AME CET Chemistry Sample Paper-1

Duration: 20 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **20** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. An organic compound contains 40% carbon, 6.67% hydrogen, and the rest is oxygen. If its vapour density is 30, what is the molecular formula of the compound?

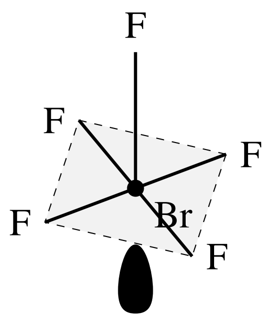
(A) CH_2O

(B) $C_2H_4O_2$

(C) $C_3H_6O_3$

(D) $C_4H_8O_2$

Q2. Which of the following molecules exhibits a square pyramidal geometry according to VSEPR theory?



(A) BrF_5

(B) PCl_5

(C) SF_6

(D) XeF_4

Q3. In the extraction of copper, the formation of copper matte primarily consists of which sulfides?

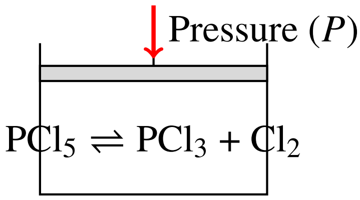
(A) Cu_2S and FeS

(B) CuS and FeS_2

(C) Cu_2O and FeS

(D) Cu_2S and FeO

Q4. For the reversible reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, the forward reaction is favored by which of the following changes?



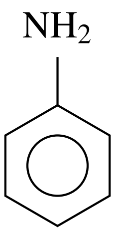
(A) Looking at an increase in the total pressure of the system

(B) Introducing an inert gas at constant volume

(C) Decreasing the volume of the container

(D) Introducing an inert gas at constant pressure

Q5. An organic compound reacts with nitrous acid at $0-5°C$ to yield a clear solution which, upon warming with water, evolves nitrogen gas and forms a phenolic compound. The original compound is most likely:



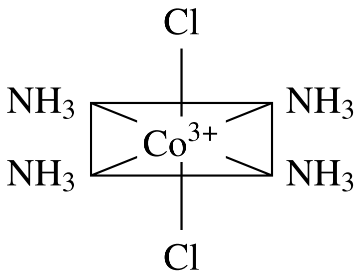
(A) Benzylamine

(B) Aniline

(C) *N*-Methylaniline

(D) Nitrobenzene

Q6. What is the correct IUPAC name for the coordination complex $[Co(NH_3)_4Cl_2]Cl$?



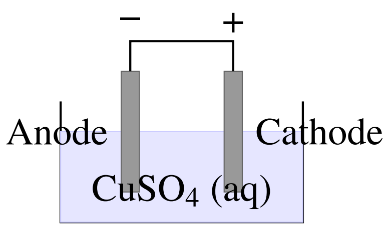
(A) Tetraamminedichlorocobalt(II) chloride

(B) Dichlorotetraamminecobalt(III) chloride

(C) Tetraamminedichlorocobalt(III) chloride

(D) Tetraamminedichlorocobaltate(III) chloride

Q7. During the electrolysis of an aqueous solution of $CuSO_4$ using platinum electrodes, what products are liberated at the cathode and anode respectively?



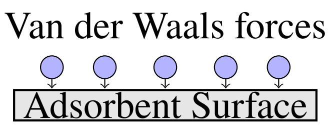
(A) Cu and O_2

(B) H_2 and O_2

(C) Cu and H_2

(D) SO_2 and O_2

Q8. Which of the following statements is correct regarding physical adsorption (physisorption)?



(A) It requires a high activation energy.

(B) It is highly specific in nature.

(C) It forms a monomolecular layer on the adsorbent surface.

(D) It decreases with an increase in temperature.

Q9. Arrange the following compounds in decreasing order of their reactivity towards nucleophilic addition reactions: HCHO (I), CH_3CHO (II), CH_3COCH_3 (III)

(A) I > II > III

(B) III > II > I

(C) II > I > III

(D) I > III > II

Q10. For a specific spontaneous chemical process occurring at constant temperature and pressure, which set of thermodynamic criteria must be satisfied?

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

(B) $\Delta H > 0, \Delta S > 0, \Delta G = 0$

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

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

Q11. According to molecular orbital theory, which of the following species is diamagnetic and possesses the highest bond order?

(A) O_2

(B) O_2^{2-}

(C) N_2

(D) N_2^+

Q12. The structural isomerism shown by the pair $[Co(NH_3)_5(NO_2)]Cl_2$ and $[Co(NH_3)_5(ONO)]C$ is classified as:

(A) Coordination isomerism

(B) Linkage isomerism

(C) Ionisation isomerism

(D) Solvate isomerism

Q13. When Xenon reacts with fluorine gas in a 1 : 5 molar ratio at 400°C and 6 bar pressure in a sealed nickel vessel, the primary product formed is:

(A) XeF_2

(B) XeF_4

(C) XeF_6

(D) $XeOF_4$

Q14. The specific conductance of a 0.01 M solution of an electrolyte is 0.002 S cm^{-1}. What is its molar conductivity (Λ_m) in S cm^2 mol^{-1}?

(A) 20

(B) 200

(C) 2000

(D) 0.2

Q15. Identify the principal organic product obtained when bromobenzene is treated with magnesium metal in dry ether, followed by reaction with ethanol.

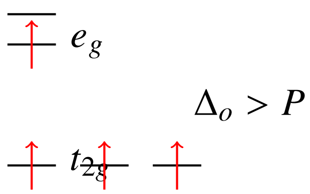
(A) Benzene

(B) Phenol

(C) Ethylbenzene

(D) Biphenyl

Q16. Which of the following oxide configurations exhibits the highest magnetic moment value based on crystal field splitting theory?



(A) High-spin d^4 octahedral complex

(B) Low-spin d^6 octahedral complex

(C) High-spin d^5 octahedral complex

(D) Low-spin d^5 octahedral complex

Q17. For a particular ideal gas reaction, the standard enthalpy change ($\Delta H°$) is -92.4 kJ at 298 K. If the change in the number of moles of gaseous products and reactants (Δn_g) is -2, what is the corresponding value of $\Delta U°$ for this reaction?

(A) -87.45 kJ

(B) -97.35 kJ

(C) -92.40 kJ

(D) -76.24 kJ

Q18. Which of the following structural arrangements possesses a permanent molecular dipole moment ($\mu \neq 0$)?

(A) BF_3

(B) NF_3

(C) CO_2

(D) CCl_4

Q19. What is the major product formed when 2-bromobutane is heated with alcoholic KOH?

(A) 1-Butene

(B) trans-2-Butene

(C) cis-2-Butene

(D) 2-Butanol

Q20. Which of the following compounds displays the highest thermal stability?

(A) PH_3

(B) AsH_3

(C) NH_3

(D) SbH_3

Detailed Solutions

Q1.

Solution

Concept:
The molecular weight is calculated as $2 \times$ Vapour Density. The empirical formula is derived from the elemental molar ratios and scaled by a factor n to determine the true molecular formula.

Solution:
Step 1: Find the mass percentage of Oxygen (O):

$$\%\,\text{O} = 100\% - (40\%\,\text{C} + 6.67\%\,\text{H}) = 53.33\%$$

Step 2: Determine the relative atomic moles ($\text{C} = 12, \text{H} = 1, \text{O} = 16$):

$$\text{Moles of C} = \frac{40}{12} = 3.33, \quad \text{Moles of H} = \frac{6.67}{1} = 6.67, \quad \text{Moles of O} = \frac{53.33}{16} = 3.33$$

Step 3: Simplify the molar ratio by dividing by 3.33:

$$\text{C} : \text{H} : \text{O} = 1 : 2 : 1 \implies \text{Empirical Formula} = CH_2O$$

Step 4: Compute the empirical formula mass and molecular weight:

$$\text{Empirical Mass} = 12 + 2(1) + 16 = 30 \text{ g/mol}$$

$$\text{Molecular Weight} = 2 \times \text{Vapour Density} = 2 \times 30 = 60 \text{ g/mol}$$

Step 5: Determine the scaling factor n and molecular formula:

$$n = \frac{\text{Molecular Weight}}{\text{Empirical Mass}} = \frac{60}{30} = 2$$

$$\text{Molecular Formula} = 2 \times (CH_2O) = C_2H_4O_2$$

Final Answer: $\boxed{C_2H_4O_2}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

According to the Valence Shell Electron Pair Repulsion (VSEPR) theory, the spatial arrangement of bonds and lone pairs around a central atom dictates the geometric shape of a molecule. A square pyramidal geometry is generated by an sp^3d^2 hybridised central atom that possesses 5 bonding pairs and exactly 1 lone pair.

Solution:

Step 1: Analyze the valence electrons of bromine (Br) in BrF_5. Bromine is a halogen belonging to Group 17 and possesses 7 valence electrons in its outermost shell.

Step 2: Determine the number of bonding electrons and lone pairs. When forming bonds with 5 monovalent fluorine atoms, bromine shares 5 of its valence electrons, leaving 2 unshared electrons. These 2 unshared electrons form 1 localized lone pair on the central bromine atom.

Step 3: Calculate the steric number to find the hybridization state:

$$\text{Steric Number} = \text{Number of bonded atoms} + \text{Number of lone pairs} = 5 + 1 = 6$$

A steric number of 6 corresponds to sp^3d^2 hybridization, which possesses an underlying octahedral electronic geometry.

Step 4: Deduce the molecular geometry. Out of the 6 coordination positions around the central atom, 5 are occupied by fluorine atoms and 1 is occupied by a bulky lone pair. The lone pair minimizes electronic repulsion by occupying an axial site, forcing the remaining 5 fluorine atoms into a square pyramidal molecular configuration.

Step 5: Compare with other given options to rule out distractors. PCl_5 has 5 bond pairs and 0 lone pairs (trigonal bipyramidal). SF_6 has 6 bond pairs and 0 lone pairs (octahedral). XeF_4 has 4 bond pairs and 2 lone pairs (square planar). Therefore, only BrF_5 is square pyramidal.

Final Answer: BrF_5

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

In the metallurgical extraction of copper from its primary sulfide ore (copper pyrites, $CuFeS_2$), the crushed ore is partially oxidized in a reverberatory furnace during the roasting phase. The resulting mixture of materials is called copper matte, which is a key intermediate phase enriched with specific metal sulfides.

Solution:

Step 1: Understand the chemical transformations occurring inside the furnace during roasting. The primary chalcopyrite ore decomposes and reacts with oxygen to form a mixture of iron(II) sulfide (FeS) and copper(I) sulfide (Cu_2S), along with unwanted iron oxides:

$$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$

Step 2: Analyze the affinity of iron and copper for oxygen and sulfur. Iron has a higher affinity for oxygen than copper does. Therefore, during roasting, a significant portion of FeS is converted into FeO, while copper remains primarily in its stable sulfide form (Cu_2S).

Step 3: Identify the composition of the fused mass known as copper matte. The material removed from the lower hearth of the reverberatory furnace contains a concentrated molten mixture of copper(I) sulfide (Cu_2S) along with remaining unreacted iron(II) sulfide (FeS).

Step 4: Distinguish copper matte from slag. Silica (SiO_2) is added as a flux to react specifically with the FeO impurities, producing a light silicate layer known as iron slag ($FeSiO_3$), which floats on top and is skimmed off:

$$FeO + SiO_2 \rightarrow FeSiO_3 \text{ (slag)}$$

The denser molten layer settled at the bottom is the copper matte, which consists primarily of Cu_2S and FeS.

Final Answer: Cu_2S and FeS

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:
Le Chatelier's principle states that if a dynamic chemical system at equilibrium experiences a change in temperature, pressure, concentration, or volume, the equilibrium position will shift in a direction that counteracts and minimizes the applied stress.

Solution:
Step 1: Analyze the stoichiometry of the gaseous reaction:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Calculate the change in the number of moles of gas (Δn_g) for this process:

$$\Delta n_g = \text{Moles of gaseous products} - \text{Moles of gaseous reactants} = (1 + 1) - 1 = +1$$

Step 2: Evaluate the option of adding an inert gas at constant pressure. When an inert gas is introduced under constant total pressure conditions, the volume of the reaction container must increase to keep the total pressure constant.

Step 3: Determine the consequence of this volume increase. An increase in volume lowers the partial pressures and concentrations of all reacting species. To counteract this dilution effect, the system shifts its equilibrium towards the side that produces a greater number of moles of gas.

Step 4: Relate the shift to the reaction direction. Since $\Delta n_g > 0$, the product side contains more gas molecules (2 moles) than the reactant side (1 mole). Therefore, expanding the volume by adding inert gas at constant pressure shifts the equilibrium in the forward direction, facilitating the dissociation of PCl_5.

Step 5: Evaluate the alternative options to verify correctness. Increasing total pressure or decreasing container volume forces the system to shift towards the side with fewer gas moles (the reverse direction). Adding an inert gas at constant volume does not alter the partial pressures of the reacting components, leaving the equilibrium position completely unchanged.

Final Answer: Introducing an inert gas at constant pressure

Answer: (D)

Go Back to Question 4

Q5.

Solution

Concept:

Primary aromatic amines react with nitrous acid (HNO_2, generated in situ from $NaNO_2$ and HCl) at low temperatures ($0-5°C$) to form stable arenediazonium salts. This synthetic pathway is known as diazotization. When heated or treated with water at higher temperatures, these diazonium salts undergo nucleophilic substitution to yield phenols alongside nitrogen gas.

Solution:

Step 1: Identify the behavior of primary aromatic amines. When aniline ($C_6H_5NH_2$) is treated with $NaNO_2$ and HCl at a chilled temperature of $0-5°C$, it undergoes diazotization to form benzenediaconium chloride ($C_6H_5N_2^+Cl^-$). This salt is soluble and forms a clear, transparent solution:

$$C_6H_5NH_2 + HNO_2 + HCl \xrightarrow{0-5°C} C_6H_5N_2^+Cl^- + 2H_2O$$

Step 2: Examine the stability and reactivity of the intermediate diazonium salt. Arenediazonium salts are stable at low temperatures due to the resonance stabilization of the diazonium group with the aromatic pi-system. However, upon warming the clear aqueous solution, the diazonium group acts as an excellent leaving group.

Step 3: Analyze the nucleophilic substitution phase. Water acts as a nucleophile, attacking the aromatic ring and displacing nitrogen gas (N_2) via an S_N1 type mechanism. This converts the salt into phenol (C_6H_5OH):

$$C_6H_5N_2^+Cl^- + H_2O \xrightarrow{\Delta} C_6H_5OH + N_2\uparrow + HCl$$

Step 4: Evaluate alternative organic compounds. Benzylamine ($C_6H_5CH_2NH_2$) is an aliphatic amine that yields an unstable diazonium salt that decomposes immediately even at 0°C to form benzyl alcohol, evolving nitrogen rapidly without needing subsequent warming. Secondary amines like *N*-methylaniline yield yellow, oily nitrosamines rather than clear diazonium solutions. Nitrobenzene does not react with nitrous acid. Thus, aniline fits the description perfectly.

Final Answer: Aniline

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:
The naming of coordination compounds follows IUPAC rules: ligands are listed alphabetically before the central metal ion, prefixed with multipliers (di-, tri-, tetra-) indicating their quantity. Anionic ligands end in "-o", while neutral ligands retain their specific names. The oxidation state of the central metal is indicated by a Roman numeral enclosed in parentheses.

Solution:
Step 1: Identify and categorize the ligands within the coordination sphere of the complex $[Co(NH_3)_4Cl_2]Cl$. The complex contains four neutral ammine (NH_3) ligands and two anionic chlorido (Cl^-) ligands.

Step 2: Arrange the ligands in alphabetical order. "Ammine" begins with 'a' and precedes "chlorido" which begins with 'c'. Therefore, the ligands are named in the order: tetraammine followed by dichloro.

Step 3: Determine the oxidation state of the central cobalt metal ion (Co). Let the oxidation state of cobalt be represented by x. The overall complex is neutral, and the counter-ion outside the bracket is a single chloride ion (Cl^-) carrying a -1 charge. This means the coordination sphere possesses a $+1$ net charge:

$$x + (4 \times 0) + (2 \times -1) = +1$$

$$x - 2 = +1 \implies x = +3$$

The cobalt ion exists in the +3 oxidation state, denoted as cobalt(III).

Step 4: Combine the components into a single systematic name. Since the coordination sphere is a cation, the metal retains its standard elemental name "cobalt". The ligands are stated first, followed by the metal with its oxidation state, and finally the counter-ion: tetraamminedichlorocobalt(III) chloride.

Final Answer: Tetraamminedichlorocobalt(III) chloride

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept:
During the electrolysis of an aqueous salt solution, competitive reduction and oxidation reactions occur at the electrodes. The species with the higher reduction potential is reduced at the cathode, while the species with the lower reduction potential (or higher oxidation potential) is oxidized at the anode.

Solution:
Step 1: Identify all ionic and molecular species present in an aqueous solution of copper(II) sulfate ($CuSO_4$). The solution contains Cu^{2+} and SO_4^{2-} ions from the salt, along with H^+ and OH^- ions (or H_2O molecules) from the water solvent.

Step 2: Analyze the competitive reduction processes occurring at the negatively charged cathode. The competing species are Cu^{2+} ions and H^+ ions (H_2O):

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \quad (E^\circ = +0.34 \text{ V})$$

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq) \quad (E^\circ = -0.83 \text{ V})$$

Since copper has a significantly higher standard reduction potential than water, Cu^{2+} ions are preferentially reduced, depositing metallic copper (Cu) on the cathode surface.

Step 3: Analyze the competitive oxidation processes occurring at the positively charged anode. The competing species are SO_4^{2-} ions and water molecules (H_2O):

$$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^- \quad (E^\circ = -1.23 \text{ V})$$

The sulfate ion (SO_4^{2-}) contains sulfur in its highest oxidation state (+6), making it exceptionally difficult to oxidize. Consequently, water molecules are preferentially oxidized at the platinum anode, liberating oxygen gas (O_2).

Step 4: Conclude the identity of the products liberated at each electrode. Copper metal (Cu) is deposited at the cathode and oxygen gas (O_2) is evolved at the anode.

Final Answer: Cu and O_2

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept:

Physical adsorption, or physisorption, involves the accumulation of gas molecules on a solid surface through weak, non-specific Van der Waals intermolecular forces. Unlike chemisorption, it does not involve chemical bond formation and behaves as an exothermic equilibrium process.

Solution:

Step 1: Understand the thermodynamic nature of physisorption. The adsorption of gas molecules onto a surface reduces the residual attractive forces of the substrate, meaning the process is always exothermic ($\Delta H < 0$).

Step 2: Apply Le Chatelier's principle to analyze the effect of temperature. Write the adsorption phenomenon as a reversible equilibrium equation:

$$\text{Gas (Adsorbate)} + \text{Solid (Adsorbent)} \rightleftharpoons \text{Adsorbed Complex} + \text{Heat}$$

According to Le Chatelier's principle, introducing thermal energy shifts an exothermic equilibrium in the reverse direction (desorption). Therefore, physical adsorption decreases continuously as temperature increases.

Step 3: Evaluate the incorrect alternative choices to solidify the reasoning. Because physisorption relies on non-specific Van der Waals interactions, it is non-specific and can form multiple molecular layers (multimolecular layers) under high pressure conditions. Furthermore, because no chemical rearrangements take place, physisorption requires virtually zero activation energy, unlike chemisorption which requires a high activation energy. Thus, statement D is the only true descriptor.

Final Answer: It decreases with an increase in temperature.

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept:
The reactivity of carbonyl compounds towards nucleophilic addition reactions depends on two factors: the magnitude of the positive partial charge on the carbonyl carbon (electronic effect) and the space occupied by surrounding groups (steric hindrance).

Solution:
Step 1: Examine the electronic effect across the three compounds. A nucleophile carries a negative charge or lone pair and attacks the electrophilic carbonyl carbon. The reactivity increases as the partial positive charge ($\delta+$) on this carbon atom increases.

Step 2: Evaluate formaldehyde (HCHO, I). Formaldehyde is bonded to two hydrogen atoms. Hydrogen atoms have negligible inductive effects, leaving the carbonyl carbon highly electron-deficient and accessible to nucleophilic attack.

Step 3: Evaluate acetaldehyde (CH_3CHO, II). Acetaldehyde contains one methyl group (–CH_3). Methyl groups are electron-donating via inductive effects ($+I$), which partially neutralizes the positive charge on the carbonyl carbon, lowering its reactivity compared to formaldehyde.

Step 4: Evaluate acetone (CH_3COCH_3, III). Acetone features two electron-donating methyl groups that release electron density toward the carbonyl carbon. This significantly reduces its partial positive charge, rendering it the least electrophilic of the three.

Step 5: Factor in steric hindrance. As the size of the substituents flanking the carbonyl group increases ($H < CH_3$), crowding around the reaction center increases. This sterically blocks the trajectory of the incoming nucleophile. Formaldehyde has zero steric hindrance, acetaldehyde has moderate hindrance, and acetone has the most hindrance. Combining both electronic and steric arguments yields the reactivity sequence: I > II > III.

Final Answer: I > II > III

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:
The fundamental criterion dictating thermodynamic spontaneity for any chemical process carried out at constant temperature (T) and pressure (P) is defined by the change in Gibbs Free Energy (ΔG), which is expressed mathematically by the Gibbs-Helmholtz equation: $\Delta G = \Delta H - T\Delta S$.

Solution:
Step 1: State the requirement for unconditional spontaneity. For a process to occur spontaneously, the total entropy of the universe must increase, which translates to a net decrease in the Gibbs Free Energy of the system. Therefore, the absolute requirement is:

$$\Delta G < 0$$

Step 2: Examine how the components of enthalpy (ΔH) and entropy (ΔS) interact within the framework of the Gibbs-Helmholtz equation:

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

Step 3: Analyze the configuration where an exothermic process ($\Delta H < 0$) undergoes an increase in structural disorder ($\Delta S > 0$). Substituting negative values for ΔH and positive values for ΔS yields:

$$\Delta G = (\text{negative value}) - T(\text{positive value})$$

Since absolute temperature T expressed in Kelvin is always positive, the term $-T\Delta S$ will remain strictly negative.

Step 4: Conclude the behavior under these conditions. The combination of a negative enthalpy change and a positive entropy change guarantees that ΔG will be negative at all temperatures. Thus, the criteria set $\Delta H < 0, \Delta S > 0, \Delta G < 0$ represents a highly favorable spontaneous process.

Final Answer: $\boxed{\Delta H < 0, \Delta S > 0, \Delta G < 0}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
According to Molecular Orbital (MO) Theory, the bond order of a homonuclear diatomic molecule is calculated as Bond Order $= \frac{1}{2}(N_b - N_a)$, where N_b is the number of electrons in bonding orbitals and N_a is the number of electrons in antibonding orbitals. A species is diamagnetic if all its electrons are paired, and paramagnetic if it contains unpaired electrons.

Solution:
Step 1: Write down the total electron count for each species:

$$O_2 = 16 \text{ electrons}, \quad O_2^{2-} = 18 \text{ electrons}, \quad N_2 = 14 \text{ electrons}, \quad N_2^+ = 13 \text{ electrons}$$

Step 2: Evaluate dinitrogen (N_2) with 14 electrons. The electronic configuration according to molecular orbital theory is:

$$\sigma_{1s}^2\, \sigma_{1s}^{*2}\, \sigma_{2s}^2\, \sigma_{2s}^{*2}\, (\pi_{2p_x}^2 = \pi_{2p_y}^2)\, \sigma_{2p_z}^2$$

Count the bonding and antibonding electrons: $N_b = 10$ and $N_a = 4$.

Step 3: Calculate the bond order for N_2:

$$\text{Bond Order} = \frac{10 - 4}{2} = 3$$

Every single molecular orbital in N_2 is completely filled with paired electrons, meaning it contains zero unpaired electrons and is diamagnetic.

Step 4: Check the other species to compare values. O_2 has a bond order of 2 and is paramagnetic due to two unpaired electrons in its π^* orbitals. O_2^{2-} has a bond order of 1 and is diamagnetic. N_2^+ has 13 electrons, yielding a bond order of 2.5, and is paramagnetic due to an unpaired electron. Thus, N_2 possesses both diamagnetism and the highest bond order (3).

Final Answer: N_2

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept:

Linkage isomerism occurs in coordination compounds containing ambidentate ligands. Ambidentate ligands possess more than one donor atom capable of coordinating to the central metal ion, but they bind using only one donor atom at a time.

Solution:

Step 1: Examine the chemical formulas of the two coordination complexes given:

$$[Co(NH_3)_5(NO_2)]Cl_2 \quad \text{and} \quad [Co(NH_3)_5(ONO)]Cl_2$$

Observe that both compounds possess the identical elemental composition, the same counter-ions, and the same central metal oxidation state.

Step 2: Identify the specific ligand that differs between the two structural expressions. The ligand responsible for the structural variation is the nitro/nitrito group (NO_2^-). This group is a classic example of an ambidentate ligand.

Step 3: Analyze the mode of attachment in the first complex, $[Co(NH_3)_5(NO_2)]Cl_2$. The ligand is written as –NO_2, indicating that the nitrogen atom is directly donating its electron pair to form a coordinate covalent bond with the central cobalt (Co–N linkage). This isomer is named the nitro isomer.

Step 4: Analyze the mode of attachment in the second complex, $[Co(NH_3)_5(ONO)]Cl_2$. The ligand is written as –ONO, indicating that one of the oxygen atoms is directly donating its lone pair to the central cobalt ion (Co–O linkage). This isomer is named the nitrito isomer. Since the difference lies strictly in the atom linked to the metal, this phenomenon is called linkage isomerism.

Final Answer: Linkage isomerism

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:

Xenon reacts directly with elemental fluorine under varying conditions of temperature, pressure, and reactant stoichiometry to form different xenon fluorides (XeF_2, XeF_4, or XeF_6). Controlling the initial molar ratio of the reactants is crucial for targeting a specific product.

Solution:

Step 1: Recall the direct synthesis pathways for xenon fluorides. Xenon combines with fluorine gas in sealed nickel containers at elevated temperatures according to the following stoichiometry-dependent reactions:

$$Xe + F_2 \xrightarrow{400^\circ\text{C, 1 bar}} XeF_2 \quad (\text{Molar ratio } 1:1)$$

$$Xe + 2F_2 \xrightarrow{400^\circ\text{C, 6 bar}} XeF_4 \quad (\text{Molar ratio } 1:5)$$

$$Xe + 3F_2 \xrightarrow{300^\circ\text{C, 60 bar}} XeF_6 \quad (\text{Molar ratio } 1:20)$$

Step 2: Match the given experimental conditions to the correct pathway. The problem specifies that Xenon gas is mixed with fluorine gas in a precise $1:5$ molar ratio, heated to 400°C, and held at a pressure of 6 bar inside a nickel vessel.

Step 3: Identify the dominant product under these conditions. The $1:5$ molar ratio provides an excess of fluorine relative to the $1:1$ ratio, but not enough to form the hexafluoride (XeF_6), which requires a massive excess ($1:20$) and much higher pressures. Therefore, these conditions selectively optimize the production of xenon tetrafluoride (XeF_4).

Final Answer: $\boxed{XeF_4}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:

Molar conductivity (Λ_m) represents the conducting power of all the ions produced by dissolving one mole of an electrolyte in solution. It is related to specific conductance (κ, kappa) and molarity (M) by the equation: $\Lambda_m = \frac{\kappa \times 1000}{M}$, where κ is expressed in S cm^{-1} and M is in mol L^{-1}.

Solution:

Step 1: Identify the given values from the problem statement:

$$\text{Specific Conductance } (\kappa) = 0.002 \text{ S cm}^{-1}$$

$$\text{Molarity of the Solution } (M) = 0.01 \text{ M} = 0.01 \text{ mol L}^{-1}$$

Step 2: Substitute these values into the standard molar conductivity formula:

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

Step 3: Perform the calculation step-by-step:

$$\Lambda_m = \frac{0.002 \times 1000}{0.01}$$

$$\Lambda_m = \frac{2}{0.01}$$

$$\Lambda_m = 200 \text{ S cm}^2 \text{ mol}^{-1}$$

Step 4: Verify that the units match the requested format. The resulting value of 200 is expressed in S cm^2 mol^{-1}, confirming choice B is correct.

Final Answer: 200

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:

Aryl halides react with magnesium metal in an anhydrous ether solvent to form organomagnesium halides, commonly known as Grignard reagents. Grignard reagents are powerful nucleophiles and strong bases that react rapidly with any compound containing proton donors (acidic hydrogens), such as water or alcohols, via an acid-base neutralization reaction to yield alkanes or arenes.

Solution:

Step 1: Analyze the first step of the reaction sequence. When bromobenzene (C_6H_5Br) is treated with magnesium turnings in dry ether, magnesium inserts into the carbon-halogen bond to form phenylmagnesium bromide (C_6H_5MgBr):

$$C_6H_5Br + Mg \xrightarrow{\text{dry ether}} C_6H_5MgBr$$

Step 2: Understand the chemical properties of the newly formed phenylmagnesium bromide. The carbon-magnesium bond is highly polar, giving the phenyl ring strong carbanionic character ($C_6H_5^{\delta-} - MgBr^{\delta+}$). This makes it an exceptionally strong base.

Step 3: Analyze the second step involving the addition of ethanol (C_2H_5OH). Ethanol contains a weakly acidic proton attached to its oxygen atom (–OH). When the Grignard reagent encounters ethanol, it undergoes rapid acid-base proton transfer rather than nucleophilic attack.

Step 4: Write out the acid-base transformation equation. The phenyl carbanion deprotonates ethanol to form benzene (C_6H_6), along with a magnesium ethoxide bromide byproduct:

$$C_6H_5MgBr + C_2H_5OH \rightarrow C_6H_6 + Mg(OC_2H_5)Br$$

Thus, the principal organic product isolated is benzene.

Final Answer: Benzene

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:
The magnetic moment (μ) of a coordination complex depends on its number of unpaired electrons (n) according to the spin-only formula: $\mu = \sqrt{n(n+2)}$ B.M. According to Crystal Field Theory (CFT), the electronic configuration of d^n ions in an octahedral field is governed by the relative magnitudes of the crystal field splitting energy (Δ_o) and the electron pairing energy (P).

Solution:
Step 1: Evaluate a high-spin d^4 configuration. In a high-spin scenario ($\Delta_o < P$), electrons occupy orbitals singly before pairing up. The 4 electrons fill the split d-orbitals as $t_{2g}^3 e_g^1$. This configuration yields $n = 4$ unpaired electrons.

Step 2: Evaluate a low-spin d^6 configuration. In a low-spin scenario ($\Delta_o > P$), electrons pair up completely in the lower-energy orbitals. The 6 electrons fill the orbitals as $t_{2g}^6 e_g^0$. This results in $n = 0$ unpaired electrons (diamagnetic).

Step 3: Evaluate a high-spin d^5 configuration. Since $\Delta_o < P$, electrons are distributed singly across all five d-orbitals without pairing: $t_{2g}^3 e_g^2$. This maximizes the spin alignment, yielding $n = 5$ unpaired electrons.

Step 4: Evaluate a low-spin d^5 configuration. Since $\Delta_o > P$, electrons pair up preferentially in the lower t_{2g} subshell, filling it as $t_{2g}^5 e_g^0$. This leaves only $n = 1$ unpaired electron.

Step 5: Determine which configuration yields the maximum magnetic moment. Since the spin-only magnetic moment increases monotonically with the number of unpaired electrons (n), the high-spin d^5 configuration ($n = 5$) produces the largest magnetic moment:

$$\mu = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92 \text{ B.M.}$$

Final Answer: High-spin d^5 octahedral complex

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept:

The relationship between the change in enthalpy (ΔH) and the change in internal energy (ΔU) for an ideal gas reaction is derived from the definition of enthalpy ($H = U + PV$) and the ideal gas law ($PV = nRT$). The equation is formulated as: $\Delta H = \Delta U + \Delta n_g RT$.

Solution:

Step 1: Identify and convert the given thermodynamic parameters into compatible SI units:

$$\Delta H^\circ = -92.4 \text{ kJ} = -92400 \text{ J}$$

$$\Delta n_g = -2$$

$$\text{Temperature } (T) = 298 \text{ K}$$

$$\text{Universal Gas Constant } (R) = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

Step 2: Rearrange the primary formula to solve directly for the change in internal energy (ΔU°):

$$\Delta U^\circ = \Delta H^\circ - \Delta n_g RT$$

Step 3: Substitute the numerical values into the rearranged expression:

$$\Delta U^\circ = -92400 - [(-2) \times 8.314 \times 298]$$

$$\Delta U^\circ = -92400 - [-4955.144]$$

$$\Delta U^\circ = -92400 + 4955.144$$

Step 4: Complete the arithmetic calculation:

$$\Delta U^\circ = -87444.856 \text{ J}$$

Step 5: Convert the final answer back to kilojoules (kJ) to match the options:

$$\Delta U^\circ \approx -87.45 \text{ kJ}$$

Final Answer: $\boxed{-87.45 \text{ kJ}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept:

The net dipole moment (μ) of a polyatomic molecule is the vector sum of its individual bond dipole moments. A molecule is polar ($\mu \neq 0$) if its spatial geometry is asymmetric, preventing the individual bond dipoles from canceling one another out.

Solution:

Step 1: Analyze BF_3. Boron trifluoride features sp^2 hybridization with a symmetric trigonal planar geometry. The three polar B–F bonds point towards the corners of an equilateral triangle at 120° angles, completely canceling each other out ($\mu = 0$).

Step 2: Analyze NF_3. Nitrogen trifluoride has sp^3 hybridization. Nitrogen possesses 5 valence electrons, using 3 to form single bonds with fluorine atoms and retaining 1 lone pair. This creates a trigonal pyramidal molecular geometry.

Step 3: Evaluate the vector alignment in NF_3. The three polar N–F bonds point downward, away from the apex. The localized lone pair at the apex points upward, creating its own lone pair dipole moment. Because the pyramidal geometry is asymmetric, the bond dipoles and the lone pair dipole do not cancel each other out, resulting in a net molecular dipole moment ($\mu \neq 0$).

Step 4: Examine CO_2 and CCl_4. CO_2 is linear (sp hybridized), so its two equal C==O dipoles pull in opposite directions and cancel out ($\mu = 0$). CCl_4 has a symmetric tetrahedral geometry (sp^3 hybridized), where the four equal C–Cl bond dipoles cancel out perfectly ($\mu = 0$). Therefore, only NF_3 possesses a permanent dipole moment.

Final Answer: NF_3

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
Heating an alkyl halide with a strong, sterically unhindered base dissolved in an alcohol (such as alcoholic KOH) induces a dehydrohalogenation reaction, which proceeds via an E2 elimination mechanism. The regioselectivity of this elimination is governed by Saytzeff's rule, which states that the preferred product is the more highly substituted, thermodynamically stable alkene.

Solution:
Step 1: Identify the structure of the reactant, 2-bromobutane:

$$CH_3–CH(Br)–CH_2–CH_3$$

The carbon atom bonded to the bromine leaving group is designated as the α-carbon. The adjacent carbons are the β-carbons. This molecule has two distinct sets of β-hydrogens: the terminal methyl group (β_1) and the internal methylene group (β_2).

Step 2: Analyze the two possible elimination pathways. Removing a proton from the terminal β_1 carbon yields 1-butene, a monosubstituted alkene:

$$CH_2{=}{=}CH–CH_2–CH_3 \quad \text{(Less stable Hoffman product)}$$

Removing a proton from the internal β_2 carbon yields 2-butene, a disubstituted alkene:

$$CH_3–CH{=}{=}CH–CH_3 \quad \text{(More stable Saytzeff product)}$$

Step 3: Determine the major alkene product using Saytzeff's rule. The internal disubstituted alkene is more stable than the monosubstituted alkene due to greater hyperconjugation and resonance stabilization. Thus, 2-butene is the major product.

Step 4: Assess the stereochemical outcomes for 2-butene, which can exist as either *cis* or *trans* stereoisomers. The *trans*-2-butene isomer experiences significantly less steric repulsion between its bulky methyl groups than the *cis*-2-butene isomer. As a result, *trans*-2-butene is the lower-energy, thermodynamically favored isomer and forms as the principal major product.

Final Answer: trans-2-Butene

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept:

The thermal stability of hydrides of Group 15 elements (NH_3, PH_3, AsH_3, SbH_3, BiH_3) depends on the strength of the covalent bond between the central atom (M) and hydrogen (H). The strength of this M–H bond is inversely related to the atomic size of the central element.

Solution:

Step 1: Examine the trend in atomic radii moving down Group 15 of the periodic table. The atomic size of the elements increases progressively in the order:

$$\mathrm{N < P < As < Sb < Bi}$$

Step 2: Relate atomic size to bond length and bond orbital overlap. As the central atom grows larger down the group, the valence orbitals become larger and more diffuse. This leads to less effective orbital overlap with the small $1s$ orbital of hydrogen, causing the M–H bond length to increase.

Step 3: Analyze the trend in bond dissociation enthalpy. An increase in bond length weakens the covalent interaction, causing the M–H bond dissociation energy to decrease down the group:

$$\mathrm{E_{diss}(N\text{–}H) > E_{diss}(P\text{–}H) > E_{diss}(As\text{–}H) > E_{diss}(Sb\text{–}H)}$$

Step 4: Conclude the relative thermal stabilities. Since ammonia (NH_3) contains the shortest, strongest, and highest-energy M–H bonds due to the small size of the nitrogen atom, it requires the most thermal energy to decompose. Therefore, ammonia possesses the highest thermal stability among all the group hydrides.

Final Answer: $\boxed{NH_3}$

Answer: (C)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	A	3	A	4	D	5	B
6	C	7	A	8	D	9	A	10	C
11	C	12	B	13	B	14	B	15	A
16	C	17	A	18	B	19	B	20	C