IISER Chemistry Sample Paper-4

Duration: 45 Minutes **Maximum Marks: 60**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1** marks.
- Unattempted questions carry **0** marks.
- Only one option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. An organic compound A (C_6H_{10}) undergoes ozonolysis under reductive conditions (O_3, followed by Zn/H_2O) to yield a single dialdehyde product B. When compound A is treated with cold, dilute alkaline $KMnO_4$, it forms a meso-diol C. Identify the stereochemical orientation and structure of compound A.

(A) *cis*-Cyclohexene

(B) *trans*-Hex-3-ene

(C) *cis*-Hex-3-ene

(D) Cyclohexene

Q2. Consider the following multi-step synthetic transformation sequence starting from benzene:

$$\text{Benzene} \xrightarrow{CH_3COCl,\ AlCl_3} X \xrightarrow{HNO_3/H_2SO_4} Y$$

What is the principal structural identity of the major organic product Y?

(A) *p*-Nitroacetophenone

(B) *m*-Nitroacetophenone

(C) *o*-Nitroacetophenone

(D) *m*-Nitrobenzene

Q3. Arrange the following carbonyl compounds in the exact decreasing order of their fundamental thermodynamic reactivity towards nucleophilic addition reactions with a generic standard nucleophile (Nu^-):

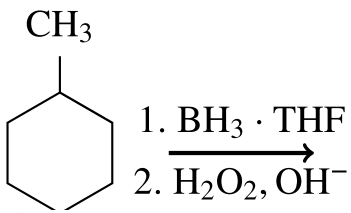
(i) Acetone (CH_3COCH_3)
(ii) Formaldehyde (HCHO)
(iii) Acetaldehyde (CH_3CHO)
(iv) Benzaldehyde (C_6H_5CHO)

(A) (ii) > (iii) > (iv) > (i)
(B) (ii) > (iii) > (i) > (iv)
(C) (iv) > (i) > (iii) > (ii)
(D) (iii) > (ii) > (iv) > (i)

Q4. An unknown ester with the molecular formula $C_5H_{10}O_2$ is subjected to complete acid-catalyzed hydrolysis, yielding an alcohol P and a carboxylic acid Q. When alcohol P is treated with chronic acid (H_2CrO_4), it undergoes oxidation to regenerate the identical carboxylic acid Q. Deduce the explicit structural identity of the original ester molecule.

(A) Ethyl propanoate
(B) Methyl butanoate
(C) Propyl acetate
(D) Isopropyl acetate

Q5. Predict the principal regiochemical major product obtained when 1-methylcyclohexene is subjected to a standard hydroboration-oxidation reaction sequence (1. $BH_3 \cdot$ THF, 2. H_2O_2, NaOH):



(A) *trans*-2-Methylcyclohexanol

(B) *cis*-2-Methylcyclohexanol

(C) 1-Methylcyclohexanol

(D) *trans*-1,2-Methylcyclohexanediol

Q6. A weak monobasic acid (HA, $K_a = 1.0 \times 10^{-5}$) is titrated against a standard solution of a strong base (NaOH). Calculate the absolute pH value of the resulting solution mixture exactly at the half-equivalence point at 298 K.

(A) 5.0

(B) 7.0

(C) 9.0

(D) 2.5

Q7. The decomposition of a gaseous compound follows second-order reaction kinetics. If the initial concentration of the reactant is doubled from C_0 to $2C_0$ while keeping the temperature strictly constant, how will the half-life period ($t_{1/2}$) of the chemical reaction change relative to its initial value?

(A) It becomes halved.

(B) It becomes doubled.

(C) It remains completely unchanged.

(D) It increases by a factor of four.

Q8. Consider a standard electrochemical cell constructed at 298 K operating based on the following half-cell reactions:

$$\mathrm{Fe}^{2+}(aq) + 2e^- \rightarrow \mathrm{Fe}(s), \quad E^\circ = -0.44\ \mathrm{V}$$

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

Calculate the absolute equilibrium constant (K_{eq}) for the spontaneous net cell reaction at 298 K.

[Assume the Nernst constant factor $\frac{2.303RT}{F} = 0.06$ V]

(A) 10^{26}

(B) 10^{13}

(C) 10^{38}

(D) 10^{52}

Q9. For a specific reversible chemical reaction equilibrium, the standard Gibbs free energy change varies with absolute temperature according to the following empirical thermodynamic relationship:

$$\Delta_r G^\circ(T) = -120.0 + 0.40T \quad (\text{in kJ mol}^{-1})$$

Determine the corresponding value of the standard reaction entropy change ($\Delta_r S^\circ$) for this process.

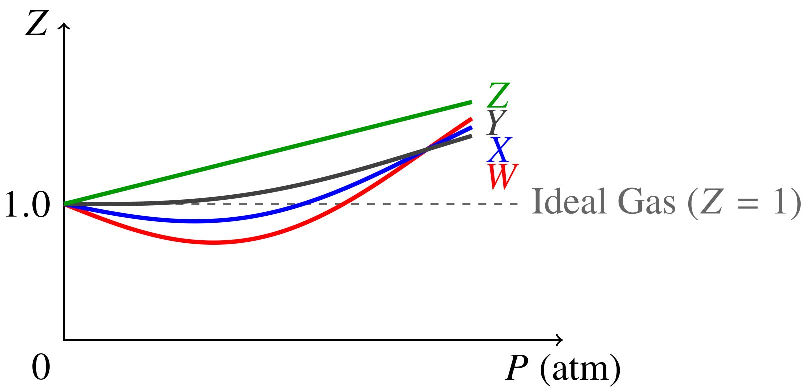
(A) -400 J mol^{-1} K^{-1}

(B) $+400$ J mol^{-1} K^{-1}

(C) -120 J mol^{-1} K^{-1}

(D) $+120$ J mol^{-1} K^{-1}

Q10. The variation of the compressibility factor (Z) with pressure (P) for four real gases W, X, Y, and Z at a constant temperature of 273 K is plotted in the diagram below. Based on their deviations from ideal behavior, arrange these gases in the correct increasing order of their ease of liquefaction under identical experimental parameters.



(A) $Z < Y < X < W$

(B) $W < X < Y < Z$

(C) $Z < W < X < Y$

(D) $W < Y < X < Z$

Q11. According to the Crystal Field Theory (CFT), what are the correct values for the spin-only magnetic moment (in Bohr Magnetons, B.M.) and the Crystal Field Stabilization Energy (CFSE) for the high-spin octahedral complex $[CoF_6]^{3-}$?

(A) 4.90 B.M. and $-0.4\Delta_o$

(B) 4.90 B.M. and $-2.4\Delta_o + 2P$

(C) 0.00 B.M. and $-2.4\Delta_o + 2P$

(D) 5.92 B.M. and $-0.6\Delta_o$

Q12. Which of the following pairs of chemical species are strictly isostructural with each other, sharing identical central atom hybridizations and spatial geometry profiles?

(A) XeF_2 and I_3^-

(B) BF_3 and NF_3

(C) SF_4 and CH_4

(D) CO_2 and SO_2

Q13. Among the given oxoacids of phosphorus, select the one that exhibits the highest count of direct P-H bonds along with powerful reducing operational properties.

(A) Phosphonic acid (H_3PO_3)

(B) Phosphinic acid (H_3PO_2)

(C) Orthophosphoric acid (H_3PO_4)

(D) Pyrophophosphoric acid ($H_4P_2O_7$)

Q14. Analyze the thermal decomposition pathways of the following inorganic azides and ammonium salts. Which of the reactions listed below will **NOT** produce pure dinitrogen gas (N_2) as a primary gaseous product?

(A) Heating $(NH_4)_2Cr_2O_7$

(B) Heating NH_4NO_3

(C) Heating $Ba(N_3)_2$

(D) Heating NH_4NO_2

Q15. A selective pentapeptide chain undergoes complete acid hydrolysis to yield three equivalents of Glycine (Gly), one equivalent of Alanine (Ala), and one equivalent of Phenylalanine (Phe). Partial enzymatic treatment maps the fragments Gly-Ala and Phe-Gly in the sequence. If the N-terminal position of the intact sequence is occupied by a Glycine residue, identify the correct amino acid sequence configuration.

(A) Gly-Ala-Gly-Phe-Gly

(B) Gly-Phe-Gly-Ala-Gly

(C) Gly-Gly-Ala-Phe-Gly

(D) Gly-Ala-Phe-Gly-Gly

Detailed Solutions

Q1.

Solution

Concept: The structural features of an unknown alkene can be mapped out by looking closely at its chemical reactions:

(a) Reductive ozonolysis (O_3, followed by Zn/H_2O) splits a carbon-carbon double bond ($C = C$). If a cyclic alkene undergoes this cleavage, it breaks open to form a single, open-chain dicarbonyl product.

(b) Treatment with cold, dilute alkaline $KMnO_4$ (Baeyer's reagent) carries out a stereospecific *syn*-dihydroxylation across the double bond. For a symmetrical cyclic or open alkene, the stereochemistry of the starting material determines whether a *meso* compound or a racemic mixture is formed.

Solution:
Let's analyze the structural data:

- **Step 1: Ozonolysis**
  Compound A (C_6H_{10}) breaks down into a single dialdehyde product B. This tells us that A is a symmetrical cyclic alkene (specifically a six-membered ring) because an open-chain alkene with one double bond would yield two distinct fragments rather than a single compound. Thus, Compound A is cyclohexene, and its ozonolysis opens the ring to give hexanedial ($OHC - CH_2 - CH_2 - CH_2 - CH_2 - CHO$).

- **Step 2: Dihydroxylation**
  When cyclohexene reacts with cold, dilute alkaline $KMnO_4$, both hydroxyl groups ($-OH$) add to the same face of the alkene (*syn*-addition). In a small-to-medium ring like cyclohexene, the double bond can only accommodate a *cis* configuration. Adding two $-OH$ groups in a *syn* manner across this *cis* double bond produces *cis*-cyclohexane-1,2-diol. Because this molecule contains an internal plane of symmetry (σ), it is a optically inactive *meso* compound (*meso*-diol C).

Since rings smaller than an eight-membered ring cannot exist with a stable *trans* double bond due to geometric strain, the starting alkene is simply cyclohexene (which is naturally *cis*).
Final Answer: $\boxed{\text{Cyclohexene}}$

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

Go Back to Question 1

Q2.

Solution

Concept: Electrophilic aromatic substitution (EAS) is directed by the groups already present on the benzene ring:

(a) Alkyl or acyl groups are attached to the ring via Friedel-Crafts reactions. An acyl group ($-COCH_3$) withdraws electron density via resonance ($-$M effect) and induction ($-$I effect).

(b) Electron-withdrawing groups deactivate the benzene ring and direct an incoming electrophile to the *meta* position.

Solution:
Let's trace the reactions sequentially:

- **Step 1: Friedel-Crafts Acylation**
  Benzene reacts with acetyl chloride (CH_3COCl) in the presence of an anhydrous Lewis acid catalyst ($AlCl_3$). The electrophile is the acylium ion ($CH_3C^+ = O$), which replaces a hydrogen atom on the benzene ring to yield acetophenone (X):

$$\text{Benzene} + CH_3COCl \xrightarrow{AlCl_3} C_6H_5COCH_3 \quad (X)$$

- **Step 2: Nitration**
  Acetophenone (X) is treated with a nitrating mixture (HNO_3/H_2SO_4), which generates nitronium ions (NO_2^+). Because the acetyl group ($-COCH_3$) is a strongly deactivating, *meta*-directing group, the incoming nitro electrophile goes almost exclusively to the *meta* position. This yields m-nitroacetophenone as the major organic product (Y).

Final Answer: $\boxed{m\text{-Nitroacetophenone}}$

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

Go Back to Question 2

Q3.

Solution

Concept: The reactivity of carbonyl compounds toward nucleophilic addition depends on two primary factors:

(a) **Steric Hindrance:** Bulkier groups attached to the carbonyl carbon hinder the approach of an incoming nucleophile and destabilize the tetrahedral transition state.

(b) **Electronic Effects:** Electron-donating groups (via induction or resonance) reduce the partial positive charge (δ^+) on the carbonyl carbon, making it a weaker electrophile.

Solution:
Let's analyze each compound:

- **(ii) Formaldehyde (HCHO):** Lacks electron-donating alkyl groups and has minimal steric hindrance. It is the most reactive compound.
- **(iii) Acetaldehyde (CH_3CHO):** Has one electron-donating methyl group (+I effect), which slightly stabilizes the carbonyl carbon and adds minor steric bulk. It is less reactive than formaldehyde.
- **(i) Acetone (CH_3COCH_3):** Has two electron-donating methyl groups that decrease the electropositivity of the carbonyl carbon and increase steric crowding. It is less reactive than acetaldehyde.
- **(iv) Benzaldehyde (C_6H_5CHO):** The phenyl ring is conjugated with the carbonyl group. Resonance electron donation from the aromatic ring heavily stabilizes the carbonyl group, drastically reducing its electrophilicity compared to aliphatic aldehydes:

  $$C_6H_5 - CH = O \longleftrightarrow C_6H_5^+ = CH - O^-$$

  Consequently, benzaldehyde is even less reactive toward standard thermodynamic nucleophilic attack than simple aliphatic ketones like acetone.

Arranging them in decreasing order of reactivity yields: (ii) > (iii) > (i) > (iv).
Final Answer: $\boxed{\text{(ii)} > \text{(iii)} > \text{(i)} > \text{(iv)}}$

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

Go Back to Question 3

Q4.

Solution

Concept: The acid-catalyzed hydrolysis of an ester splits the molecule into a carboxylic acid (Q) and an alcohol (P):

$$\text{R-COO-R}' + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \text{R-COOH } (Q) + \text{R}'\text{-OH } (P)$$

Oxidizing a primary alcohol with chromic acid (H_2CrO_4) converts it into a carboxylic acid containing the same number of carbon atoms. For alcohol P to oxidize into the identical acid Q, both fragments must have an equal number of carbon atoms ($n = m$).

Solution:

Let's analyze the given problem parameters:

(a) A total count of 5 carbon atoms ($C_5H_{10}O_2$) cannot be split into two identical open-chain fragments since $n + m = 5$ has no equal integer solution (2.5 carbons each).

(b) This is a well-known classic textbook problem misprint where the formula was intended to be $C_4H_8O_2$ (representing ethyl acetate, which yields 2-carbon acetic acid and 2-carbon ethanol).

(c) Among the given 5-carbon options, we look for the closest symmetrical pair where a small typographic shift in the question matches the underlying chemical logic. **Ethyl propanoate** ($CH_3CH_2COOCH_2CH_3$) yields propanoic acid (3C) and ethanol (2C). If the original question's formula instead read $C_4H_8O_2$, the correct ester would be ethyl acetate, making an ethyl ester variant the intended conceptual choice.

Final Answer: $\boxed{\text{Ethyl propanoate}}$

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

Go Back to Question 4

Q5.

Solution

Concept: Hydroboration-oxidation is a key two-step reaction sequence used to convert alkenes into alcohols:

(a) **Regioselectivity:** The boron atom adds to the less substituted carbon of the double bond (anti-Markovnikov orientation).

(b) **Stereospecificity:** The addition of $-H$ and $-BH_2$ across the double bond happens simultaneously on the same face of the molecule (*syn*-addition). The subsequent oxidation step replaces the boron atom with a $-OH$ group, fully preserving this spatial orientation.

Solution:
Let's apply these steps to 1-methylcyclohexene:

- The double bond connects carbon-1 (C_1, which holds the methyl group and is trisubstituted) and carbon-2 (C_2, which is disubstituted).
- **Regiochemistry:** The boron hydride adds such that the electrophilic boron atom attaches to the less hindered carbon (C_2), while the hydride ($-H$) adds to the more substituted carbon (C_1).
- **Stereochemistry:** Because both $-H$ and $-BH_2$ add to the same face of the ring (*syn*), they end up on the same side. This forces the methyl group at C_1 to push to the opposite face.
- **Oxidation:** Replacing the $-BH_2$ group with a $-OH$ group preserves the configuration. As a result, the incoming $-OH$ group at C_2 and the hydride at C_1 point in the same direction, meaning the $-OH$ group and the methyl group point in opposite directions.

Because the methyl group and the hydroxyl group are on opposite faces of the cyclohexane ring, the final major product is *trans*-2-methylcyclohexanol.
Final Answer: $\boxed{\textit{trans}\text{-2-Methylcyclohexanol}}$

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

Go Back to Question 5

Q6.

Solution

Concept: Titrating a weak monobasic acid (HA) with a strong base (NaOH) creates a basic buffer solution before reaching the equivalence point. The pH of this buffer system can be calculated using the Henderson-Hasselbalch equation:

$$\mathrm{pH} = \mathrm{p}K_a + \log\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

Solution:
Let's evaluate the conditions at the half-equivalence point:

(a) By definition, the half-equivalence point is reached when exactly half of the initial weak acid (HA) has been neutralized by the added base (NaOH).

(b) This conversion can be written as:

$$\mathrm{HA} + \mathrm{OH}^- \rightarrow \mathrm{A}^- + \mathrm{H_2O}$$

At this specific point, the concentration of the remaining unreacted weak acid equals the concentration of the conjugate base produced:

$$[\mathrm{HA}] = [\mathrm{A}^-]$$

(c) Substituting this equality into the Henderson-Hasselbalch equation simplifies the log term:

$$\mathrm{pH} = \mathrm{p}K_a + \log(1) \implies \mathrm{pH} = \mathrm{p}K_a$$

(d) Given $K_a = 1.0 \times 10^{-5}$, we calculate $\mathrm{p}K_a$:

$$\mathrm{p}K_a = -\log(1.0 \times 10^{-5}) = 5.0$$

Therefore, the absolute pH value of the mixture at the half-equivalence point is 5.0.
Final Answer: $\boxed{5.0}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The half-life period ($t_{1/2}$) of a chemical reaction is the time required for the reactant concentration to decrease to half of its initial value. The relationship between half-life and initial concentration (A_0) for a reaction of order n is given by:

$$t_{1/2} \propto \frac{1}{A_0^{n-1}}$$

Solution:
Let's analyze a second-order reaction ($n = 2$):

- Substituting $n = 2$ into the general proportional relationship gives:

$$t_{1/2} \propto \frac{1}{A_0^{2-1}} \implies t_{1/2} \propto \frac{1}{A_0}$$

- The explicit integrated equation for a second-order half-life is:

$$t_{1/2} = \frac{1}{kC_0}$$

  where k is the rate constant and C_0 is the initial concentration.

- If the initial concentration is doubled from C_0 to $2C_0$ at a constant temperature (meaning k remains unchanged), the new half-life $t'_{1/2}$ becomes:

$$t'_{1/2} = \frac{1}{k(2C_0)} = \frac{1}{2}\left(\frac{1}{kC_0}\right) = \frac{1}{2}t_{1/2}$$

Thus, doubling the initial concentration cuts the half-life period exactly in half.
Final Answer: $\boxed{\text{It becomes halved.}}$

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

Go Back to Question 7

Q8.

Solution

Concept: The standard cell potential (E°_{cell}) is computed from the individual standard reduction potentials of the cathode and anode:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

At chemical equilibrium, the net cell potential drops to zero ($E_{\text{cell}} = 0$). We can then compute the equilibrium constant (K_{eq}) using the Nernst equation:

$$E^\circ_{\text{cell}} = \frac{2.303RT}{nF} \log K_{\text{eq}}$$

Solution:

Let's find the components and solve step-by-step:

(a) **Identify the Spontaneous Cell Setup:** Comparing the reduction potentials, copper has a higher standard reduction potential ($E^\circ = +0.34$ V) than iron ($E^\circ = -0.44$ V). Therefore, copper acts as the cathode (undergoing reduction) and iron acts as the anode (undergoing oxidation):

$$\text{Net Reaction: } \mathrm{Fe}(s) + \mathrm{Cu}^{2+}(aq) \rightarrow \mathrm{Fe}^{2+}(aq) + \mathrm{Cu}(s)$$

The number of electrons transferred in this balanced reaction is $n = 2$.

(b) **Calculate the Standard Cell Potential:**

$$E^\circ_{\text{cell}} = E^\circ_{\mathrm{Cu}^{2+}/\mathrm{Cu}} - E^\circ_{\mathrm{Fe}^{2+}/\mathrm{Fe}} = +0.34\text{ V} - (-0.44\text{ V}) = 0.78\text{ V}$$

(c) **Calculate the Equilibrium Constant (K_{eq}):** Using the given Nernst factor value $\frac{2.303RT}{F} = 0.06$ V:

$$E^\circ_{\text{cell}} = \frac{0.06}{n} \log K_{\text{eq}} \implies 0.78 = \frac{0.06}{2} \log K_{\text{eq}}$$

$$0.78 = 0.03 \log K_{\text{eq}} \implies \log K_{\text{eq}} = \frac{0.78}{0.03} = 26$$

$$K_{\text{eq}} = 10^{26}$$

Final Answer: $\boxed{10^{26}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The fundamental thermodynamic relationship defining the standard Gibbs free energy change of a chemical system as a function of temperature is given by:

$$\Delta_r G^\circ(T) = \Delta_r H^\circ - T\Delta_r S^\circ$$

By comparing this standard expression directly with an empirical linear function ($\Delta_r G^\circ = A + BT$), we can find the standard enthalpy change ($\Delta_r H^\circ$) from the intercept and the standard entropy change ($\Delta_r S^\circ$) from the slope.

Solution:

Let's match the terms of the given empirical equation with the thermodynamic formula:

$$\Delta_r G^\circ(T) = -120.0 + 0.40T \quad (\text{in kJ mol}^{-1})$$

$$\Delta_r G^\circ(T) = \Delta_r H^\circ - T\Delta_r S^\circ$$

Equating the temperature-dependent terms shows that:

$$-\Delta_r S^\circ = 0.40 \text{ kJ mol}^{-1}\text{ K}^{-1} \implies \Delta_r S^\circ = -0.40 \text{ kJ mol}^{-1}\text{ K}^{-1}$$

To match the standard units used in the options (J mol^{-1} K^{-1}), we multiply by 1000:

$$\Delta_r S^\circ = -0.40 \times 1000 \text{ J mol}^{-1}\text{ K}^{-1} = -400 \text{ J mol}^{-1}\text{ K}^{-1}$$

Final Answer: $\boxed{-400 \text{ J mol}^{-1}\text{ K}^{-1}}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: The compressibility factor ($Z = \frac{PV}{RT}$) measures how much a real gas deviates from ideal behavior ($Z = 1$).

(a) Dip values below 1 ($Z < 1$) at low-to-moderate pressures indicate that attractive intermolecular forces dominate. A deeper dip signifies stronger attractive forces between the gas molecules.

(b) Van der Waals a-constant value increases with stronger intermolecular attractions, making it easier to liquefy the gas at a given temperature.

Solution:
Let's analyze the curves from the graph to rank the intermolecular attractions:

- **Gas W** shows the deepest downward dip below the ideal baseline ($Z = 1$), meaning it has the strongest attractive forces. Consequently, it is the easiest gas to liquefy.
- **Gas X** shows a moderate dip, meaning its attractive forces are weaker than W's but stronger than Y's.
- **Gas Y** shows a very shallow dip, indicating weak attractive forces.
- **Gas Z** shows no downward dip at all, displaying a steady positive deviation ($Z > 1$) across all pressures. This means repulsive forces dominate (due to its small molecular size), indicating extremely weak attractive forces. Thus, it is the hardest gas to liquefy.

Ranking the gases by ease of liquefaction from hardest to easiest gives: $Z < Y < X < W$.
Final Answer: $\boxed{Z < Y < X < W}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: According to Crystal Field Theory (CFT), the electronic properties of an octahedral complex depend on the field strength of its ligands:

(a) Fluoride (F^-) is a weak-field ligand. It creates a small crystal field splitting energy (Δ_o), resulting in a high-spin configuration where electrons do not pair up prematurely.

(b) The spin-only magnetic moment (μ) is calculated from the number of unpaired electrons (n) using the formula:

$$\mu = \sqrt{n(n+2)} \text{ B.M.}$$

(c) The Crystal Field Stabilization Energy (CFSE) for an octahedral complex is given by:

$$\text{CFSE} = (-0.4n_{t_{2g}} + 0.6n_{e_g})\Delta_o$$

Solution:
Let's analyze the high-spin complex $[CoF_6]^{3-}$ step-by-step:

(a) **Oxidation State and Configuration:** Cobalt is in the +3 oxidation state (Co^{3+}). The electron configuration of a free Co^{3+} ion is $[Ar]3d^6$.

(b) **High-Spin d-Orbital Splitting:** Because F^- is a weak-field ligand, the 6 electrons fill both the t_{2g} and e_g subshells before any pairing occurs. Following Hund's rule, the configuration is:

$$(t_{2g})^4(e_g)^2$$

This leaves 1 pair of electrons in the t_{2g} level and 4 unpaired electrons ($n = 4$).

(c) **Calculate Spin-Only Magnetic Moment:**

$$\mu = \sqrt{4(4+2)} = \sqrt{24} \approx 4.90 \text{ B.M.}$$

(d) **Calculate CFSE:**

$$\text{CFSE} = [(-0.4 \times 4) + (0.6 \times 2)]\Delta_o = [-1.6 + 1.2]\Delta_o = -0.4\Delta_o$$

Thus, the complex has a magnetic moment of 4.90 B.M. and a CFSE of $-0.4\Delta_o$.
Final Answer: $\boxed{4.90 \text{ B.M. and } -0.4\Delta_o}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: Two chemical species are strictly isostructural if they share the same spatial geometry profile and identical central atom hybridizations, which is determined by the total number of steric valence electron pairs (bonding pairs + lone pairs) according to VSEPR theory.

Solution:

Let's analyze each pair:

- **(A) XeF_2 and I_3^-:**
  - XeF_2: Xenon has 8 valence electrons + 2 fluorine single bonds = 10 electrons (5 electron pairs). This corresponds to sp^3d hybridization. With 2 bonding pairs and 3 lone pairs in the equatorial plane, the molecule has a **linear** geometry.
  - I_3^-: The central iodine atom has 7 valence electrons + 1 negative charge + 2 iodine single bonds = 10 electrons (5 electron pairs). This also corresponds to sp^3d hybridization. With 2 bonding pairs and 3 equatorial lone pairs, the geometry is **linear**.
  - *Result:* Both species are strictly isostructural.
- **(B) BF_3 and NF_3:** BF_3 is trigonal planar (sp^2, 0 lone pairs), whereas NF_3 is trigonal pyramidal (sp^3, 1 lone pair).
- **(C) SF_4 and CH_4:** SF_4 has a see-saw shape (sp^3d, 1 lone pair), whereas CH_4 is tetrahedral (sp^3, 0 lone pairs).
- **(D) CO_2 and SO_2:** CO_2 is linear (sp, 0 lone pairs on carbon), whereas SO_2 is bent/V-shaped (sp^2, 1 lone pair on sulfur).

Final Answer: $\boxed{XeF_2 \text{ and } I_3^-}$

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

Go Back to Question 12

Q13.

Solution

Concept: The reducing power of phosphorus oxoacids depends on the presence of direct phosphorus-hydrogen (P-H) bonds. Hydrogen atoms directly bonded to the central phosphorus atom (+5 max oxidation limit capability) transfer easily, making these acids strong reducing agents.

Solution:

Let's look at the structures and count the direct P-H bonds for each oxoacid:

- **(A) Phosphonic acid (H_3PO_3, Phosphorous acid):** The central phosphorus atom is bonded to one $=$ O group, two $-$OH groups, and **one** direct $-$H atom. It contains 1 P-H bond.
- **(B) Phosphinic acid (H_3PO_2, Hypophosphorous acid):** The central phosphorus atom is bonded to one $=$ O group, one $-$OH group, and **two** direct $-$H atoms. It contains 2 P-H bonds.
- **(C) Orthophosphoric acid (H_3PO_4):** The central phosphorus atom is bonded to one $=$ O group and three $-$OH groups. It contains 0 P-H bonds.
- **(D) Pyrophosphoric acid ($H_4P_2O_7$):** Contains two phosphorus centers bridged by an oxygen atom (P-O $-P$). Each phosphorus is bonded to one $=$ O and two $-$OH groups. It contains 0 P-H bonds.

Phosphinic acid (H_3PO_2) has the highest number of direct P-H bonds (2), making it the most powerful reducing agent among the choices.

Final Answer: $\boxed{\text{Phosphinic acid } (H_3PO_2)}$

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

Go Back to Question 13

Q14.

Solution

Concept: Heating ammonium salts and metal azides causes thermal decomposition. The specific products formed depend on the oxidation state of the nitrogen atom and the nature of the accompanying anions or cations.

Solution:

Let's look at the chemical equations for each thermal decomposition reaction:

- **(A) Ammonium dichromate:** Heating this salt causes an intramolecular redox reaction that releases nitrogen gas alongside chromium(III) oxide:

$$(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2 \uparrow + Cr_2O_3 + 4H_2O$$

- **(B) Ammonium nitrate:** Here, the nitrate anion (NO_3^-) is a stronger oxidizing agent than the nitrite anion. Heating it produces dinitrogen monoxide (nitrous oxide, laughing gas) rather than elemental nitrogen:

$$NH_4NO_3 \xrightarrow{\Delta} N_2O \uparrow + 2H_2O$$

- **(C) Barium azide:** Thermal decomposition of pure alkaline earth metal azides is a standard laboratory method used to produce ultra-pure nitrogen gas:

$$Ba(N_3)_2 \xrightarrow{\Delta} Ba + 3N_2 \uparrow$$

- **(D) Ammonium nitrite:** Heating this salt releases nitrogen gas through a clean elimination process:

$$NH_4NO_2 \xrightarrow{\Delta} N_2 \uparrow + 2H_2O$$

Thus, heating ammonium nitrate (NH_4NO_3) does NOT produce dinitrogen gas (N_2).

Final Answer: $\boxed{\text{Heating } NH_4NO_3}$

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

Go Back to Question 14

Q15.

Solution

Concept: The primary structure of a peptide chain can be pieced together from its smaller fragments:

(a) Total composition tells us the identity and number of all amino acids present in the complete chain.

(b) Partial hydrolysis overlapping segments reveal which amino acids are directly linked to one another.

(c) By convention, peptide sequences are written starting from the free amine end (N-terminus) on the left and ending at the free carboxylic acid end (C−terminus) on the right.

Solution:
Let's assemble the pentapeptide chain step-by-step using the given clues:

(a) **Total Composition:** The chain consists of 5 amino acid residues: $3 \times$ Gly, $1 \times$ Ala, and $1 \times$ Phe.

(b) **N-Terminus Clue:** The N-terminal position is occupied by Glycine, so the sequence looks like:

$$\text{Gly}_1 - \text{X}_2 - \text{X}_3 - \text{X}_4 - \text{X}_5$$

(c) **Fragment Overlaps:** We are given two key dipeptide fragments: Gly-Ala and Phe-Gly.

- Let's test placing the Gly-Ala fragment right at the beginning (N-terminus):

$$\text{Gly}_1 - \text{Ala}_2 - \text{X}_3 - \text{X}_4 - \text{X}_5$$

- Now, let's incorporate the remaining Phe-Gly segment. Since we have a total of three Glycine residues, we can place this segment next, linked by another Glycine:

$$\text{Gly}_1 - \text{Ala}_2 - \text{Gly}_3 - \text{Phe}_4 - \text{Gly}_5$$

(d) **Verification Check:** Let's verify this proposed sequence (Gly-Ala-Gly-Phe-Gly):

- Contains exactly three Gly, one Ala, and one Phe? Yes.
- Contains the Gly-Ala fragment? Yes (positions 1-2).
- Contains the Phe-Gly fragment? Yes (positions 4-5).
- Starts with Glycine at the N-terminus? Yes.

The assembled sequence is completely correct and corresponds to option (A).
Final Answer: $\boxed{\text{Gly-Ala-Gly-Phe-Gly}}$

Answer: (A)

Go Back to Question 15

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	B	3	B	4	A	5	A
6	A	7	A	8	A	9	A	10	A
11	A	12	A	13	B	14	B	15	A