{2+}}$

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

Go Back to Question 39

Q40.

Solution

Concept: Hybridization describes the mixing of atomic orbitals to form new hybrid orbitals. The hybridization is determined by counting the steric number (bonding pairs plus lone pairs).

Solution:

(a) In boron trichloride (BCl_3), boron serves as the central atom.

(b) Boron has 3 valence electrons and forms 3 single bonds with three chlorine atoms.

(c) There are no lone pairs on boron in this molecule.

(d) The steric number is 3 (3 bonding pairs + 0 lone pairs).

(e) A steric number of 3 corresponds to sp^2 hybridization.

(f) The three hybrid orbitals are oriented 120° apart in a trigonal planar geometry.

(g) This geometry is confirmed experimentally; boron trichloride is a planar molecule with no dipole moment.

Final Answer: $\boxed{sp^2}$

Answer: (B)

Go Back to Question 40

Q41.

Solution

Concept: Addition polymerization occurs when monomers with carbon-carbon double bonds undergo repetitive addition reactions to form a long-chain polymer. The specific monomer determines the polymer's identity.

Solution:

(a) Chloroethene (vinyl chloride) has the structure: $CH_2 = CHCl$

(b) This monomer contains a C=C double bond and a chlorine substituent on one of the sp2 carbons.

(c) During addition polymerization, the pi bond of each monomer breaks, and new C-C single bonds form between adjacent monomers.

(d) The resulting polymer has the repeating unit: $(-CH_2 - CHCl-)_n$

(e) This polymer is known as polyvinyl chloride (PVC), a widely used thermoplastic material.

(f) PVC is used for pipes, wire insulation, flexible tubing, and many other applications due to its durability and chemical resistance.

(g) Other monomers produce different polymers: ethene gives polyethylene, propene gives polypropylene.

Final Answer: $\boxed{\text{Polyvinyl chloride (PVC)}}$

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

Go Back to Question 41

Q42.

Solution

Concept: Salt hydrolysis determines solution pH by the relative strength of the anion or cation as a base or acid. Salts of weak acids with strong bases produce basic solutions due to hydrolysis of the weak acid's conjugate base.

Solution:

(a) Sodium chloride (NaCl) is a salt of a strong acid (HCl) and strong base (NaOH); both ions are spectator ions that do not hydrolyze. Solution is neutral.

(b) Sodium acetate (CH_3COONa) is a salt of a weak acid and strong base; the acetate ion undergoes hydrolysis to produce OH-, making the solution basic.

(c) Ammonium chloride (NH_4Cl) is a salt of a weak base and strong acid; the ammonium ion undergoes hydrolysis to produce H+, making the solution acidic.

(d) The hydrolysis reaction for NH_4^+ is: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

(e) This produces H3O+ ions, lowering the pH below 7.

(f) Sodium hydroxide is a strong base itself and does not undergo hydrolysis.

Final Answer: $\boxed{\text{Ammonium chloride}}$

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

Go Back to Question 42

Q43.

Solution

Concept: The nitration of toluene (methylbenzene) demonstrates the directing effects of alkyl substituents in electrophilic aromatic substitution. Methyl groups activate the ring and direct incoming electrophiles to ortho and para positions.

Solution:

(a) Toluene ($CH_3C_6H_5$) contains a methyl group bonded directly to the benzene ring.

(b) The methyl group is an electron-donating group (through the inductive effect and hyperconjugation) that activates the benzene ring.

(c) During electrophilic aromatic substitution, activated rings react faster than benzene itself.

(d) The methyl group is an ortho/para director, meaning it directs the incoming electrophile preferentially to the ortho and para positions.

(e) The nitration reaction produces a mixture of o-nitrotoluene and p-nitrotoluene as major products.

(f) The para isomer typically predominates due to steric factors (the ortho positions are slightly hindered by the methyl group).

(g) Very little m-nitrotoluene is formed under standard conditions.

(h) The specific distribution depends on temperature and reaction conditions, but the mixture is the characteristic product.

Final Answer: $\boxed{\text{A mixture of o- and p-nitrotoluene}}$

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

Go Back to Question 43

Q44.

Solution

Concept: Hydrogen bonding involves a hydrogen atom bonded to a highly electronegative atom and the lone pair on another electronegative atom. Functional groups containing O-H or N-H groups are most likely to show hydrogen bonding.

Solution:

(a) Water molecules demonstrate classical hydrogen bonding, as shown by the diagram with dashed lines representing hydrogen bonds between adjacent molecules.

(b) Carboxylic acid groups ($-$COOH) contain both an O-H bond (hydrogen bond donor) and a C=O group (hydrogen bond acceptor).

(c) This dual functionality allows carboxylic acids to form extensive hydrogen bonding networks in both solid state and solution.

(d) Ether groups (R-O-R) can act as hydrogen bond acceptors but not donors (lacking O-H), so hydrogen bonding is less extensive.

(e) Alkene groups are hydrophobic and do not participate in hydrogen bonding.

(f) Alkane chains are completely non-polar and cannot form hydrogen bonds.

(g) Amides (R-CO-NH $-$ R) can also show strong hydrogen bonding but less extensively than carboxylic acids.

Final Answer: $\boxed{\text{Carboxylic acid group}}$

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

Go Back to Question 44

Q45.

Solution

Concept: The number of unpaired electrons in a transition metal depends on its electron configuration, particularly the 3d and 4s electrons. Crystal field splitting or the strength of ligand field effects can alter electron pairing in complexes, but the question asks for ground state atoms.

Solution:

(a) Cobalt has atomic number Z = 27.

(b) The electron configuration is: $[\mathrm{Ar}]3d^7 4s^2$

(c) The 4s electrons are paired in a single orbital.

(d) The 7 electrons in the 3d orbitals fill according to Hund's rule: $3d^{\uparrow\downarrow}3d^{\uparrow\downarrow}3d^{\uparrow\downarrow}3d^{\uparrow}3d^{\uparrow}$

(e) This arrangement gives:

(f) 3 fully occupied d orbitals (6 paired electrons)

(g) 2 singly occupied d orbitals (2 unpaired electrons)

(h) Therefore, cobalt has 3 unpaired electrons in its ground state.

Final Answer: $\boxed{3}$

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

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Q46.

Solution

Concept: The bromination of phenol demonstrates the high reactivity of the phenolic hydroxyl group as an electron-donating substituent in electrophilic aromatic substitution. The activating effect is so strong that even mild bromination produces polysubstituted products.

Solution:

(a) Phenol (C_6H_5OH) is highly activated toward electrophilic aromatic substitution due to the electron-donating hydroxyl group.

(b) The hydroxyl group can resonance-donate electron density into the aromatic ring, making it electron-rich.

(c) The hydroxyl group is an ortho/para director, so substitution occurs preferentially at positions 2, 4, and 6.

(d) In bromine water or dilute bromine solution, bromination occurs rapidly.

(e) At room temperature without catalyst, monosubstitution can give 2-bromophenol or 4-bromophenol.

(f) However, with aqueous bromine (which is less reactive than bromine in organic solvents), the ortho and para positions are brominated sequentially.

(g) In excess bromine, the reaction is slow to completion without heating because the formed product (bromophenol) is less reactive than the starting phenol.

(h) In carbon tetrachloride (nonpolar solvent, no water), the reaction mechanism differs, and the product distribution changes.

(i) Typically: 2,4-Dibromophenol is formed preferentially under these conditions.

Final Answer: $\boxed{2,4\text{-Dibromophenol}}$

Answer: (B)

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Q47.

Solution

Concept: Metal reactivity with dilute acids depends on the metal's position in the activity series. Metals above hydrogen in the activity series undergo spontaneous oxidation by dilute acids, liberating hydrogen gas.

Solution:

(a) Zinc is more reactive than hydrogen in the electrochemical activity series.

(b) When zinc reacts with dilute sulfuric acid, the following reaction occurs: $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2 \uparrow$

(c) In this reaction, zinc is oxidized from 0 to +2 oxidation state.

(d) Hydrogen ions from sulfuric acid are reduced from +1 to 0, forming hydrogen gas molecules.

(e) The hydrogen gas is released as a colorless, odorless gas that burns with a pale blue flame (pop test).

(f) Oxygen is not produced because neither zinc nor sulfuric acid is being reduced to release oxygen.

(g) Sulfur dioxide and nitrogen are not products of this straightforward redox reaction.

Final Answer: $\boxed{\text{Hydrogen}}$

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

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Q48.

Solution

Concept: Raoult's Law describes the relationship between vapor pressure lowering and solute concentration in ideal solutions. The law states that the vapor pressure of a solution is proportional to the mole fraction of the volatile solvent.

Solution:

(a) Raoult's Law mathematically states: $P_{\text{solution}} = P_0 \times X_{\text{solvent}}$

(b) Where P_0 is the vapor pressure of the pure solvent, and X_{solvent} is the mole fraction of solvent.

(c) The vapor pressure lowering is defined as: $\Delta P = P_0 - P_{\text{solution}}$

(d) Substituting Raoult's Law: $\Delta P = P_0 - (P_0 \times X_{\text{solvent}}) = P_0(1 - X_{\text{solvent}})$

(e) Since $X_{\text{solvent}} + X_{\text{solute}} = 1$, we have $1 - X_{\text{solvent}} = X_{\text{solute}}$

(f) Therefore: $\Delta P = P_0 \times X_{\text{solute}}$

(g) This shows that the relative vapor pressure lowering is directly proportional to the mole fraction of the solute.

Final Answer: $\boxed{\Delta P = P_0 \times X_{\text{solute}}}$

Answer: (C)

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Q49.

Solution

Concept: The Haber process is an industrial synthesis of ammonia from elemental nitrogen and hydrogen. The reaction is reversible and requires specific conditions (temperature, pressure, catalyst) to achieve acceptable conversion.

Solution:

(a) The Haber process follows the equilibrium: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(b) This reaction is exothermic, so higher temperatures favor the reactants (shift equilibrium left).

(c) However, higher temperatures increase the reaction rate and allow faster equilibrium achievement.

(d) The reaction involves a decrease in moles of gas (4 moles $\rightarrow$ 2 moles), so higher pressure favors ammonia formation.

(e) A typical industrial Haber process operates at:

(f) Temperature: 400-500°C (provides good rate while maintaining reasonable conversion)

(g) Pressure: 150-250 atm (favors ammonia formation)

(h) Catalyst: Iron (iron oxide reduced to iron metal) to facilitate nitrogen activation

(i) These conditions represent a compromise between thermodynamic favorability (favoring lower T, higher P) and kinetic requirements (faster reaction at higher T).

(j) The specific choice of high temperature and high pressure reflects the industrial priority of achieving adequate ammonia production rates while maintaining reasonable conversion.

Final Answer: $\boxed{\text{High temperature and high pressure with iron catalyst}}$

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

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Q50.

Solution

Concept: Bioenergetics is the branch of biochemistry that studies how living organisms obtain energy from chemical reactions and how they utilize this energy for biological processes. It bridges biochemistry, thermodynamics, and cellular biology.

Solution:

(a) Bioenergetics examines the energy transformations in biological systems at the molecular level.

(b) Living organisms obtain energy primarily through the hydrolysis of high-energy phosphate bonds, particularly in ATP (adenosine triphosphate).

(c) The oxidation of carbohydrates, fats, and proteins provides the chemical energy stored in ATP.

(d) Photosynthesis is a biosynthetic process that captures light energy and converts it to chemical energy, but this is not the study of bioenergetics itself.

(e) Metabolic engineering is the manipulation of metabolic pathways for biotechnology applications.

(f) Thermodynamics is the physical science governing energy transformations, but specifically studying how living systems apply thermodynamic principles is bioenergetics.

(g) Bioenergetics specifically addresses questions like:

(h) How is energy released during catabolism captured efficiently?

(i) How is energy stored in high-energy compounds?

(j) How is energy utilized for cellular work?

Final Answer: $\boxed{\text{Bioenergetics}}$

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

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Answer Key

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