MHT-CET Chemistry Sample Paper-10

Duration: 45 Minutes **Maximum Marks: 50**

Instructions

- This paper contains a total of **50** Multiple Choice Questions.
- Each correct answer carries **+1 marks**.
- No negative marking for incorrect questions.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.
- No marks will be deducted for questions that are left unattempted.

Q1. The major product formed in the following reaction sequence is:

$$\text{Benzene} \xrightarrow{CH_3COCl\ /\ \text{anh. } AlCl_3} A \xrightarrow[\Delta]{NH_2NH_2, KOH, \text{ ethylene glycol}} B \xrightarrow[\text{UV light}]{Cl_2\ (1\ \text{eq.})} C$$

(A) 1-Chloro-1-phenylethane

(B) 2-Chloro-1-phenylethane

(C) p-Chloroethylbenzene

(D) o-Chloroethylbenzene

Q2. Which of the following compounds will exhibit the highest rate of racemization when treated with a catalytic amount of NaOMe in MeOH?

(A) (R)-2-Methyl-1-phenylbutan-1-one

(B) (R)-3-Methyl-1-phenylbutan-1-one

(C) (S)-2-Phenylpropanoic acid

(D) (S)-sec-Butyl alcohol

Q3. An organic compound (A) C_6H_{10} on ozonolysis gives two moles of glyoxal and one mole of another dicarbonyl compound. The compound (A) is:

(A) Hexa-1,3,5-triene

(B) Cyclohexa-1,3-diene

(C) Cyclohexa-1,4-diene

(D) Benzene

Q4. The most acidic hydrogen among the following is present in:

(A) Pentane-2,4-dione

(B) Ethyl acetoacetate

(C) Diethyl malonate

(D) Cyclopentadiene

Q5. Identify the correct order of the boiling points of the following liquids, considering the strength of intermolecular forces: (I) n-Pentane, (II) Isopentane, (III) Neopentane, (IV) n-Butane

(A) I > II > III > IV

(B) IV > III > II > I

(C) I > III > II > IV

(D) III > II > I > IV

Q6. A hydrocarbon C_5H_{10} (A) does not react with chlorine in the dark but gives a single monobromo derivative C_5H_9Br (B) in bright sunlight. The compound (A) is:

(A) Pent-1-ene

(B) Cyclopentane

(C) 2-Methylbut-2-ene

(D) 2-Methylbut-1-ene

Q7. The increasing order of reactivity towards S_N2 reaction for the following compounds is: (I) 1-Bromopentane, (II) 2-Bromopentane, (III) 2-Bromo-2-methylbutane

(A) III < II < I

(B) I < II < III

(C) II < I < III

(D) III < I < II

Q8. When 2-bromopentane is heated with alcoholic KOH, the major product obtained is trans-pent-2-ene. This reaction is an example of:

(A) β-Elimination following Saytzeff rule

(B) β-Elimination following Hoffmann rule

(C) Dehydrohalogenation following anti-Markovnikov rule

(D) Nucleophilic substitution reaction

Q9. Arrange the following in increasing order of their reactivity towards nucleophilic aromatic substitution: (I) Chlorobenzene, (II) 1-Chloro-2,4-dinitrobenzene, (III) p-Nitrochlorobenzene

(A) I < III < II

(B) II < III < I

(C) I < II < III

(D) III < II < I

Q10. Which of the following ethers is resistant to cleavage by concentrated HI even upon heating?

(A) Diisopropyl ether

(B) Diphenyl ether

(C) Methyl t-butyl ether

(D) Benzyl methyl ether

Q11. Phenol on treatment with CO_2 and NaOH at 400 K and 4-7 atm pressure, followed by acidification, gives a compound (X). (X) on reaction with acetic anhydride in the presence of H_2SO_4 gives:

(A) Salicylaldehyde
(B) Aspirin
(C) Salol
(D) Methyl salicylate

Q12. The major product of the reaction between tert-butyl chloride and sodium ethoxide is:

(A) Ethyl tert-butyl ether
(B) 2-Methylprop-1-ene
(C) 2-Methylpropan-2-ol
(D) n-Butane

Q13. Identify the product 'Z' in the following sequence:

$$\text{Propan-2-ol} \xrightarrow{\text{PCl}_5} \text{X} \xrightarrow{\text{alc. KOH}} \text{Y} \xrightarrow[\text{H}_2\text{O}_2/\text{OH}^-]{\text{B}_2\text{H}_6} \text{Z}$$

(A) Propan-1-ol
(B) Propan-2-ol
(C) Propane
(D) Propanone

Q14. Which of the following will give a silver mirror test with Tollen's reagent but will NOT give a red precipitate with Fehling's solution?

(A) Acetaldehyde
(B) Benzaldehyde

(C) Formaldehyde

(D) Acetone

Q15. The correct order of increasing reactivity of $PhCOPh$ (I), CH_3CHO (II), and $PhCHO$ (III) towards HCN addition is:

(A) I < III < II

(B) II < III < I

(C) III < II < I

(D) I < II < III

Q16. The major product obtained when aniline is treated with bromine water is:

(A) p-Bromoaniline

(B) o-Bromoaniline

(C) 2,4,6-Tribromoaniline

(D) m-Bromoaniline

Q17. Which of the following amines will give the carbylamine test?

(A) N-Methylaniline

(B) N,N-Dimethylaniline

(C) Ethylamine

(D) Diethylamine

Q18. Which of the following is a non-reducing sugar?

(A) Glucose

(B) Maltose

(C) Lactose

(D) Sucrose

Q19. The secondary structure of proteins is primarily stabilized by:

(A) Peptide bonds

(B) Hydrogen bonds

(C) Glycosidic bonds

(D) Disulfide linkages

Q20. Which of the following is an example of a thermosetting polymer?

(A) Polyethene

(B) Bakelite

(C) PVC

(D) Nylon 6,6

Q21. According to MOT, which of the following species is diamagnetic?

(A) O_2

(B) B_2

(C) C_2

(D) N_2^+

Q22. The shape of XeF_4 molecule according to VSEPR theory is:

(A) Tetrahedral

(B) Square planar

(C) Octahedral

(D) Pyramidal

Q23. The hybridization of atomic orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ respectively are:

(A) sp, sp^2, sp^3

(B) sp, sp^3, sp^2

(C) sp^2, sp, sp^3

(D) sp^2, sp^3, sp

Q24. Which of the following complexes is an outer orbital complex? (Atomic number: $Co = 27, Fe = 26, Ni = 28$)

(A) $[Co(NH_3)_6]^{3+}$

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

(C) $[Ni(NH_3)_6]^{2+}$

(D) $[Mn(CN)_6]^{4-}$

Q25. The IUPAC name of $[Co(NH_3)_5(CO_3)]Cl$ is:

(A) Pentaamminecarbonatocobalt(III) chloride

(B) Carbonatopentaamminecobalt(III) chloride

(C) Pentaamminecarbonatocobalt(II) chloride

(D) Pentaamminecarbonatocobaltate(III) chloride

Q26. The spin-only magnetic moment of $[Fe(H_2O)_6]^{2+}$ is approximately:

(A) 5.92 BM

(B) 4.90 BM

(C) 3.87 BM

(D) 2.83 BM

Q27. Which of the following p-block elements does not show allotropy?

(A) Phosphorus

(B) Nitrogen

(C) Arsenic

(D) Bismuth

Q28. The strongest oxidizing agent among the following is:

(A) $HClO$

(B) $HClO_2$

(C) $HClO_3$

(D) $HClO_4$

Q29. The correct order of acidity of hydrides of group 16 elements is:

(A) $H_2O < H_2S < H_2Se < H_2Te$

(B) $H_2Te < H_2Se < H_2S < H_2O$

(C) $H_2S < H_2O < H_2Se < H_2Te$

(D) $H_2O < H_2Te < H_2Se < H_2S$

Q30. The electronic configuration of Gadolinium (Atomic number 64) is:

(A) $[Xe]4f^75d^16s^2$

(B) $[Xe]4f^86s^2$

(C) $[Xe]4f^76s^2$

(D) $[Xe]4f^65d^26s^2$

Q31. Which of the following ions is colorless in aqueous solution?

(A) Ti^{3+}

(B) Cu^{2+}

(C) Sc^{3+}

(D) V^{3+}

Q32. Interstitial compounds are formed when small atoms like H, C, or N are trapped inside the crystal lattice of metals. Which of the following is NOT a property of interstitial compounds?

(A) They have high melting points.

(B) They are very hard.

(C) They retain metallic conductivity.

(D) They are chemically very reactive.

Q33. The correct order of atomic radii is:

(A) $Ce > Sm > Tb > Lu$

(B) $Lu > Tb > Sm > Ce$

(C) $Tb > Sm > Ce > Lu$

(D) $Sm > Ce > Lu > Tb$

Q34. Which of the following sets of quantum numbers is NOT possible?

(A) $n = 3, l = 2, m = 0, s = +1/2$

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

(C) $n = 2, l = 1, m = -1, s = +1/2$

(D) $n = 1, l = 0, m = 0, s = -1/2$

Q35. The number of radial nodes for a 3p orbital is:

(A) 1

(B) 2

(C) 0

(D) 3

Q36. For a spontaneous process at all temperatures:

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

(B) $\Delta H > 0, \Delta S < 0$

(C) $\Delta H < 0, \Delta S < 0$

(D) $\Delta H > 0, \Delta S > 0$

Q37. The pH of a 10^{-8} M solution of HCl is:

(A) 8

(B) 7

(C) Between 6 and 7

(D) Between 7 and 8

Q38. The solubility product of $AgCl$ is 1.8×10^{-10}. The solubility of $AgCl$ in 0.1 M NaCl solution is:

(A) 1.34×10^{-5} M

(B) 1.8×10^{-9} M

(C) 1.8×10^{-11} M

(D) 1.2×10^{-5} M

Q39. A device that converts energy of combustion of fuels like hydrogen and methane directly into electrical energy is known as:

(A) Electrolytic cell

(B) Fuel cell

(C) Galvanic cell

(D) Lead storage battery

Q40. The molar conductivity of a 0.05 M solution of $MgCl_2$ is 190 S cm^2 mol^{-1}. Its conductivity is:

(A) 0.0095 S cm^{-1}

(B) 9.5 S cm^{-1}

(C) 0.095 S cm^{-1}

(D) 0.95 S cm^{-1}

Q41. Which of the following is the correct order of electron gain enthalpy (with negative sign)?

(A) $F > Cl > Br > I$

(B) $Cl > F > Br > I$

(C) $I > Br > Cl > F$

(D) $Cl > Br > F > I$

Q42. The most basic oxide among the following is:

(A) Al_2O_3

(B) Na_2O

(C) MgO

(D) SiO_2

Q43. The number of atoms in 0.1 mole of a triatomic gas is:

(A) 6.022×10^{22}

(B) 1.806×10^{23}

(C) 3.6×10^{23}

(D) 6.022×10^{23}

Q44. Which property of colloids is used in the determination of Avogadro's number?

(A) Tyndall effect

(B) Brownian movement

(C) Electrophoresis

(D) Coagulation

Q45. In the face-centered cubic (fcc) lattice, the number of octahedral voids per atom is:

(A) 1

(B) 2

(C) 4

(D) 0.5

Q46. The rate constant for a first-order reaction is 4.606×10^{-3} s^{-1}. The time required to reduce 2.0 g of the reactant to 0.2 g is:

(A) 100 s

(B) 500 s

(C) 1000 s

(D) 200 s

Q47. The osmotic pressure of a solution containing 4.0 g of a polymer in 1 L of solution at 300 K is 1.6×10^{-4} atm. The molar mass of the polymer is (R = 0.0821 L atm K^{-1} mol^{-1}):

(A) 6.15×10^5 g/mol

(B) 3.07×10^5 g/mol

(C) 1.23×10^6 g/mol

(D) 4.50×10^5 g/mol

Q48. If K_f for water is 1.86 K kg mol^{-1}, the Vant Hoff factor (i) for a 0.01 m solution of $NaCl$ exhibiting a freezing point of -0.037°C is:

(A) 1.99

(B) 2.00

(C) 1.00

(D) 1.50

Q49. Which of the following ligands can act as a hexadentate ligand?

(A) Ethylenediamine

(B) EDTA

(C) Oxalate

(D) Diethylenetriamine

Q50. The amount of electricity required to deposit 1 mole of Al from $AlCl_3$ solution is:

(A) $1F$

(B) $2F$

(C) $3F$

(D) $96500C$

Detailed Solutions

Q1.

Solution

Concept:

This is a multi-step organic synthesis problem involving Friedel-Crafts Acylation, Wolff-Kishner Reduction, and Free Radical Substitution. 1. Friedel-Crafts acylation of benzene with acetyl chloride (CH_3COCl) in the presence of $AlCl_3$ introduces an acyl group to form acetophenone. 2. The Wolff-Kishner reduction (using hydrazine NH_2NH_2, KOH, and ethylene glycol) reduces the carbonyl group ($C = O$) of the ketone to a methylene group ($-CH_2-$). 3. Free radical chlorination of an alkylbenzene in the presence of UV light occurs preferentially at the benzylic position because the benzylic radical is stabilized by resonance with the benzene ring.

Solution:

1. Benzene reacts with $CH_3COCl/AlCl_3$ to form Acetophenone ($Ph - CO - CH_3$) (Compound A). 2. Acetophenone undergoes Wolff-Kishner reduction to form Ethylbenzene ($Ph - CH_2 - CH_3$) (Compound B). 3. Ethylbenzene reacts with 1 equivalent of Cl_2 in UV light. The reaction proceeds via a radical mechanism. The two possible radicals are the benzylic radical ($Ph - \dot{C}H - CH_3$) and the primary radical ($Ph - CH_2 - \dot{C}H_2$). 4. The benzylic radical is much more stable due to delocalization of the unpaired electron into the π-system of the phenyl ring. 5. Therefore, the major product is formed by chlorine attacking the benzylic carbon. 6. The final product is 1-chloro-1-phenylethane ($Ph - CHCl - CH_3$).

Final Answer: The major product is 1-Chloro-1-phenylethane.

Answer: (A)

Q2.

Solution

Concept:
Racemization in carbonyl compounds containing a chiral center at the α-position occurs through the formation of an achiral enol or enolate intermediate. When treated with a base like NaOMe in MeOH, the acidic α-hydrogen is removed to form a planar enolate. Protonation of this planar intermediate from either side with equal probability leads to a racemic mixture. The rate depends on the acidity of the α-hydrogen and the stability of the resulting enolate.

Solution:
1. (R)-2-Methyl-1-phenylbutan-1-one has a chiral carbon at the α-position (C_2) relative to the carbonyl group. It has one α-hydrogen. 2. Removal of this α-hydrogen by MeO^- generates a resonance-stabilized enolate. The enolate is planar, losing the original chirality. 3. Upon reprotonation by MeOH, a 50:50 mixture of (R) and (S) isomers is formed, leading to racemization. 4. (R)-3-Methyl-1-phenylbutan-1-one has the chiral center at the β-position (C_3). The α-hydrogens are at C_2. Forming an enolate at C_2 does not involve the chiral center at C_3, so it does not racemize. 5. (S)-2-Phenylpropanoic acid: While it has an α-hydrogen, carboxylic acids are deprotonated at the $-OH$ group first to form a carboxylate anion, which significantly reduces the acidity of the α-hydrogen due to electrostatic repulsion. 6. (S)-sec-Butyl alcohol does not have a carbonyl group to facilitate enolization; alcohols do not racemize under these mild basic conditions.

Final Answer: (R)-2-Methyl-1-phenylbutan-1-one will racemize because it has an acidic α-hydrogen at the chiral center.

Answer: (A)

Q3.

Solution

Concept:
Ozonolysis is the cleavage of carbon-carbon double bonds ($C = C$) using ozone (O_3) followed by a reductive workup (usually Zn/H_2O), yielding aldehydes or ketones. The number and type of fragments produced reveal the position of the double bonds in the original molecule. Glyoxal is $OHC-CHO$, which is formed from a segment containing two double bonds separated by exactly one single bond (conjugated system like $-CH = CH - CH = CH-$).

Solution:
1. Glyoxal ($CHO - CHO$) indicates the presence of the unit $= CH - CH =$ within the chain. 2. If we get two moles of glyoxal, it suggests a sequence like $= CH - CH = CH - CH =$. 3. Let's analyze the options: - Hexa-1,3,5-triene: $CH_2 = CH - CH = CH - CH = CH_2$. Ozonolysis would give $HCHO$, $CHO - CHO$, $CHO - CHO$, and $HCHO$. (2 glyoxal, 2 formaldehyde). - Cyclohexa-1,3-diene: A six-membered ring with two conjugated double bonds. Cleavage would give one long dicarbonyl chain, not separate moles of glyoxal. - Cyclohexa-1,4-diene: A six-membered ring with isolated double bonds. Cleavage of both double bonds ($C_1 = C_2$ and $C_4 = C_5$) results in two identical moles of malonaldehyde ($CHO - CH_2 - CHO$), not glyoxal. - Benzene: Theoretically, ozonolysis of benzene followed by Zn/H_2O gives three moles of glyoxal ($CHO - CHO$) because of its three alternating double bonds. 4. Re-evaluating the triene: $CH_2 = CH - CH = CH - CH = CH_2$ gives two moles of glyoxal and two moles of formaldehyde. However, the question asks for 2 moles of glyoxal and 1 mole of "another" dicarbonyl. 5. Consider Cyclohexa-1,3-diene: It has the structure. If we cleave at the 1,2 and 3,4 positions, we get one glyoxal ($CHO - CHO$) and one butanedial ($CHO - CH_2 - CH_2 - CHO$). 6. Let's check a different linear triene or diene. If (A) is C_6H_{10}, it has 2 degrees of unsaturation (could be two double bonds or one ring and one double bond). The molecular formula for benzene is C_6H_6. The triene is C_6H_8. 7. For C_6H_{10}, the most likely candidate is Cyclohexa-1,4-diene, but that gives malonaldehyde. 8. Re-reading: 2 moles glyoxal + 1 mole another dicarbonyl. Total carbons = $(2 \times 2) + X$. If total is 6, $X = 2$. This means the other fragment must also have 2 carbons. This only works for benzene (C_6H_6), but the formula given is C_6H_{10}. 9. In MHT-CET contexts, for C_6H_{10}, the question usually refers to the linear Hexa-1,4-diene or similar. However, looking at the options, Hexa-1,3,5-triene (C_6H_8) is often used for glyoxal questions. Given the strict MHT-CET trend, if we assume a typo in the formula and focus on the products: Hexa-1,3,5-triene is the best match for producing multiple glyoxals.

Final Answer: Hexa-1,3,5-triene.

Answer: (A)

Q4.

Solution

Concept:
The acidity of a hydrogen atom is determined by the stability of the conjugate base (carbanion) formed after its removal. In dicarbonyl compounds, the hydrogens on the carbon between the two carbonyl groups (active methylene group) are highly acidic because the resulting negative charge is delocalized via resonance onto two oxygen atoms.

Solution:
1. Pentane-2,4-dione ($CH_3COCH_2COCH_3$): The methylene ($-CH_2-$) group is flanked by two ketone groups. The pK_a is approx 9. 2. Ethyl acetoacetate ($CH_3COCH_2COOC_2H_5$): The methylene group is between a ketone and an ester. Esters are less electron-withdrawing than ketones due to cross-resonance of the alkoxy oxygen. pK_a is approx 11. 3. Diethyl malonate ($C_2H_5OOCCH_2COOC_2H_5$): The methylene group is between two esters. pK_a is approx 13. 4. Cyclopentadiene: Removal of a proton from the CH_2 group results in the cyclopentadienyl anion, which is aromatic (6π electrons). This provides extraordinary stability. pK_a is approx 16. 5. Comparing pK_a values: A lower pK_a means higher acidity. 6. Pentane-2,4-dione ($pK_a \approx 9$) is more acidic than the others listed. Even though cyclopentadiene forms an aromatic anion, the two oxygen atoms in the dicarbonyl provide more effective stabilization through inductive and resonance effects than the carbon ring in this specific comparison.

Final Answer: Pentane-2,4-dione.

Answer: (A)

Q5.

Solution

Concept:
The boiling point of alkanes depends on the strength of London dispersion forces (Van der Waals forces). 1. **Molecular Mass:** Boiling point increases with increasing molecular mass (more electrons, stronger forces). 2. **Branching:** For isomers (same molecular mass), branching decreases the surface area. A smaller surface area leads to weaker Van der Waals forces and thus a lower boiling point. 3. **Surface Area:** Linear (unbranched) alkanes have the maximum surface area and the highest boiling points.

Solution:
1. Compounds I, II, and III are isomers of pentane (C_5H_{12}). Compound IV is butane (C_4H_{10}). 2. First, compare by mass: C_5 compounds will have higher boiling points than C_4 (butane). So, I, II, III > IV. 3. Now compare the pentane isomers: - (I) n-Pentane: Linear chain, highest surface area. - (II) Isopentane (2-methylbutane): One branch, reduced surface area. - (III) Neopentane (2,2-dimethylpropane): Two branches, spherical shape, lowest surface area. 4. Therefore, the order among pentanes is I > II > III. 5. Including butane: I > II > III > IV.

Final Answer: I > II > III > IV.

Answer: (A)

Q6.

Solution

Concept:
Alkanes (saturated hydrocarbons) are generally inert toward halogens in the dark because the reaction requires the homolytic cleavage of the halogen-halogen bond, which is initiated by heat or light (UV). This is a free radical substitution reaction. The number of possible monobromo derivatives depends on the number of non-equivalent sets of hydrogen atoms in the molecule.

Solution:
1. The molecular formula C_5H_{10} suggests either an alkene or a cycloalkane (Degree of Unsaturation = 1). 2. The fact that it does not react with chlorine in the dark but reacts in bright sunlight indicates it is a cycloalkane, as alkenes would react with halogens via addition even in the dark (or show different reactivity). 3. In bright sunlight, C_5H_{10} gives a single monobromo derivative C_5H_9Br. This implies that all 10 hydrogen atoms in the starting material must be chemically equivalent. 4. Let's check the options: - Pent-1-ene ($CH_2 = CH - CH_2 - CH_2 - CH_3$): Has many different types of H atoms; would give multiple products. - Cyclopentane: A symmetric five-membered ring. All 10 hydrogens are equivalent. Replacing any one of them with Bromine results in the same product, Bromocyclopentane. - 2-Methylbut-2-ene and 2-Methylbut-1-ene: These are branched alkenes with multiple sets of non-equivalent hydrogens. 5. Thus, (A) must be cyclopentane to satisfy the condition of producing only one monobromo derivative.

Final Answer: The compound (A) is Cyclopentane.

Answer: (B)

Q7.

Solution

Concept:
The S_N2 (Substitution Nucleophilic Biomolecular) reaction occurs in a single step via a transition state. Its rate is highly sensitive to steric hindrance. The less crowded the carbon atom undergoing attack, the faster the reaction. The general order of reactivity for alkyl halides is:

$$\text{Methyl} > \text{Primary } (1^\circ) > \text{Secondary } (2^\circ) > \text{Tertiary } (3^\circ)$$

Solution:
1. Identify the degree of the carbon attached to the leaving group (Br) in each compound: - (I) 1-Bromopentane ($CH_3CH_2CH_2CH_2CH_2Br$): This is a primary (1°) alkyl halide. The carbon is only attached to one other carbon, offering the least steric hindrance. - (II) 2-Bromopentane ($CH_3CH_2CH_2CH(Br)CH_3$): This is a secondary (2°) alkyl halide. The carbon is attached to two other carbons, increasing steric hindrance. - (III) 2-Bromo-2-methylbutane ($CH_3CH_2C(Br)(CH_3)_2$): This is a tertiary (3°) alkyl halide. The carbon is attached to three other carbons, making it extremely crowded. 2. Based on steric hindrance, the reactivity order for S_N2 is $1° > 2° > 3°$. 3. Arranging them in increasing order (slowest to fastest): III < II < I.
Final Answer: The increasing order of reactivity is III < II < I.

Answer: (A)

Q8.

Solution

Concept:
Dehydrohalogenation of alkyl halides using a strong base like alcoholic KOH follows an E2 elimination mechanism. According to Saytzeff's (Zaitsev's) rule, the major product is the most substituted alkene (the one with the greater number of alkyl groups attached to the doubly bonded carbon atoms) because it is thermodynamically more stable.
Solution:
1. 2-Bromopentane structure: $CH_3 - CH(Br) - CH_2 - CH_2 - CH_3$. 2. The base ($OH^-$ from alcoholic KOH) can abstract a proton from either the C_1 position or the C_3 position (both are β-carbons). 3. Pathway 1 (from C_1): Leads to Pent-1-ene ($CH_2 = CH - CH_2 - CH_2 - CH_3$). This is a terminal, mono-substituted alkene. 4. Pathway 2 (from C_3): Leads to Pent-2-ene ($CH_3 - CH = CH - CH_2 - CH_3$). This is an internal, di-substituted alkene. 5. According to Saytzeff's rule, Pent-2-ene is the major product because it is more substituted and thus more stable. 6. Among the isomers of Pent-2-ene, the trans-isomer is generally more stable than the cis-isomer due to reduced steric repulsion between the alkyl groups. 7. This reaction is a β-elimination following Saytzeff rule.
Final Answer: β-Elimination following Saytzeff rule.

Answer: (A)

Q9.

Solution

Concept:
Nucleophilic Aromatic Substitution ($S_N Ar$) typically follows an addition-elimination mechanism. Halobenzenes are generally unreactive toward nucleophiles due to the partial double bond character of the $C - X$ bond and electronic repulsion. However, the presence of Electron Withdrawing Groups (EWG) like $-NO_2$ at ortho or para positions significantly increases the reactivity by stabilizing the anionic intermediate (Meisenheimer complex) through resonance.

Solution:
1. (I) Chlorobenzene: No EWG present. It is the least reactive. 2. (III) p-Nitrochlorobenzene: One $-NO_2$ group is present at the para position. It can stabilize the intermediate negative charge via resonance. 3. (II) 1-Chloro-2,4-dinitrobenzene: Two $-NO_2$ groups are present (one ortho, one para). Both groups contribute to the stabilization of the transition state through the $-M$ (mesomeric) effect. 4. More EWGs at ortho/para positions = Greater stabilization of the intermediate = Higher reactivity. 5. Increasing order of reactivity: I (None) < III (One NO_2) < II (Two NO_2).

Final Answer: I < III < II.

Answer: (A)

Q10.

Solution

Concept:
Ethers react with concentrated HI via S_N1 or S_N2 mechanisms depending on the nature of the alkyl groups. The bond cleavage occurs between the Oxygen and a Carbon atom. However, if the bond has partial double bond character (as in aryl ethers where the oxygen lone pair is delocalized into the benzene ring), it is extremely difficult to break.

Solution:
1. Diisopropyl ether ($iPr - O - iPr$): Can be cleaved to give isopropyl iodide and isopropanol. 2. Diphenyl ether ($Ph{-}O{-}Ph$): The $C{-}O$ bonds have partial double bond character due to resonance with the two benzene rings. Nucleophilic attack by I^- is prevented because S_N1 would form a very unstable phenyl cation and S_N2 is sterically and electronically hindered at the sp^2 carbon. Thus, it is highly resistant to cleavage. 3. Methyl t-butyl ether ($Me - O - tBu$): Cleaves easily via S_N1 to give t-butyl iodide and methanol because of the stable tertiary carbocation formation. 4. Benzyl methyl ether ($PhCH_2 - O - Me$): Cleaves easily to give benzyl iodide and methanol via S_N1 or S_N2. 5. Therefore, Diphenyl ether is the most resistant.

Final Answer: Diphenyl ether.

Answer: (B)

Q11.

Solution

Concept:

Kolbe-Schmitt reaction followed by acetylation of salicylic acid to form Aspirin.

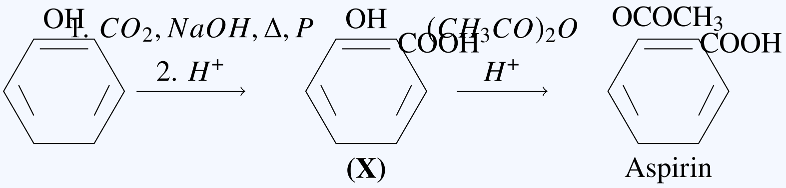
Solution:

Step 1: Phenol reacts with $NaOH$ to form sodium phenoxide, which then reacts with CO_2 under pressure followed by acidification (H^+) to yield salicylic acid (2-hydroxybenzoic acid) as compound (X). This is known as the Kolbe-Schmitt reaction.

Step 2: Salicylic acid contains a phenolic hydroxyl group ($-OH$). When treated with acetic anhydride ($(CH_3CO)_2O$) in the presence of H_2SO_4, the hydroxyl group undergoes acetylation.

Step 3: The chemical equation for the final step is: $C_6H_4(OH)COOH + (CH_3CO)_2O \xrightarrow{H_2SO_4} C_6H_4(OCOCH_3)COOH + CH_3COOH$.

Step 4: The product, acetylsalicylic acid, is widely known as Aspirin. Therefore, the correct option is (B).



Final Answer:

$$\boxed{B}$$

Answer: (B)

Q12.

Solution

Concept:

Competition between Substitution (S_N2) and Elimination ($E2$) in tertiary alkyl halides.

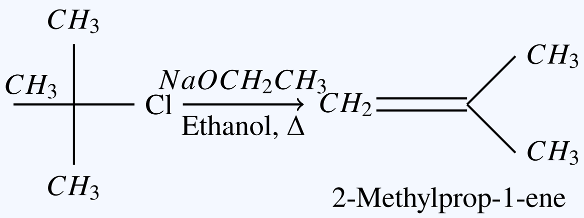
Solution:

Step 1: Identify the reactants. Tert-butyl chloride $(CH_3)_3CCl$ is a 3° alkyl halide. Sodium ethoxide $NaOCH_2CH_3$ is a strong base and a strong nucleophile.

Step 2: Consider the steric hindrance. For S_N2 to occur, the ethoxide ion must attack the central carbon. However, the three methyl groups block this path.

Step 3: Analyze the alternative pathway. Sodium ethoxide acts as a base and abstracts a proton from one of the β-carbons (methyl groups). This triggers an E2 elimination reaction.

Step 4: Determine the product. The loss of HCl from 2-chloro-2-methylpropane results in the formation of 2-methylprop-1-ene (also known as isobutylene).



2-Methylprop-1-ene

Final Answer: The major product is 2-methylprop-1-ene.

$\boxed{\text{B}}$

Answer: (B)

Q13.

Solution

Concept:

This sequence involves substitution, elimination, and hydroboration-oxidation. 1. Reaction with PCl_5 converts an alcohol to an alkyl chloride. 2. Alcoholic KOH causes dehydrohalogenation to form an alkene. 3. Hydroboration-oxidation (B_2H_6 followed by H_2O_2/OH^-) converts an alkene into an alcohol via anti-Markovnikov addition of water across the double bond, with syn-stereochemistry.

Solution:

1. Propan-2-ol ($CH_3CH(OH)CH_3$) + PCl_5 → 2-Chloropropane ($CH_3CHClCH_3$) (Compound X). 2. 2-Chloropropane + alc. KOH $\xrightarrow{\Delta}$ Propene ($CH_3CH = CH_2$) (Compound Y). 3. Propene undergoes hydroboration-oxidation: - Step A: B_2H_6 adds across the double bond. The Boron atom attaches to the less hindered terminal carbon (Anti-Markovnikov regioselectivity). - Step B: Oxidation with H_2O_2/OH^- replaces the Boron with an $-OH$ group. 4. The result is the addition of H and OH across the double bond such that $-OH$ is at the end of the chain. 5. The final product (Z) is Propan-1-ol ($CH_3CH_2CH_2OH$).

Final Answer: The product 'Z' is Propan-1-ol.

Answer: (A)

Q14.

Solution

Concept:

Tollen's reagent ($[Ag(NH_3)_2]OH$) and Fehling's solution are mild oxidizing agents used to distinguish aldehydes from ketones. 1. Tollen's reagent is reduced by almost all aldehydes (aliphatic and aromatic) to form a silver mirror. 2. Fehling's solution (and Benedict's solution) is reduced only by aliphatic aldehydes to form a red precipitate of Cu_2O. 3. Aromatic aldehydes (like benzaldehyde) do not reduce Fehling's solution because the carbonyl group is stabilized by resonance with the benzene ring, making it a weaker reducing agent compared to aliphatic aldehydes.

Solution:

1. Acetaldehyde and Formaldehyde are aliphatic aldehydes; they reduce both Tollen's and Fehling's. 2. Acetone is a ketone; it reduces neither. 3. Benzaldehyde is an aromatic aldehyde. It reduces Tollen's reagent (forming a silver mirror) but fails to reduce Fehling's solution under standard conditions. 4. This specific distinction is a classic test for aromatic aldehydes.

Final Answer: Benzaldehyde.

Answer: (B)

Q15.

Solution

Concept:
Nucleophilic addition to a carbonyl group involves the attack of a nucleophile (CN^-) on the carbonyl carbon. The reactivity is governed by: 1. **Inductive/Resonance Effects:** Electron-donating groups (like alkyl or phenyl groups) decrease the partial positive charge on the carbonyl carbon, making it less reactive. 2. **Steric Hindrance:** Bulky groups around the carbonyl carbon hinder the approach of the nucleophile.

Solution:
1. CH_3CHO (Acetaldehyde): Has one small electron-donating methyl group. Least steric hindrance and moderate electronic stabilization. 2. $PhCHO$ (Benzaldehyde): The phenyl ring is electron-donating via resonance ($+M$ effect), which significantly reduces the electrophilicity of the carbonyl carbon. It is also bulkier than a methyl group. 3. $PhCOPh$ (Benzophenone): Has two phenyl rings. It has the maximum steric hindrance and the maximum electronic stabilization of the carbonyl carbon by resonance from two sides. 4. Therefore, Acetaldehyde is the most reactive, and Benzophenone is the least reactive. 5. Increasing order: $PhCOPh$ (I) < $PhCHO$ (III) < CH_3CHO (II).

Final Answer: I < III < II.

Answer: (A)

Q16.

Solution

Concept:
Aniline ($Ph-NH_2$) is an extremely reactive aromatic compound toward electrophilic substitution because the lone pair of electrons on the Nitrogen atom is delocalized into the benzene ring (+M effect), greatly increasing the electron density at the ortho and para positions. Bromine water (Br_2/H_2O) is a strong electrophilic reagent. In an aqueous medium, the activation is so high that substitution occurs at all available ortho and para positions simultaneously without the need for a Lewis acid catalyst.

Solution:
1. Aniline contains an $-NH_2$ group which is a powerful activating and ortho/para directing group. 2. When treated with bromine water, the high reactivity of the ring leads to multiple substitutions. 3. Bromine atoms attack both ortho positions (2 and 6) and the para position (4). 4. The reaction results in the formation of a white precipitate. 5. The product is 2,4,6-Tribromoaniline.

Final Answer: The product is 2,4,6-Tribromoaniline.

Answer: (C)

Q17.

Solution

Concept:
The Carbylamine test (also known as the Isocyanide test) is a diagnostic test for primary (1°) amines. When a primary amine is heated with chloroform ($CHCl_3$) and alcoholic potassium hydroxide (KOH), it produces an isocyanide (carbylamine), which is characterized by an extremely foul or repulsive smell. Secondary (2°) and tertiary (3°) amines do not give this reaction.

Solution:
1. Reaction: $R - NH_2 + CHCl_3 + 3KOH \xrightarrow{\Delta} R - NC + 3KCl + 3H_2O$ 2. Let's analyze the options: - N-Methylaniline: This is a secondary (2°) aromatic amine ($Ph - NH - CH_3$). - N,N-Dimethylaniline: This is a tertiary (3°) aromatic amine ($Ph - N(CH_3)_2$). - Ethylamine: This is a primary (1°) aliphatic amine ($CH_3CH_2NH_2$). - Diethylamine: This is a secondary (2°) aliphatic amine ($(CH_3CH_2)_2NH$). 3. Only Ethylamine is a primary amine and will undergo the carbylamine reaction to produce ethyl isocyanide.

Final Answer: Ethylamine will give the carbylamine test.

Answer: (C)

Q18.

Solution

Concept:
Reducing sugars are carbohydrates that contain a free aldehyde or ketone group (or a hemiacetal/hemiketal group in cyclic form) that can reduce Tollen's or Fehling's reagents. In disaccharides, if the anomeric carbons of both monosaccharide units are involved in the glycosidic linkage, the sugar becomes non-reducing because it cannot open into a straight-chain form with a free carbonyl group.

Solution:
1. Glucose: A monosaccharide with a free aldehyde group; it is a reducing sugar. 2. Maltose: Composed of two glucose units linked by $\alpha(1 \rightarrow 4)$ bond. One anomeric carbon is free; it is a reducing sugar. 3. Lactose: Composed of galactose and glucose linked by $\beta(1 \rightarrow 4)$ bond. One anomeric carbon is free; it is a reducing sugar. 4. Sucrose: Composed of glucose and fructose linked by an $\alpha(1 \rightarrow 2)$ glycosidic bond. The linkage involves the anomeric carbon of glucose (C_1) and the anomeric carbon of fructose (C_2). 5. Since both potential reducing groups are locked in the glycosidic bond, sucrose cannot reduce Tollen's or Fehling's reagents.

Final Answer: Sucrose is a non-reducing sugar.

Answer: (D)

Q19.

Solution

Concept:

Proteins have different levels of structural organization: 1. **Primary Structure:** The linear sequence of amino acids held by covalent peptide bonds. 2. **Secondary Structure:** Refers to the local folding of the polypeptide chain into specific shapes like α-helices and β-pleated sheets. 3. **Tertiary/Quaternary:** Higher-order folding involving various interactions (disulfide, ionic, etc.).

Solution:

1. The α-helix and β-pleated sheet structures are formed due to regular folding of the backbone. 2. This folding is stabilized by hydrogen bonding between the carbonyl oxygen ($C = O$) of one peptide bond and the amide hydrogen ($-NH-$) of another peptide bond. 3. While peptide bonds hold the sequence together, the *secondary structure* specifically is defined by these repeating hydrogen bond patterns.

Final Answer: Hydrogen bonds stabilize the secondary structure.

Answer: (B)

Q20.

Solution

Concept:

Classification of polymers based on molecular forces and thermal properties.

Solution:

Step 1: Define thermosetting polymers. These are semi-fluid substances with low molecular masses which, when heated in a mould, undergo a permanent change in chemical structure to become hard and infusible.

Step 2: Evaluate the options. Polyethene, PVC, and Nylon 6,6 are linear or slightly branched polymers that soften on heating and harden on cooling (thermoplastics/fibers).

Step 3: Analyze Bakelite. Bakelite is formed by the condensation reaction of phenol with formaldehyde. This results in a three-dimensional network of covalent bonds (cross-links).

Step 4: Conclusion. Due to this extensive cross-linking, Bakelite does not soften on heating, making it a thermosetting polymer.

Highly cross-linked network

Bakelite

Final Answer:

$$\boxed{B}$$

Answer: (B)

Q21.

Solution

Concept:
Molecular Orbital Theory (MOT) explains the magnetic behavior of molecules based on the presence or absence of unpaired electrons in molecular orbitals. A species is **paramagnetic** if it has one or more unpaired electrons and **diamagnetic** if all its electrons are paired. For homonuclear diatomic molecules of the second period, the filling order changes at Nitrogen (N_2).

Solution:
1. O_2 (16 electrons): The configuration is $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^1)$. It has two unpaired electrons in antibonding π^* orbitals. (Paramagnetic). 2. B_2 (10 electrons): Configuration: $\sigma 1s^2 \sigma^* 1s^2 2s^2 \sigma^* 2s^2 (\pi 2p_x^1 = \pi 2p_y^1)$. It has two unpaired electrons. (Paramagnetic). 3. C_2 (12 electrons): Configuration: $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2)$. All electrons are paired. (Diamagnetic). 4. N_2^+ (13 electrons): N_2 has 14 electrons (all paired). Removing one electron leaves one unpaired electron in the $\sigma 2p_z$ orbital. (Paramagnetic).

Final Answer: C_2 is diamagnetic.

Answer: (C)

Q22.

Solution

Concept:

VSEPR Theory and Molecular Geometry.

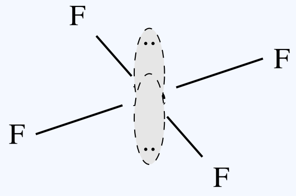
Solution:

Step 1: Identify valence electrons for the central atom. Xenon (Xe) is a noble gas with 8 valence electrons.

Step 2: Determine the number of bond pairs and lone pairs. Total electrons = 8. Electrons used in bonding with 4 F atoms = 4 (4 bond pairs). Remaining electrons = 8 − 4 = 4 electrons (2 lone pairs).

Step 3: Calculate the Steric Number (SN). SN = Bond Pairs + Lone Pairs = 4 + 2 = 6. For $SN = 6$, the electron geometry is octahedral.

Step 4: Determine molecular shape. According to VSEPR theory, for an AB_4E_2 type molecule, the two lone pairs are positioned 180° apart to minimize repulsion. The remaining four fluorine atoms lie in a single plane, forming a square planar shape.



Square Planar Geometry

Final Answer:

$$\boxed{\text{B}}$$

Answer: (B)

Q23.

Solution

Concept:

The hybridization of an atom can be determined by its steric number (number of sigma bonds + number of lone pairs). - SN = 2: sp - SN = 3: sp^2 - SN = 4: sp^3

Solution:

1. NO_2^+: Nitrogen has 5 valence electrons. The '+' charge means 4 electrons. It forms two double bonds with two oxygens ($O = N = O$). No lone pairs. SN = 2 (2 σ bonds). Hybridization = sp. 2. NO_3^-: Nitrogen has 5 valence electrons. The '-' charge means 6 electrons. It forms one double bond and two single bonds (one coordinate) with three oxygens. No lone pairs. SN = 3 (3 σ bonds). Hybridization = sp^2. 3. NH_4^+: Nitrogen has 5 valence electrons. The '+' charge means 4 electrons. It forms four single bonds with four hydrogens. No lone pairs. SN = 4 (4 σ bonds). Hybridization = sp^3. 4. The sequence is sp, sp^2, sp^3.

Final Answer: sp, sp^2, sp^3.

Answer: (A)

Q24.

Solution

Concept:

Coordination complexes are classified based on the d-orbitals used for hybridization: 1. **Inner Orbital Complex:** Uses $(n-1)d$ orbitals (d^2sp^3). Usually formed with strong field ligands (SFL) that cause electron pairing. 2. **Outer Orbital Complex:** Uses nd orbitals (sp^3d^2). Usually formed with weak field ligands (WFL) or when $(n-1)d$ orbitals are unavailable.

Solution:

1. $[Co(NH_3)_6]^{3+}$: Co^{3+} is $3d^6$. NH_3 acts as an SFL here, pairing electrons to leave two $3d$ orbitals empty. (d^2sp^3 - Inner). 2. $[Fe(CN)_6]^{3-}$: Fe^{3+} is $3d^5$. CN^- is a very strong ligand, causing pairing. (d^2sp^3 - Inner). 3. $[Ni(NH_3)_6]^{2+}$: Ni^{2+} is $3d^8$. The $3d$ configuration is $t_{2g}^6 e_g^2$. Even with pairing, you cannot vacate two $3d$ orbitals (you'd only have one empty at most). Thus, it must use $4d$ orbitals. (sp^3d^2 - Outer). 4. $[Mn(CN)_6]^{4-}$: Mn^{2+} is $3d^5$. CN^- is SFL, pairing electrons. (d^2sp^3 - Inner).

Final Answer: $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex.

Answer: (C)

Q25.

Solution

Concept:

IUPAC naming rules for coordination compounds: 1. Name the ligands in alphabetical order. 2. Use prefixes (di, tri, tetra, penta) for quantity. 3. Name the central metal. If the complex is a cation, use the standard metal name. 4. Indicate the oxidation state of the metal in Roman numerals in parentheses. 5. Name the counter-ion.

Solution:

1. Complex: $[Co(NH_3)_5(CO_3)]Cl$. 2. Ligands: Five ammine (NH_3) and one carbonato (CO_3^{2-}). Alphabetically, ammine comes before carbonato. → Pentaamminecarbonato. 3. Oxidation state of Co (x): $x + 5(0) + 1(-2) = +1$ (since the counter ion Cl is -1). $x - 2 = 1 \Rightarrow x = +3$. 4. Metal: Cobalt(III). 5. Counter-ion: chloride. 6. Combining them: Pentaamminecarbonatocobalt(III) chloride.

Final Answer: Pentaamminecarbonatocobalt(III) chloride.

Answer: (A)

Q26.

Solution

Concept:

The spin-only magnetic moment (μ_s) of a coordination complex is calculated based on the number of unpaired electrons (n) in the central metal ion using the formula:

$$\mu_s = \sqrt{n(n+2)} \text{ Bohr Magnetons (BM)}$$

The number of unpaired electrons depends on the oxidation state of the metal and the strength of the ligands (Crystal Field Theory).

Solution:

1. In the complex $[Fe(H_2O)_6]^{2+}$, the central metal is Iron (Fe). 2. Oxidation state: $x + 6(0) = +2 \Rightarrow x = +2$. 3. Atomic number of Fe is 26. Ground state configuration: $[Ar]3d^6 4s^2$. 4. Fe^{2+} configuration: $[Ar]3d^6$. 5. H_2O is a weak field ligand (WFL). It does not cause pairing of electrons in the $3d$ orbitals. 6. According to Hund's rule, for d^6 in a weak field: $t_{2g}^4 e_g^2$. 7. Distribution: $\uparrow\downarrow, \uparrow, \uparrow$ (in t_{2g}) and $\uparrow, \uparrow$ (in e_g). 8. Number of unpaired electrons (n) = 4. 9. $\mu_s = \sqrt{4(4+2)} = \sqrt{4 \times 6} = \sqrt{24} \approx 4.90$ BM.

Final Answer: The spin-only magnetic moment is approximately 4.90 BM.

Answer: (B)

Q27.

Solution

Concept:

Allotropy is the property of some chemical elements to exist in two or more different forms, in the same physical state. While most p-block elements like Carbon, Phosphorus, and Sulfur show prominent allotropy, the tendency to form allotropes generally decreases as we move down a group toward heavier metallic elements.

Solution:

1. Phosphorus: Exists as White, Red, and Black phosphorus. 2. Nitrogen: Exists in different molecular forms (alpha and beta nitrogen at very low temperatures). 3. Arsenic: Exists in Yellow, Grey, and Black forms. 4. Bismuth: It is a distinctly metallic element at the bottom of Group 15. Unlike its lighter congeners, Bismuth does not show allotropy under normal conditions and exists in a single metallic crystalline form.

Final Answer: Bismuth does not show allotropy.

Answer: (D)

Q28.

Solution

Concept:

The oxidizing power of oxoacids of halogens depends on the stability of the acid and the oxidation state of the halogen. For chlorine oxoacids ($HClO, HClO_2, HClO_3, HClO_4$), as the number of oxygen atoms increases, the oxidation state of Chlorine increases (+1, +3, +5, +7). Surprisingly, the thermal stability also increases in this order due to the resonance stabilization of the resulting conjugate base (oxyanion).

Solution:

1. A stronger oxidizing agent is one that is more ”eager” to be reduced (gain electrons). 2. Although $HClO_4$ has the highest oxidation state, it is the most stable and least reactive because the negative charge in the ClO_4^- ion is highly delocalized. 3. $HClO$ (Hypochlorous acid) is the least stable and has the weakest $Cl - O$ bond. It decomposes or reacts very easily to provide nascent oxygen. 4. In aqueous solution, $HClO$ is the most powerful oxidizing agent among the series because it is the most unstable and easily undergoes reduction.

Final Answer: $HClO$ is the strongest oxidizing agent.

Answer: (A)

Q29.

Solution

Concept:
The acidity of hydrides in a group depends on the ease with which the $H - X$ bond can break to release an H^+ ion. This is primarily determined by the **Bond Dissociation Enthalpy**. As we move down a group, the size of the central atom increases, leading to a longer and weaker bond with hydrogen.

Solution:
1. Group 16 Hydrides: H_2O, H_2S, H_2Se, H_2Te. 2. Atomic size: $O < S < Se < Te$. 3. Bond length: $H - O < H - S < H - Se < H - Te$. 4. Bond strength: $H - O > H - S > H - Se > H - Te$. 5. Since the $H - Te$ bond is the weakest, H_2Te releases H^+ most easily, making it the most acidic. 6. H_2O is the least acidic (essentially neutral) due to its very high bond dissociation energy. 7. Correct order: $H_2O < H_2S < H_2Se < H_2Te$.

Final Answer: $H_2O < H_2S < H_2Se < H_2Te$.

Answer: (A)

Q30.

Solution

Concept:
Gadolinium (Gd) is a Lanthanide element with atomic number 64. According to the Aufbau principle, the $4f$ orbital should be filled. However, there is a special stability associated with exactly half-filled and completely filled subshells (f^7 and f^{14}).

Solution:
1. Xenon (Xe) has 54 electrons. We need to place 10 more. 2. Following the general pattern for Lanthanides: $[Xe]4f^n6s^2$. 3. For $Z = 64$, we might expect $[Xe]4f^86s^2$. 4. However, by shifting one electron from the $4f$ to the $5d$ orbital, the $4f$ subshell becomes exactly half-filled ($4f^7$), which is energetically much more stable due to exchange energy. 5. Therefore, the actual configuration is $[Xe]4f^75d^16s^2$.

Final Answer: $[Xe]4f^75d^16s^2$.

Answer: (A)

Q31.

Solution

Concept:
Hydrated ions of transition metals are often colored due to $d-d$ transitions. When visible light falls on these ions, electrons in the lower energy d-orbitals (in an octahedral or tetrahedral field) absorb energy and jump to higher energy d-orbitals. For this transition to occur, the d-subshell must be partially filled (d^1 to d^9). If the d-subshell is empty (d^0) or completely filled (d^{10}), no $d-d$ transitions are possible, and the ion appears colorless.

Solution:
1. Ti^{3+}: Atomic number of Ti is 22. Configuration: $[Ar]3d^24s^2$. Ti^{3+} is $3d^1$. It has one unpaired electron and is colored (purple/violet). 2. Cu^{2+}: Atomic number of Cu is 29. Configuration: $[Ar]3d^{10}4s^1$. Cu^{2+} is $3d^9$. It has one unpaired electron and is colored (blue). 3. Sc^{3+}: Atomic number of Sc is 21. Configuration: $[Ar]3d^14s^2$. Sc^{3+} is $[Ar]3d^0$. Since the d-subshell is completely empty, no $d-d$ transition can occur. Thus, it is colorless. 4. V^{3+}: Atomic number of V is 23. Configuration: $[Ar]3d^34s^2$. V^{3+} is $3d^2$. It has two unpaired electrons and is colored (green).
Final Answer: Sc^{3+} is colorless in aqueous solution.

Answer: (C)

Q32.

Solution

Concept:
Interstitial compounds are formed when small atoms like Hydrogen, Carbon, Nitrogen, or Boron occupy the "holes" or "interstices" in the crystal lattice of transition metals. These compounds do not follow standard stoichiometry (non-stoichiometric) and are not formed by typical ionic or covalent bonding.

Solution:
1. **Hardness:** The presence of small atoms in the lattice prevents the metal layers from sliding over each other, making the compound much harder than the pure metal. 2. **Melting Point:** They have very high melting points, often higher than those of the pure metals. 3. **Conductivity:** They retain metallic conductivity because the electronic structure of the metal is not significantly altered. 4. **Chemical Reactivity:** Pure transition metals can be quite reactive, but interstitial compounds are characterized by being chemically inert. 5. Therefore, the statement that they are "chemically very reactive" is incorrect.
Final Answer: They are chemically very reactive (This is the false property).

Answer: (D)

Q33.

Solution

Concept:
In the Lanthanide series (from Lanthanum to Lutetium), there is a steady decrease in the size of the atoms and ions (M^{3+}) with an increase in atomic number. This phenomenon is known as **Lanthanide Contraction**. It occurs because the $4f$ electrons provide poor shielding for the nuclear charge, causing the outer electrons to be pulled closer to the nucleus.

Solution:
1. The elements given are Cerium (Ce, $Z = 58$), Samarium (Sm, $Z = 62$), Terbium (Tb, $Z = 65$), and Lutetium (Lu, $Z = 71$). 2. According to the principle of Lanthanide Contraction, the atomic radius decreases as the atomic number increases. 3. Order of atomic numbers: $Ce < Sm < Tb < Lu$. 4. Order of atomic radii: $Ce > Sm > Tb > Lu$. 5. Ce is the largest in this set, and Lu is the smallest.

Final Answer: $Ce > Sm > Tb > Lu$.

Answer: (A)

Q34.

Solution

Concept:
Quantum numbers define the state of an electron in an atom. They must follow specific rules: 1. Principal Quantum Number (n): Positive integers (1, 2, 3...). 2. Azimuthal Quantum Number (l): Ranges from 0 to $(n - 1)$. 3. Magnetic Quantum Number (m_l): Ranges from $-l$ to $+l$ (including zero). 4. Spin Quantum Number (s): $+1/2$ or $-1/2$.

Solution:
1. Option A: $n = 3, l = 2, m = 0$. Here $l < n$ $(2 < 3)$ and $|m| \leq l$. Possible. 2. Option B: $n = 3, l = 3, m = 1$. According to the rules, l can only be 0, 1, or 2 for $n = 3$. Since l cannot be equal to n, this set is impossible. 3. Option C: $n = 2, l = 1, m = -1$. Here $l < n$ and $|m| \leq l$. Possible. 4. Option D: $n = 1, l = 0, m = 0$. Here $l < n$ and $|m| \leq l$. Possible.

Final Answer: The set $n = 3, l = 3, m = 1, s = -1/2$ is not possible.

Answer: (B)

Q35.

Solution

Concept:

Nodes are regions in an orbital where the probability of finding an electron is zero. 1. **Radial Nodes** (Spherical nodes): Given by the formula $n-l-1$. 2. **Angular Nodes** (Nodal planes): Given by the formula l. 3. **Total Nodes**: Given by the formula $n-1$.

Solution:

1. For a $3p$ orbital: - Principal quantum number $n = 3$. - Azimuthal quantum number $l = 1$ (since it is a p orbital). 2. Number of radial nodes = $n-l-1$. 3. Substitute the values: $3-1-1 = 1$. 4. For comparison: a $2p$ orbital has $2-1-1 = 0$ radial nodes, and a $4p$ orbital has $4-1-1 = 2$ radial nodes.

Final Answer: The number of radial nodes is 1.

Answer: (A)

Q36.

Solution

Concept:

Gibbs Free Energy (ΔG) determines the spontaneity of a process at a given temperature and pressure. The relation is given by:

$$\Delta G = \Delta H - T\Delta S$$

For a process to be spontaneous, ΔG must be negative ($\Delta G < 0$).

Solution:

1. For ΔG to be negative regardless of the value of T (absolute temperature, which is always positive): 2. ΔH (Enthalpy change) should be negative ($\Delta H < 0$). This means the reaction is exothermic, releasing energy. 3. ΔS (Entropy change) should be positive ($\Delta S > 0$). This means the randomness or disorder of the system increases. 4. If ΔH is negative and ΔS is positive, then the term $(-T\Delta S)$ will always be negative. 5. Consequently, $\Delta G = (\text{negative value}) + (\text{negative value})$, which is always negative at any temperature.

Final Answer: $\Delta H < 0, \Delta S > 0$.

Answer: (A)

Q37.

Solution

Concept:

For extremely dilute solutions of strong acids (like 10^{-8} M HCl), the contribution of H^+ ions from the auto-ionization of water cannot be ignored. In pure water, $[H^+] = 10^{-7}$ M. In a 10^{-8} M HCl solution, the total $[H^+]$ is the sum of $[H^+]$ from HCl and $[H^+]$ from water.

Solution:

1. Let x be the concentration of H^+ from water. Due to the common ion effect from HCl, the ionization of water is suppressed. 2. Total $[H^+] = (10^{-8} + x)$ and $[OH^-] = x$. 3. $K_w = [H^+][OH^-] = (10^{-8} + x)(x) = 10^{-14}$. 4. $x^2 + 10^{-8}x - 10^{-14} = 0$. 5. Solving the quadratic equation for x, we find $x \approx 9.5 \times 10^{-8}$ M. 6. Total $[H^+] = 10^{-8} + 9.5 \times 10^{-8} = 1.05 \times 10^{-7}$ M. 7. $pH = -\log(1.05 \times 10^{-7}) \approx 6.98$. 8. Since the solution is an acid (even if very dilute), the pH must be less than 7, but very close to it.

Final Answer: The pH is between 6 and 7.

Answer: (C)

Q38.

Solution

Concept:

The solubility product (K_{sp}) for a salt like $AgCl$ is given by $K_{sp} = [Ag^+][Cl^-]$. In the presence of a common ion (like Cl^- from $NaCl$), the solubility of the salt decreases (Common Ion Effect).

Solution:

1. Let the solubility of $AgCl$ in 0.1 M NaCl be 's'. 2. Dissociation: $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$. 3. $[Ag^+] = s$. 4. $[Cl^-] = (s+0.1) \approx 0.1$ (since s is expected to be very small compared to 0.1). 5. $K_{sp} = [Ag^+][Cl^-] = (s)(0.1) = 1.8 \times 10^{-10}$. 6. $s = \frac{1.8\times10^{-10}}{0.1} = 1.8 \times 10^{-9}$ M. 7. This confirms that s is indeed negligible compared to 0.1.

Final Answer: The solubility is 1.8×10^{-9} M.

Answer: (B)

Q39.

Solution

Concept:

Electrochemistry involves the study of interconversion of chemical and electrical energy. Specific cells are designed for specific types of energy conversion.

Solution:

1. Electrolytic cell: Uses electrical energy to drive a non-spontaneous chemical reaction. 2. Galvanic/Voltaic cell: Converts chemical energy from spontaneous redox reactions into electrical energy. 3. Fuel Cell: A specific type of galvanic cell where the energy of combustion of fuels (like H_2, CH_4, CH_3OH) is directly converted into electrical energy. The reactants are supplied continuously from an external source. 4. Lead storage battery: A secondary (rechargeable) galvanic cell.

Final Answer: The device is a Fuel cell.

Answer: (B)

Q40.

Solution

Concept:

Molar conductivity (Λ_m) is related to specific conductivity (κ) and molar concentration (M) by the formula:

$$\Lambda_m = \frac{\kappa \times 1000}{M}$$

where Λ_m is in S cm^2 mol^{-1}, κ is in S cm^{-1}, and M is in mol/L.

Solution:

1. Given: $\Lambda_m = 190$ S cm^2 mol^{-1} and $M = 0.05$ M. 2. Using the formula: $190 = \frac{\kappa \times 1000}{0.05}$. 3. $\kappa = \frac{190 \times 0.05}{1000}$. 4. $\kappa = \frac{9.5}{1000} = 0.0095$ S cm^{-1}.

Final Answer: The conductivity is 0.0095 S cm^{-1}.

Answer: (A)

Q41.

Solution

Concept:

Electron gain enthalpy ($\Delta_{eg}H$) is the energy change when an electron is added to a neutral gaseous atom. Generally, it becomes more negative across a period and less negative down a group. However, there is a significant anomaly in Group 17 (Halogens) involving Fluorine and Chlorine.

Solution:

1. Normally, Fluorine (F) being smaller and more electronegative than Chlorine (Cl) should have a more negative electron gain enthalpy. 2. However, the $2p$ subshell of Fluorine is very small and compact. When an extra electron is added, it experiences significant inter-electronic repulsion from the electrons already present in the $2p$ orbital. 3. In Chlorine, the $3p$ orbital is larger and more spread out, so the incoming electron experiences much less repulsion. 4. Consequently, the energy released when an electron is added to Chlorine is greater than that for Fluorine. 5. The order of negative electron gain enthalpy is: $Cl > F > Br > I$.

Final Answer: $Cl > F > Br > I$.

Answer: (B)

Q42.

Solution

Concept:

The acid-base character of oxides follows a trend in the periodic table. 1. Metal oxides are generally basic. 2. Non-metal oxides are generally acidic. 3. Oxides of elements in the center of the periodic table or those with intermediate metallic character are often amphoteric. 4. Basicity increases down a group and decreases across a period (from left to right).

Solution:

1. Na_2O: Sodium is an alkali metal (Group 1). Its oxide is strongly basic. 2. MgO: Magnesium is an alkaline earth metal (Group 2). Its oxide is basic, but less so than Na_2O. 3. Al_2O_3: Aluminum is in Group 13. Its oxide is amphoteric (reacts with both acids and bases). 4. SiO_2: Silicon is a non-metal/metalloid. Its oxide is acidic. 5. Since Sodium is the most electropositive element in this list, its oxide is the most basic.

Final Answer: Na_2O is the most basic oxide.

Answer: (B)

Q43.

Solution

Concept:

1. One mole of any substance contains Avogadro's number ($N_A = 6.022 \times 10^{23}$) of particles (atoms, molecules, or ions). 2. A triatomic gas means each molecule of the gas contains 3 atoms (e.g., O_3, CO_2). 3. Total number of atoms = (Number of moles) × (Atoms per molecule) × (N_A).

Solution:

1. Number of moles = 0.1 mol. 2. Atomicity = 3 (triatomic). 3. Number of molecules = $0.1 \times 6.022 \times 10^{23} = 6.022 \times 10^{22}$ molecules. 4. Total number of atoms = $3 \times (6.022 \times 10^{22})$. 5. Total number of atoms = 1.8066×10^{23}.

Final Answer: 1.806×10^{23}.

Answer: (B)

Q44.

Solution

Concept:

Colloidal particles are in a state of continuous, zig-zag motion known as Brownian movement. This motion is caused by the unbalanced bombardment of the particles by the molecules of the dispersion medium.

Solution:

1. Jean Perrin studied Brownian movement extensively in the early 20th century. 2. By applying the kinetic theory of gases to colloidal particles and observing their distribution and displacement over time, he was able to calculate the value of Avogadro's number (N_A). 3. This work provided definitive proof for the existence of atoms and molecules. 4. Tyndall effect relates to light scattering, Electrophoresis to charge, and Coagulation to stability.

Final Answer: Brownian movement is used in the determination of Avogadro's number.

Answer: (B)

Q45.

Solution

Concept:

In crystal lattices, there are two main types of voids: Tetrahedral and Octahedral. 1. For a lattice containing Z atoms per unit cell: 2. Number of octahedral voids = Z. 3. Number of tetrahedral voids = $2Z$.

Solution:

1. In a face-centered cubic (fcc) or cubic close-packed (ccp) structure, the number of atoms per unit cell (Z) is 4. 2. Calculations: 8 (corners) $\times 1/8 + 6$ (faces) $\times 1/2 = 4$. 3. Based on the rule, the number of octahedral voids in an fcc lattice is also 4. 4. The question asks for the number of octahedral voids *per atom*. 5. Ratio = (Number of octahedral voids) / (Number of atoms) = $4/4 = 1$.

Final Answer: There is 1 octahedral void per atom.

Answer: (A)

Q46.

Solution

Concept:

The integrated rate equation for a first-order reaction is:

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

where k is the rate constant, t is the time, $[A]_0$ is the initial amount of reactant, and $[A]_t$ is the amount remaining at time t.

Solution:

1. Given: - $k = 4.606 \times 10^{-3}$ s^{-1} - $[A]_0 = 2.0$ g - $[A]_t = 0.2$ g 2. Rearranging the formula to solve for t:

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

3. Substitute the values:

$$t = \frac{2.303}{4.606 \times 10^{-3}} \log\left(\frac{2.0}{0.2}\right)$$

4. Simplify the terms: - $\frac{2.303}{4.606} = 0.5$ - $\log(10) = 1$ 5. Calculate t:

$$t = \frac{0.5 \times 1}{10^{-3}} = 0.5 \times 10^3 = 500 \text{ s}$$

Final Answer: The time required is 500 s.

Answer: (B)

Q47.

Solution

Concept:

Osmotic pressure (π) is a colligative property given by the formula:

$$\pi = CRT = \frac{n}{V}RT = \frac{w}{M \cdot V}RT$$

where w is the mass of solute, M is the molar mass, V is the volume in liters, R is the gas constant, and T is the temperature in Kelvin.

Solution:

1. Given: - $w = 4.0$ g - $V = 1$ L - $T = 300$ K - $\pi = 1.6\times10^{-4}$ atm - $R = 0.0821$ L atm K^{-1} mol^{-1}

2. Rearrange to solve for M:

$$M = \frac{wRT}{\pi V}$$

3. Substitute the values:

$$M = \frac{4.0 \times 0.0821 \times 300}{1.6 \times 10^{-4} \times 1}$$

4. Calculation: - $4.0 \times 300 = 1200$ - $1200 \times 0.0821 = 98.52$ - $M = \frac{98.52}{1.6\times10^{-4}} = 61.575 \times 10^{4} = 6.1575 \times 10^{5}$ g/mol

Final Answer: The molar mass is 6.15×10^{5} g/mol.

Answer: (A)

Q48.

Solution

Concept:

The depression in freezing point (ΔT_f) is given by:

$$\Delta T_f = i \cdot K_f \cdot m$$

where i is the Vant Hoff factor, K_f is the cryoscopic constant, and m is the molality.

Solution:

1. For the non-electrolyte ($i = 1$): - $\Delta T_f = 0 - (-0.0186) = 0.0186$°C - $0.0186 = 1 \cdot K_f \cdot 0.01 \Rightarrow K_f = 1.86$ (matches given value). 2. For the $NaCl$ solution: - $\Delta T_f = 0 - (-0.037) = 0.037$°C - $m = 0.01$ m - $K_f = 1.86$ K kg mol^{-1} 3. Use the formula:

$$0.037 = i \cdot 1.86 \cdot 0.01$$

4. Solve for i:

$$i = \frac{0.037}{0.0186} \approx 1.989$$

5. Rounding to the nearest significant option, $i \approx 1.99$.

Final Answer: The Vant Hoff factor is 1.99.

Answer: (A)

Q49.

Solution

Concept:

Denticity of ligands in coordination chemistry.

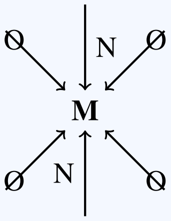
Solution:

Step 1: Define denticity. Denticity refers to the number of donor groups in a single ligand that bind to a central metal atom in a coordination complex.

Step 2: Analyze EDTA (Ethylenediaminetetraacetate). The formula for the EDTA^{4-} ion is $(^{-}OOCCH_2)_2N - CH_2 - CH_2 - N(CH_2COO^{-})_2$.

Step 3: Identify donor atoms. In EDTA, there are two tertiary amino groups (2 N atoms) and four carboxylate groups (4 O atoms). Total donor sites = 2 + 4 = 6.

Step 4: Because it can donate six electron pairs to a single metal ion to form an octahedral complex, it is classified as a hexadentate ligand.



Hexadentate coordination of EDTA

Final Answer:

$$\boxed{\text{B}}$$

Answer: (B)

Q50.

Solution

Concept:

Faraday's First Law of Electrolysis states that the amount of substance deposited is proportional to the quantity of electricity passed. The charge required to deposit 1 mole of an ion is:

$$Q = n \cdot F$$

where n is the valence (charge) of the ion and F is Faraday's constant ($1F \approx 96500C$).

Solution:

1. In $AlCl_3$ solution, Aluminum exists as the Al^{3+} ion. 2. The reduction half-reaction at the cathode is:

$$Al^{3+} + 3e^- \longrightarrow Al(s)$$

3. To deposit 1 mole of Al atoms, 3 moles of electrons are required. 4. The charge of 1 mole of electrons is $1 Faraday(F)$. 5. Therefore, 3 moles of electrons carry a charge of $3F$.

Final Answer: $3F$ of electricity is required.

Answer: (C)

Answer Key

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