

# WBJEE Chemistry Sample Paper-8

Duration: 60 Minutes

Maximum Marks: 50

## Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Sections**.
- **Section A (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **–0.25** marks. Only **one** correct option.
- **Section B (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **–0.5** marks. Only **one** correct option.
- **Section C (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

**Section–A — 30 Questions × 1 Mark Each**  
**(Negative Marking: –0.25) [Single Correct]**

- Q1.** An aqueous solution of a non-volatile solute has a boiling point of  $101.04^{\circ}\text{C}$ . What is the precise mole fraction of the solute within this solution? (Given:  $K_b$  of water =  $0.52 \text{ K kg mol}^{-1}$ , molar mass of water =  $18 \text{ g mol}^{-1}$ )
- (A) 0.0177  
(B) 0.0348  
(C) 0.0526  
(D) 0.0681
- Q2.** A 20.0 mL sample of an aqueous solution containing a mixture of  $\text{Na}_2\text{CO}_3$  and  $\text{NaHCO}_3$  requires 15.0 mL of 0.1 M HCl using phenolphthalein indicator for the first end point. Another 20.0 mL sample of the same solution requires 40.0 mL



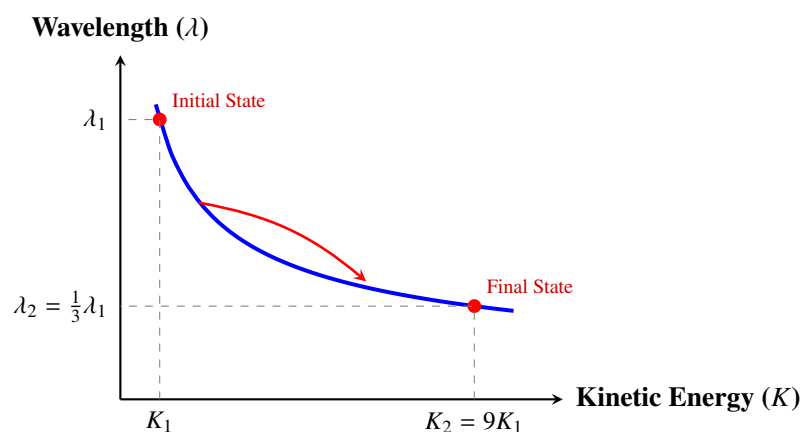
of 0.1 M HCl using methyl orange indicator from the start. What is the molarity of  $\text{NaHCO}_3$  in the original mixture?

- (A) 0.05 M
- (B) 0.075 M
- (C) 0.10 M
- (D) 0.125 M

**Q3.** In a hydrogen atom, an electron transitions from an excited state  $n$  to the ground state ( $n = 1$ ). The wavelength of the emitted photon is  $\lambda$ . If the same transition occurs in a  $\text{He}^+$  ion, the wavelength of the emitted photon will be:

- (A)  $4\lambda$
- (B)  $2\lambda$
- (C)  $\frac{\lambda}{2}$
- (D)  $\frac{\lambda}{4}$

**Q4.** If the kinetic energy of an electron is increased by a factor of 9, by what percentage does its de Broglie wavelength decrease?



**Formula:**  $\lambda = \frac{h}{\sqrt{2mK}} \Rightarrow \text{If } K \times 9, \lambda \times \frac{1}{3} \Rightarrow 66.7\% \text{ Decrease}$

- (A) 33.3%
- (B) 50.0%
- (C) 66.7%
- (D) 75.0%



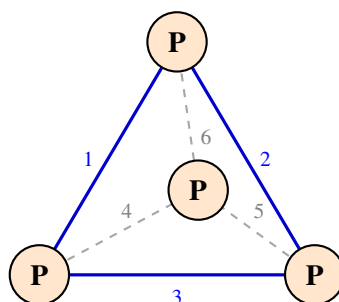
- Q5.** Which of the following chemical species exhibits a linear molecular geometry according to VSEPR theory?
- (A)  $\text{NO}_2^-$   
(B)  $\text{O}_3$   
(C)  $\text{ICl}_2^-$   
(D)  $\text{SO}_2$
- Q6.** Which of the following pairs of molecules are completely isostructural and iso-electronic with each other?
- (A)  $\text{CO}_2$  and  $\text{NO}_2$   
(B)  $\text{BF}_3$  and  $\text{NF}_3$   
(C)  $\text{XeF}_2$  and  $\text{IF}_2^-$   
(D)  $\text{SiF}_4$  and  $\text{SF}_4$
- Q7.** For a real gas obeying the van der Waals equation of state, the critical temperature ( $T_c$ ) and critical pressure ( $P_c$ ) are given. The compressibility factor ( $Z$ ) of this gas explicitly at its critical point is:
- (A) 0.375  
(B) 1.000  
(C) 0.750  
(D) 0.500
- Q8.** For a given chemical reaction,  $\Delta H = -40.0 \text{ kJ mol}^{-1}$  and  $\Delta S = -100.0 \text{ J K}^{-1} \text{ mol}^{-1}$ . Above what absolute temperature will this reaction become non-spontaneous in the forward direction?
- (A) 250 K  
(B) 400 K  
(C) 300 K  
(D) 500 K



- Q9.** The solubility product ( $K_{sp}$ ) of  $\text{CaF}_2$  in pure water at a specific temperature is  $4.0 \times 10^{-11}$ . What is its molar solubility in a 0.05 M NaF solution?
- (A)  $1.6 \times 10^{-8}$  M  
(B)  $4.0 \times 10^{-9}$  M  
(C)  $2.0 \times 10^{-5}$  M  
(D)  $8.0 \times 10^{-9}$  M
- Q10.** For a second-order reaction where the initial concentration of the reactant is  $[\text{A}]_0$ , a straight line plot is obtained by plotting which parameter on the y-axis against time ( $t$ ) on the x-axis?
- (A)  $\ln[\text{A}]_t$   
(B)  $\frac{1}{[\text{A}]_t}$   
(C)  $[\text{A}]_t^2$   
(D)  $\frac{1}{[\text{A}]_t^2}$
- Q11.** For a first-order chemical reaction, the time taken for 99.9% completion ( $t_{99.9\%}$ ) is approximately how many times its half-life ( $t_{1/2}$ )?
- (A) 3 times  
(B) 5 times  
(C) 10 times  
(D) 20 times
- Q12.** When 1 mole of ferrous oxalate ( $\text{FeC}_2\text{O}_4$ ) is completely oxidized by acidified potassium permanganate ( $\text{KMnO}_4$ ) solution, the total number of moles of  $\text{KMnO}_4$  consumed is:
- (A) 0.2 moles  
(B) 0.4 moles  
(C) 0.6 moles  
(D) 1.0 mole



- Q13.** The standard reduction potentials of three metallic elements A, B, and C are  $+0.80\text{ V}$ ,  $-2.37\text{ V}$ , and  $-0.44\text{ V}$  respectively. What is the correct increasing order of their reducing power?
- (A)  $A < B < C$   
(B)  $B < C < A$   
(C)  $A < C < B$   
(D)  $C < A < B$
- Q14.** Which of the following alkali metal nitrates, upon strong thermal decomposition, leaves behind a transition-like metal oxide rather than a metal nitrite?
- (A)  $\text{KNO}_3$   
(B)  $\text{NaNO}_3$   
(C)  $\text{LiNO}_3$   
(D)  $\text{RbNO}_3$
- Q15.** Which description accurately portrays the structural configuration of orthoboric acid ( $\text{H}_3\text{BO}_3$ ) in its solid crystalline form?
- (A) It consists of discrete  $\text{H}_3\text{BO}_3$  tetrahedral units.  
(B) It forms a layered two-dimensional network stabilized by extensive hydrogen bonding.  
(C) It forms a linear polymeric chain through oxygen bridging.  
(D) It is a strong tribasic Lewis acid with a cage structure.
- Q16.** In the structure of white phosphorus ( $\text{P}_4$ ), what is the precise P-P-P bond angle and the total number of single P-P covalent bonds present within a single molecule?



- (A)  $60^\circ$ , 6 bonds
- (B)  $109.5^\circ$ , 4 bonds
- (C)  $90^\circ$ , 6 bonds
- (D)  $60^\circ$ , 4 bonds

**Q17.** The chemical composition of the dark green solution obtained when manganese dioxide ( $\text{MnO}_2$ ) is fused with potassium hydroxide (KOH) in the presence of an oxidizing agent like  $\text{KNO}_3$  is:

- (A)  $\text{KMnO}_4$
- (B)  $\text{K}_2\text{MnO}_4$
- (C)  $\text{Mn}_2\text{O}_7$
- (D)  $\text{K}_3\text{MnO}_4$

**Q18.** The spin-only magnetic moment of the coordination complex  $[\text{Fe}(\text{H}_2\text{O})_5(\text{NO})]\text{SO}_4$  (responsible for the classic brown ring test) is observed to be 3.87 BM. This value confirms that the oxidation state of the central iron atom and the number of unpaired electrons are respectively:

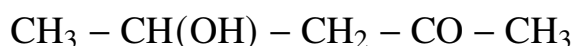
- (A) +1, 3
- (B) +2, 4
- (C) +3, 5
- (D) +1, 5

**Q19.** Which of the following chemical species is classified as the primary secondary pollutant responsible for the eye irritation and hazardous tear-inducing effects within photochemical smog?

- (A) Carbon monoxide (CO)
- (B) Sulfur dioxide ( $\text{SO}_2$ )
- (C) Peroxyacetyl nitrate (PAN)
- (D) Nitric oxide (NO)



**Q20.** What is the correct IUPAC name of the following organic compound?



- (A) 2-Hydroxypentan-4-one
- (B) 4-Hydroxypentan-2-one
- (C) Pentan-2-ol-4-one
- (D) 4-Oxopentan-2-ol

**Q21.** Among the following carbocations, which one exhibits the highest thermodynamic stability due to resonance and hyperconjugation?

- (A)  $(\text{CH}_3)_3\text{C}^+$
- (B)  $\text{C}_6\text{H}_5 - \text{CH}_2^+$
- (C)  $(\text{C}_6\text{H}_5)_3\text{C}^+$
- (D)  $\text{CH}_2 = \text{CH} - \text{CH}_2^+$

**Q22.** Ozonolysis of an alkene X followed by reductive workup with  $\text{Zn}/\text{H}_2\text{O}$  yields an equimolar mixture of propanone ( $\text{CH}_3\text{COCH}_3$ ) and ethanal ( $\text{CH}_3\text{CHO}$ ). What is the systematic IUPAC name of alkene X?

- (A) 2-Methylbut-2-ene
- (B) Pent-2-ene
- (C) 3-Methylbut-1-ene
- (D) 2-Methylbut-1-ene

**Q23.** When optical isomers of 2-bromobutane are subjected to a nucleophilic substitution reaction with aqueous KOH via an  $\text{S}_{\text{N}}1$  kinetic pathway, the configuration of the resulting product shows:

- (A) Complete inversion of configuration
- (B) Complete retention of configuration
- (C) Predominant racemization with slight inversion



(D) Formation of a diastereomeric mixture

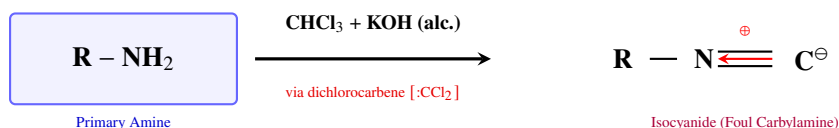
**Q24.** An organic ether compound Y reacts with excess hot concentrated hydroiodic acid (HI) to yield a single alkyl iodide as the sole organic product. Which of the following structural layouts matches compound Y?

- (A) Anisole ( $C_6H_5OCH_3$ )
- (B) Diethyl ether ( $CH_3CH_2OCH_2CH_3$ )
- (C) Methyl ethyl ether ( $CH_3OCH_2CH_3$ )
- (D) Tert-butyl methyl ether

**Q25.** Which of the following organic compounds will *not* undergo a self-condensation Cannizzaro reaction when treated with a concentrated (50%) aqueous solution of sodium hydroxide?

- (A) Formaldehyde (HCHO)
- (B) Benzaldehyde ( $C_6H_5CHO$ )
- (C) Acetaldehyde ( $CH_3CHO$ )
- (D) Trimethylacetaldehyde [ $(CH_3)_3CCHO$ ]

**Q26.** When an organic primary amine is heated with chloroform ( $CHCl_3$ ) and ethanolic potassium hydroxide (KOH), an exceptionally foul-smelling substance is synthesized. The functional group present in this foul-smelling substance is:



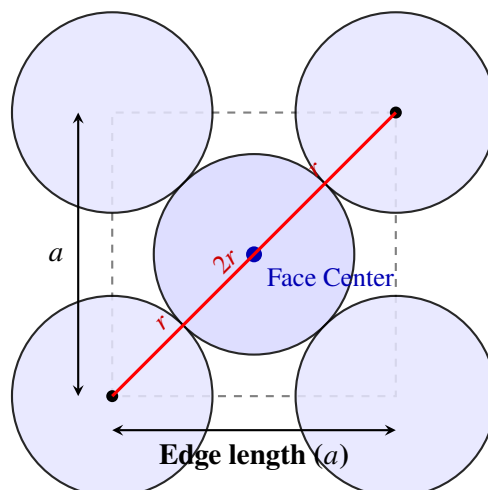
- (A) Isocyanide (-NC)
- (B) Cyanide (-CN)
- (C) Nitro group ( $-NO_2$ )
- (D) Amide ( $-CONH_2$ )



**Q27.** Which of the following structural linkages connects the constituent monosaccharide units (D-glucose and D-fructose) within a non-reducing disaccharide sucrose molecule?

- (A)  $C_1 - \alpha -$  D-glucopyranoside –  $C_4 - \beta -$  D-glucopyranose  
 (B)  $C_1 - \alpha -$  D-glucopyranoside –  $C_2 - \beta -$  D-fructofuranoside  
 (C)  $C_1 - \beta -$  D-glucopyranoside –  $C_4 - \alpha -$  D-galactopyranoside  
 (D)  $C_1 - \alpha -$  D-glucopyranoside –  $C_6 - \alpha -$  D-glucopyranose

**Q28.** An element crystallizes in a face-centered cubic (fcc) lattice arrangement. If the length of the unit cell edge is  $a$ , what is the closest distance of approach between any two adjacent atoms in this crystal lattice?



- (A)  $a/2$   
 (B)  $a\sqrt{2}$   
 (C)  $a/\sqrt{2}$   
 (D)  $a\sqrt{3}/2$

**Q29.** The solubility of alkaline earth metal sulfates in water decreases down the group from  $MgSO_4$  to  $BaSO_4$ . This observation is fundamentally due to:

- (A) A rapid decrease in lattice energy down the group.  
 (B) A rapid decrease in hydration energy down the group.  
 (C) An increase in covalent character of the sulfates.



(D) An increase in the metallic character of the cation.

**Q30.** What is the ratio of the root-mean-square velocity ( $v_{\text{rms}}$ ) of  $\text{H}_2$  gas at 50 K to that of  $\text{O}_2$  gas at 800 K?

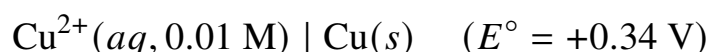
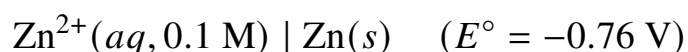
- (A) 1 : 1
- (B) 1 : 2
- (C) 2 : 1
- (D) 1 : 4

**Section-B — 5 Questions × 2 Marks Each**  
**(Negative Marking: -0.5) [Single Correct]**

**Q31.** A crystalline salt  $\text{MCl}_x \cdot 2\text{H}_2\text{O}$  was analyzed. When 2.44 g of this hydrated salt is heated to constant mass, the anhydrous residue weighs 2.08 g. If the atomic mass of the metal M is  $137 \text{ g mol}^{-1}$ , what is the value of the stoichiometric variable  $x$ ? (Atomic masses:  $\text{Cl} = 35.5 \text{ g mol}^{-1}$ ,  $\text{H} = 1 \text{ g mol}^{-1}$ ,  $\text{O} = 16 \text{ g mol}^{-1}$ )

- (A) 1
- (B) 2
- (C) 3
- (D) 4

**Q32.** A standard galvanic cell is constructed using the following half-cells at 298 K:



Using the Nernst equation, what is the precise electromotive force ( $E_{\text{cell}}$ ) of this non-standard chemical system? (Given:  $\frac{2.303RT}{F} = 0.0591 \text{ V}$ )

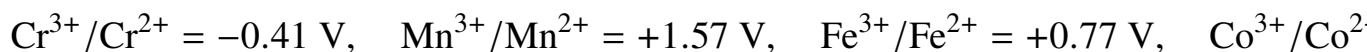
- (A) 1.130 V
- (B) 1.100 V



(C) 1.070 V

(D) 1.041 V

**Q33.** The standard reduction potential ( $E^\circ$ ) values for the trivalent-to-divalent state ( $M^{3+}/M^{2+}$ ) couples of chromium, manganese, iron, and cobalt are listed below:



Based on these values, which of the following tripositive metal ions acts as the strongest oxidizing agent in an aqueous solution?

(A)  $\text{Cr}^{3+}$

(B)  $\text{Mn}^{3+}$

(C)  $\text{Fe}^{3+}$

(D)  $\text{Co}^{3+}$

**Q34.** An aromatic compound Z ( $\text{C}_7\text{H}_8$ ) undergoes free-radical chlorination with excess  $\text{Cl}_2$  under intense UV light to give a chlorinated intermediate. This intermediate is subsequently treated with boiling aqueous NaOH followed by acidification to produce a crystalline organic product. What is the molecular structure of this final organic product?

(A) Benzyl alcohol

(B) Benzaldehyde

(C) Benzoic acid

(D) o-Chlorotoluene

**Q35.** A weak monoprotic acid (HA) has an acid dissociation constant  $K_a = 1.0 \times 10^{-5}$  at 298 K. What is the absolute pH of a 0.10 M aqueous solution of the sodium salt of this acid (NaA)?

(A) 5.0

(B) 7.0

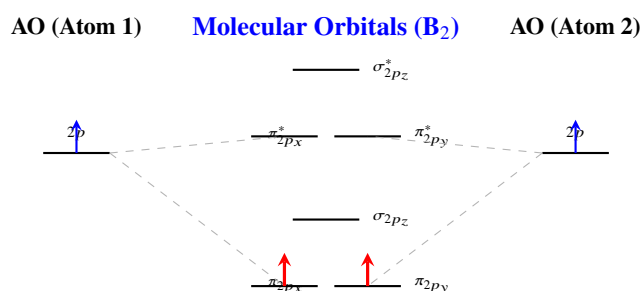
(C) 9.0



(D) 11.0

Section-C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

**Q36.** According to Molecular Orbital Theory (MOT), which of the following homonuclear diatomic chemical species are paramagnetic in nature?



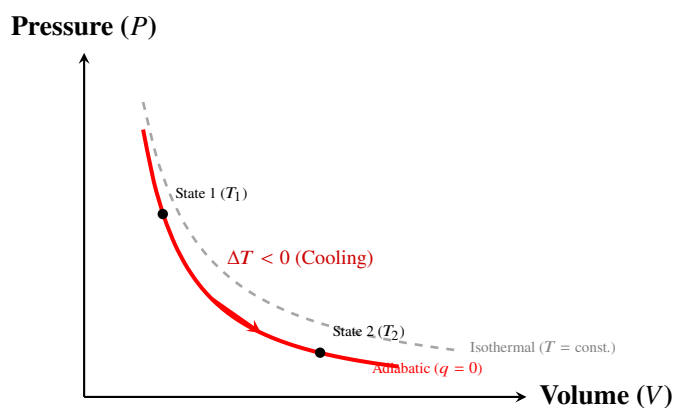
- (A)  $B_2$
- (B)  $C_2$
- (C)  $O_2$
- (D)  $N_2^{2-}$

**Q37.** Consider the coordination octahedral complex ion  $[\text{Co}(\text{ox})_3]^{3-}$  (where ox = oxalate ion). Which of the following statements regarding its configuration are completely correct?

- (A) It is an inner-orbital dsp-hybridized complex.
- (B) It is completely diamagnetic.
- (C) It exhibits optical activity and exists as non-superimposable d- and l-enantiomers.
- (D) The coordination number of the central cobalt atom is 3.

**Q38.** For an ideal gas undergoing a perfectly reversible adiabatic expansion process into an expanded volume, which of the following thermodynamic relationships are completely correct?





- (A)  $\Delta S_{\text{system}} = 0$
- (B)  $q = 0$
- (C)  $\Delta T < 0$
- (D)  $w > 0$

**Q39.** Which of the following organic structures will react with a solution of iodine ( $I_2$ ) and sodium hydroxide (NaOH) to form a bright yellow precipitate of iodoform ( $CHI_3$ )?

- (A) Pentan-2-one
- (B) Pentan-3-one
- (C) Ethanol
- (D) Propan-2-ol

**Q40.** Which of the following chemical equations represent true intramolecular redox thermal decomposition reactions?

- (A)  $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$
- (B)  $NH_4NO_2 \xrightarrow{\Delta} N_2 + 2H_2O$
- (C)  $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
- (D)  $NH_4Cl \xrightarrow{\Delta} NH_3 + HCl$



## Detailed Solutions

Q1.

## Solution

**Concept:**

The elevation in boiling point ( $\Delta T_b$ ) of a solution containing a non-volatile solute is a colligative property that depends directly on the molality ( $m$ ) of the solution. The relation is expressed as  $\Delta T_b = K_b \cdot m$ . To find the precise mole fraction of the solute ( $\chi_{\text{solute}}$ ), we can use the relationship between molality and mole fraction:  $m = \frac{\chi_{\text{solute}} \cdot 1000}{(1 - \chi_{\text{solute}}) \cdot M_{\text{solvent}}}$ , where  $M_{\text{solvent}}$  is the molar mass of the solvent (water,  $18 \text{ g mol}^{-1}$ ).

**Solution:**

- (a) Calculate the elevation in boiling point ( $\Delta T_b$ ): The boiling point of pure water is  $100^\circ\text{C}$ . The boiling point of the solution is given as  $101.04^\circ\text{C}$ .

$$\Delta T_b = T_b - T_b^\circ = 101.04^\circ\text{C} - 100^\circ\text{C} = 10.04 - 9.00 = 1.04 \text{ K}$$

- (b) Determine the molality ( $m$ ) of the solution using the formula  $\Delta T_b = K_b \cdot m$ :

$$1.04 = 0.52 \cdot m \implies m = \frac{1.04}{0.52} = 2.0 \text{ mol kg}^{-1}$$

- (c) Express the molality in terms of mole fraction ( $\chi_{\text{solute}}$ ): Molality is defined as the moles of solute per 1 kg (1000 g) of solvent. The number of moles of water in 1000 g is:

$$n_{\text{water}} = \frac{1000 \text{ g}}{18 \text{ g mol}^{-1}} = 55.56 \text{ moles}$$

Since the molality is  $2.0 \text{ mol kg}^{-1}$ , there are 2.0 moles of solute for every 55.56 moles of water.

- (d) Calculate the precise mole fraction of the solute ( $\chi_{\text{solute}}$ ):

$$\chi_{\text{solute}} = \frac{n_{\text{solute}}}{n_{\text{solute}} + n_{\text{water}}} = \frac{2.0}{2.0 + 55.56} = \frac{2.0}{57.56} \approx 0.034746$$

Comparing this value with the given choices, it matches option (B) which is 0.0348.

**Final Answer:** The precise mole fraction of the solute within the solution is 0.0348.

**Answer: (B)**

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Q2.

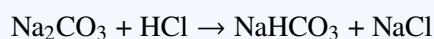
### Solution

#### Concept:

This problem involves a double indicator titration method used to analyze a mixture of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) and sodium bicarbonate ( $\text{NaHCO}_3$ ) using hydrochloric acid ( $\text{HCl}$ ). Phenolphthalein is used to track the completion of the first stage of titration where  $\text{Na}_2\text{CO}_3$  is quantitatively converted into  $\text{NaHCO}_3$ . Methyl orange is an indicator that tracks the complete neutralization of all basic species ( $\text{Na}_2\text{CO}_3$  and original  $\text{NaHCO}_3$ ) down to carbon dioxide and water from the very start.

#### Solution:

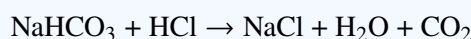
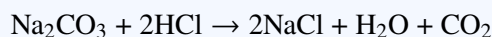
- (a) Let the millimoles of  $\text{Na}_2\text{CO}_3$  in the 20.0 mL sample be  $x$  and the millimoles of  $\text{NaHCO}_3$  be  $y$ .
- (b) At the phenolphthalein end point, only half of the carbonate reacts to form bicarbonate:



The original bicarbonate does not react at this stage. Thus, the millimoles of  $\text{HCl}$  consumed are equal to the millimoles of  $\text{Na}_2\text{CO}_3$ :

$$\text{Molarity of HCl} \times \text{Volume (mL)} = x \implies 0.1 \text{ M} \times 15.0 \text{ mL} = x \implies x = 1.5 \text{ mmol}$$

- (c) At the methyl orange end point from the start, both components are fully neutralized:



The total millimoles of  $\text{HCl}$  needed from the start are  $2x + y$ :

$$2x + y = 0.1 \text{ M} \times 40.0 \text{ mL} = 4.0 \text{ mmol}$$

- (d) Substitute the value of  $x = 1.5 \text{ mmol}$  into the second equation:

$$2(1.5) + y = 4.0 \implies 3.0 + y = 4.0 \implies y = 1.0 \text{ mmol}$$

- (e) Determine the molarity of  $\text{NaHCO}_3$  in the original mixture:

$$\text{Molarity} = \frac{\text{millimoles of NaHCO}_3}{\text{Volume of sample in mL}} = \frac{1.0 \text{ mmol}}{20.0 \text{ mL}} = 0.05 \text{ M}$$

This perfectly corresponds to option (A).

**Final Answer:** The molarity of  $\text{NaHCO}_3$  in the original mixture is 0.05 M.

**Answer:** (A)

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Q3.

**Solution****Concept:**

According to Bohr's atomic theory, the wavelength ( $\lambda$ ) of a photon emitted during an electronic transition between two energy levels in a hydrogen-like species is given by the Rydberg formula:  $\frac{1}{\lambda} = R_H \cdot Z^2 \cdot \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ , where  $R_H$  is the Rydberg constant,  $Z$  is the atomic number of the species,  $n_1$  is the lower energy level, and  $n_2$  is the higher excited state level.

**Solution:**

- (a) Write the Rydberg equation for the transition in the hydrogen atom ( $Z = 1$ ):

$$\frac{1}{\lambda_H} = R_H \cdot (1)^2 \cdot \left(\frac{1}{1^2} - \frac{1}{n^2}\right) = R_H \cdot \left(1 - \frac{1}{n^2}\right)$$

Given that  $\lambda_H = \lambda$ , we have:

$$\frac{1}{\lambda} = R_H \cdot \left(1 - \frac{1}{n^2}\right)$$

- (b) Write the Rydberg equation for the identical transition in the helium ion ( $\text{He}^+$ ,  $Z = 2$ ):

$$\frac{1}{\lambda_{\text{He}^+}} = R_H \cdot (2)^2 \cdot \left(\frac{1}{1^2} - \frac{1}{n^2}\right) = 4 \cdot R_H \cdot \left(1 - \frac{1}{n^2}\right)$$

- (c) Substitute the expression for the hydrogen atom into the helium ion equation:

$$\frac{1}{\lambda_{\text{He}^+}} = 4 \cdot \left(\frac{1}{\lambda}\right) = \frac{4}{\lambda}$$

- (d) Solve for the new wavelength  $\lambda_{\text{He}^+}$ :

$$\lambda_{\text{He}^+} = \frac{\lambda}{4}$$

This matches option (D). Therefore, increasing the nuclear charge by a factor of 2 increases the energy change by a factor of 4, causing the emitted wavelength to shrink to one-fourth of its initial value.

**Final Answer:** The wavelength of the emitted photon in  $\text{He}^+$  will be  $\frac{\lambda}{4}$ .

**Answer: (D)**

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Q4.

**Solution****Concept:**

The de Broglie hypothesis relates the wave nature of a particle to its momentum. The de Broglie wavelength ( $\lambda$ ) is given by  $\lambda = \frac{h}{p}$ , where  $h$  is Planck's constant and  $p$  is the momentum of the particle. Since kinetic energy ( $K$ ) is related to momentum by  $p = \sqrt{2mK}$ , we can substitute this to express the wavelength explicitly as a function of kinetic energy:  $\lambda = \frac{h}{\sqrt{2mK}}$ . This shows that the de Broglie wavelength is inversely proportional to the square root of the particle's kinetic energy ( $\lambda \propto \frac{1}{\sqrt{K}}$ ).

**Solution:**

- (a) Let the initial kinetic energy of the electron be  $K_1$  and its initial wavelength be  $\lambda_1$ .

$$\lambda_1 = \frac{h}{\sqrt{2mK_1}}$$

- (b) The kinetic energy is increased by a factor of 9, so the new kinetic energy is  $K_2 = 9K_1$ .

$$\lambda_2 = \frac{h}{\sqrt{2mK_2}} = \frac{h}{\sqrt{2m(9K_1)}} = \frac{1}{\sqrt{9}} \cdot \frac{h}{\sqrt{2mK_1}} = \frac{1}{3}\lambda_1$$

- (c) Calculate the fractional decrease in the wavelength:

$$\Delta\lambda = \lambda_1 - \lambda_2 = \lambda_1 - \frac{1}{3}\lambda_1 = \frac{2}{3}\lambda_1$$

- (d) Convert this change into a percentage decrease:

$$\text{Percentage decrease} = \left(\frac{\Delta\lambda}{\lambda_1}\right) \times 100\% = \left(\frac{\frac{2}{3}\lambda_1}{\lambda_1}\right) \times 100\% = \frac{2}{3} \times 100\% \approx 66.67\%$$

This aligns with option (C).

**Final Answer:** The de Broglie wavelength decreases by 66.7%.

**Answer: (C)**

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Q5.

**Solution****Concept:**

According to the Valence Shell Electron Pair Repulsion (VSEPR) theory, the molecular geometry of a species depends on the number of bonding electron pairs and lone pairs around the central atom (the steric number). The layout minimizes the electrostatic repulsion between these electron domains. A linear molecular geometry requires the bonded atoms to lie along a straight line, which typically occurs for steric arrangements like  $AX_2$  (linear electron geometry with no lone pairs) or  $AX_2E_3$  (trigonal bipyramidal electron geometry with 3 lone pairs in the equatorial positions).

**Solution:**

- (a) Analyze  $NO_2^-$ : The central nitrogen atom has 5 valence electrons + 1 extra negative charge = 6 electrons. It forms two bonds with oxygen atoms and retains one lone pair (steric number = 3,  $AX_2E$ ). Its shape is bent or angular.
- (b) Analyze  $O_3$ : The central oxygen atom has 6 valence electrons. It forms a double bond with one oxygen, a coordinate bond with another, and retains one lone pair (steric number = 3,  $AX_2E$ ). Its shape is bent or angular.
- (c) Analyze  $ICl_2^-$ : The central iodine atom has 7 valence electrons + 1 negative charge = 8 valence electrons. It forms two single covalent bonds with chlorine atoms, leaving 6 unshared electrons, which constitute 3 lone pairs. The steric number is 2 bonds + 3 lone pairs = 5 ( $AX_2E_3$ ). The electron geometry is trigonal bipyramidal, where the 3 lone pairs occupy the equatorial positions to minimize repulsion, leaving the two chlorine atoms at the axial positions. This results in a completely linear molecular geometry ( $180^\circ$  bond angle).
- (d) Analyze  $SO_2$ : The central sulfur atom has 6 valence electrons. It forms two double bonds with oxygen atoms and retains one lone pair (steric number = 3,  $AX_2E$ ). Its shape is bent or angular.

**Final Answer:** The chemical species that exhibits a linear molecular geometry is  $ICl_2^-$ .

**Answer:** (C)

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Q6.

**Solution****Concept:**

Isoelectronic chemical species possess the exact same total number of electrons, including valence and inner-shell electrons. Isostructural chemical species share identical molecular geometries and spatial arrangements of their constituent atoms and lone pairs around the central atom according to Valence Shell Electron Pair Repulsion theory. To determine if a pair is both completely isostructural and iso-electronic, we must compute the total electron count and find the specific steric number and lone pair configuration for each molecule.

**Solution:**

- (a) Analyze  $\text{CO}_2$  and  $\text{NO}_2$ : Carbon dioxide has  $6 + 8 \times 2 = 22$  electrons and a linear shape. Nitrogen dioxide has  $7 + 8 \times 2 = 23$  electrons and a bent shape. They are neither isostructural nor iso-electronic.
- (b) Analyze  $\text{BF}_3$  and  $\text{NF}_3$ : Boron trifluoride has  $5 + 9 \times 3 = 32$  electrons and a trigonal planar shape. Nitrogen trifluoride has  $7 + 9 \times 3 = 34$  electrons and a trigonal pyramidal shape. They are neither isostructural nor iso-electronic.
- (c) Analyze  $\text{XeF}_2$  and  $\text{IF}_2^-$ : For  $\text{XeF}_2$ , the total number of electrons is  $54 + 9 \times 2 = 72$ . The central xenon atom has 8 valence electrons, forms 2 single bonds with fluorine, and retains 3 lone pairs. The steric number is  $2 + 3 = 5$ , giving a trigonal bipyramidal electron geometry and a linear molecular geometry. For  $\text{IF}_2^-$ , the total number of electrons is  $53 + 9 \times 2 + 1 = 72$ . The central iodine atom has 7 valence electrons + 1 negative charge = 8 valence electrons. It forms 2 single bonds with fluorine and retains 3 lone pairs. The steric number is  $2 + 3 = 5$ , giving a trigonal bipyramidal electron geometry and a linear molecular geometry. Since both species have 72 electrons and a linear shape, they are perfectly iso-electronic and isostructural.
- (d) Analyze  $\text{SiF}_4$  and  $\text{SF}_4$ : Silicon tetrafluoride has 40 electrons and a tetrahedral shape, while sulfur tetrafluoride has 42 electrons and a see-saw shape.

**Final Answer:** The pair of molecules that are completely isostructural and iso-electronic with each other is  $\text{XeF}_2$  and  $\text{IF}_2^-$ .

**Answer: (C)**

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Q7.

**Solution****Concept:**

A real gas can be described by the van der Waals equation of state:  $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$ , where  $a$  accounts for intermolecular attractive forces and  $b$  accounts for the finite excluded volume of the gas molecules. At the critical point of the gas, the isotherms exhibit an inflection point where the first and second derivatives of pressure with respect to volume at constant temperature are both exactly equal to zero. Solving these calculus conditions yields expressions for the critical parameters:  $V_c = 3b$ ,  $P_c = \frac{a}{27b^2}$ , and  $T_c = \frac{8a}{27Rb}$ . The compressibility factor  $Z$  measures deviation from ideal behavior and is defined as  $Z = \frac{PV}{RT}$ .

**Solution:**

- (a) Identify the explicit algebraic formulas for the critical constants of a van der Waals real gas:

$$\text{Critical Volume } (V_c) = 3b$$

$$\text{Critical Pressure } (P_c) = \frac{a}{27b^2}$$

$$\text{Critical Temperature } (T_c) = \frac{8a}{27Rb}$$

- (b) Substitute these critical parameters directly into the standard formula for the compressibility factor evaluated specifically at the critical point ( $Z_c$ ):

$$Z_c = \frac{P_c V_c}{RT_c}$$

- (c) Perform the algebraic substitution and simplify the resulting expression:

$$Z_c = \frac{\left(\frac{a}{27b^2}\right) \cdot (3b)}{R \cdot \left(\frac{8a}{27Rb}\right)} = \frac{\frac{3a}{27b}}{\frac{8a}{27b}} = \frac{3}{8}$$

- (d) Convert the fraction into a precise decimal value:

$$Z_c = \frac{3}{8} = 0.375$$

This value shows that at the critical point, a van der Waals gas occupies only 37.5% of the volume that an ideal gas would occupy under identical conditions, matching option (A).

**Final Answer:** The compressibility factor of this gas explicitly at its critical point is 0.375.

**Answer: (A)**

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Q8.

### Solution

#### Concept:

The spontaneity of a chemical process under conditions of constant temperature and pressure is dictated by the change in Gibbs free energy ( $\Delta G$ ), as defined by the fundamental thermodynamic relationship:  $\Delta G = \Delta H - T\Delta S$ . For a reaction to be spontaneous in the forward direction,  $\Delta G$  must be strictly negative ( $\Delta G < 0$ ). When both enthalpy ( $\Delta H$ ) and entropy ( $\Delta S$ ) are negative, the process is exothermic but leads to an increase in order. The favorable enthalpy term drives the reaction at low temperatures, while the unfavorable entropy term makes it non-spontaneous at high temperatures. The threshold temperature where the behavior flips occurs precisely when  $\Delta G = 0$ .

#### Solution:

- (a) Identify the given thermodynamic values and ensure unit consistency:

$$\Delta H = -40.0 \text{ kJ mol}^{-1} = -40000 \text{ J mol}^{-1}$$

$$\Delta S = -100.0 \text{ J K}^{-1}\text{mol}^{-1}$$

- (b) Set up the equilibrium condition where the reaction changes from spontaneous to non-spontaneous ( $\Delta G = 0$ ):

$$\Delta H - T\Delta S = 0 \implies T = \frac{\Delta H}{\Delta S}$$

- (c) Calculate this transition temperature ( $T$ ):

$$T = \frac{-40000 \text{ J mol}^{-1}}{-100.0 \text{ J K}^{-1}\text{mol}^{-1}} = 400 \text{ K}$$

- (d) Analyze the inequality for temperatures above this value: If  $T > 400 \text{ K}$ , the magnitude of the  $-T\Delta S$  term (which becomes positive since  $\Delta S$  is negative) will outgrow the negative enthalpy term. For example, at  $T = 500 \text{ K}$ :

$$\Delta G = -40000 - (500 \times -100) = -40000 + 50000 = +10000 \text{ J mol}^{-1} > 0$$

Since  $\Delta G > 0$ , the reaction becomes non-spontaneous above 400 K, matching option (B).

**Final Answer:** The reaction will become non-spontaneous in the forward direction above 400 K.

**Answer: (B)**

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Q9.

### Solution

#### Concept:

The solubility of a sparingly soluble salt like calcium fluoride ( $\text{CaF}_2$ ) is severely suppressed in the presence of a strong electrolyte containing a common ion, such as sodium fluoride ( $\text{NaF}$ ). This phenomenon is known as the common-ion effect and can be quantitatively explained using Le Chatelier's principle and the solubility product constant ( $K_{\text{sp}}$ ). The equilibrium reaction for the dissolution of the salt is  $\text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2\text{F}^-(aq)$ . The solubility expression is written as  $K_{\text{sp}} = [\text{Ca}^{2+}][\text{F}^-]^2$ .

#### Solution:

- (a) Write down the concentrations of the ions at equilibrium in the presence of 0.05 M  $\text{NaF}$ . Let  $S$  be the molar solubility of  $\text{CaF}_2$  in this solution. Sodium fluoride dissociates completely:  $\text{NaF}(aq) \rightarrow \text{Na}^+(aq) + \text{F}^-(aq)$ . Therefore, it contributes 0.05 M of  $\text{F}^-$  ions. From the dissolution of  $\text{CaF}_2$ , we obtain:

$$[\text{Ca}^{2+}] = S$$

$$[\text{F}^-] = 2S + 0.05$$

- (b) Since  $K_{\text{sp}}$  is extremely small ( $4.0 \times 10^{-11}$ ), the value of  $S$  will be tiny, meaning  $2S \ll 0.05$ . Therefore, we can approximate the fluoride ion concentration as:

$$[\text{F}^-] \approx 0.05 \text{ M}$$

- (c) Substitute these concentrations into the solubility product expression:

$$K_{\text{sp}} = [\text{Ca}^{2+}][\text{F}^-]^2 \implies 4.0 \times 10^{-11} = S \cdot (0.05)^2$$

- (d) Solve for the molar solubility  $S$ :

$$4.0 \times 10^{-11} = S \cdot (2.5 \times 10^{-3}) \implies S = \frac{4.0 \times 10^{-11}}{2.5 \times 10^{-3}} = 1.6 \times 10^{-8} \text{ M}$$

This result matches option (A).

**Final Answer:** Its molar solubility in a 0.05 M  $\text{NaF}$  solution is  $1.6 \times 10^{-8}$  M.

**Answer:** (A)

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## Q10.

## Solution

**Concept:**

Chemical kinetics explores how the rate of a reaction depends on the concentrations of reactants. For a second-order reaction involving a single reactant,  $-\frac{d[A]}{dt} = k[A]^2$ , where  $k$  is the second-order rate constant and  $[A]$  is the instantaneous concentration of the reactant at time  $t$ . To establish a linear graphical relationship that helps determine the rate constant, this differential rate law must be integrated from the initial conditions at  $t = 0$  where  $[A] = [A]_0$  to any arbitrary time  $t$  where  $[A] = [A]_t$ .

**Solution:**

- (a) Separate the variables in the differential equation to prepare for integration:

$$-\frac{d[A]}{[A]^2} = k dt$$

- (b) Perform the definite integration on both sides within the specified limits:

$$\int_{[A]_0}^{[A]_t} -\frac{1}{[A]^2} d[A] = \int_0^t k dt$$

$$\left[ \frac{1}{[A]} \right]_{[A]_0}^{[A]_t} = k[t]_0^t \implies \frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

- (c) Rearrange the integrated rate law into the standard slope-intercept slope equation of a straight line ( $y = mx + c$ ):

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

- (d) Identify the variables corresponding to each axis: Here, the independent variable on the x-axis is time ( $t$ ). The dependent variable assigned to the y-axis must be  $\frac{1}{[A]_t}$ . The slope of this line represents the positive rate constant ( $k$ ), and the y-intercept is  $\frac{1}{[A]_0}$ . This matches option (B).

**Final Answer:** A straight line plot is obtained by plotting  $\frac{1}{[A]_t}$  on the y-axis.

**Answer: (B)**

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Q11.

**Solution****Concept:**

In a first-order chemical reaction, the rate of the reaction is directly proportional to the instantaneous concentration of a single reactant. The integrated rate law for such a process is expressed as  $k = \frac{2.303}{t} \log \left( \frac{[A]_0}{[A]_t} \right)$ , where  $k$  is the first-order rate constant,  $[A]_0$  is the initial concentration of the reactant at  $t = 0$ , and  $[A]_t$  represents the remaining concentration of the reactant at any specified time  $t$ . The half-life ( $t_{1/2}$ ) is defined as the time required for the reactant concentration to decrease to exactly half of its initial value, which is given by the relation  $t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$ .

**Solution:**

- (a) Use the expression for the half-life to relate the rate constant  $k$  with  $t_{1/2}$ :

$$k = \frac{0.693}{t_{1/2}}$$

- (b) Determine the remaining concentration of the reactant at 99.9% completion ( $t_{99.9\%}$ ): If the reaction has reached 99.9% completion, the amount of reactant consumed is 99.9% of  $[A]_0$ . Therefore, the remaining concentration  $[A]_t$  is:

$$[A]_t = [A]_0 - 0.999[A]_0 = 0.001[A]_0 = 10^{-3}[A]_0$$

- (c) Substitute this value into the integrated rate law to find an expression for  $t_{99.9\%}$ :

$$t_{99.9\%} = \frac{2.303}{k} \log \left( \frac{[A]_0}{10^{-3}[A]_0} \right) = \frac{2.303}{k} \log (10^3)$$

Since  $\log (10^3) = 3$ , the equation simplifies to:

$$t_{99.9\%} = \frac{2.303 \times 3}{k} = \frac{6.909}{k}$$

- (d) Find the ratio of  $t_{99.9\%}$  to  $t_{1/2}$  by substituting the value of  $k$ :

$$\frac{t_{99.9\%}}{t_{1/2}} = \frac{\frac{6.909}{k}}{\frac{0.693}{k}} = \frac{6.909}{0.693} \approx 9.97 \approx 10$$

Therefore, the time required for 99.9% completion of a first-order chemical reaction is approximately 10 times its half-life, which matches option (C).

**Final Answer:** The time taken for 99.9% completion is approximately 10 times its half-life.

**Answer: (C)**

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Q12.



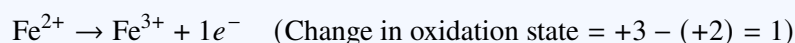
## Solution

### Concept:

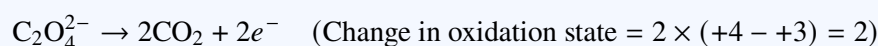
This problem involves a redox titration where ferrous oxalate ( $\text{FeC}_2\text{O}_4$ ) is completely oxidized by potassium permanganate ( $\text{KMnO}_4$ ) in an acidic medium. To determine the number of moles of  $\text{KMnO}_4$  consumed, we apply the principle of equivalence, which states that the total number of equivalents of the reducing agent must equal the total number of equivalents of the oxidizing agent at the end point. The number of equivalents is calculated as the product of the number of moles and the n-factor (valence factor), which represents the total number of electrons gained or lost per formula unit of the substance during the redox reaction.

### Solution:

- (a) Determine the n-factor of the reducing agent, ferrous oxalate ( $\text{FeC}_2\text{O}_4$ ): Ferrous oxalate contains two components that can undergo oxidation: the ferrous ion ( $\text{Fe}^{2+}$ ) and the oxalate ion ( $\text{C}_2\text{O}_4^{2-}$ ). In an acidic oxidizing medium,  $\text{Fe}^{2+}$  is oxidized to ferric ion ( $\text{Fe}^{3+}$ ):

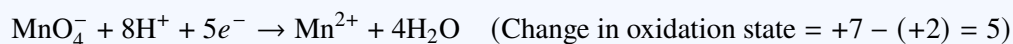


The oxalate ion ( $\text{C}_2\text{O}_4^{2-}$ ) where carbon is in a +3 state is oxidized to carbon dioxide ( $\text{CO}_2$ ) where carbon is in a +4 state:



The total number of electrons lost by 1 mole of  $\text{FeC}_2\text{O}_4$  is  $1 + 2 = 3$ . Thus, the n-factor of  $\text{FeC}_2\text{O}_4$  is 3.

- (b) Determine the n-factor of the oxidizing agent, potassium permanganate ( $\text{KMnO}_4$ ): In an acidic medium, the permanganate ion ( $\text{MnO}_4^-$ ) where manganese is in a +7 state is reduced to manganese(II) ion ( $\text{Mn}^{2+}$ ):



Thus, the n-factor of  $\text{KMnO}_4$  in an acidic medium is 5.

- (c) Apply the law of chemical equivalence:

$$\text{Equivalents of } \text{KMnO}_4 = \text{Equivalents of } \text{FeC}_2\text{O}_4$$

$$\text{Moles of } \text{KMnO}_4 \times \text{n-factor of } \text{KMnO}_4 = \text{Moles of } \text{FeC}_2\text{O}_4 \times \text{n-factor of } \text{FeC}_2\text{O}_4$$

$$\text{Moles of } \text{KMnO}_4 \times 5 = 1 \times 3$$

$$\text{Moles of } \text{KMnO}_4 = \frac{3}{5} = 0.6 \text{ moles}$$

This corresponds directly to option (C).

**Final Answer:** The total number of moles of  $\text{KMnO}_4$  consumed is 0.6 moles.

**Answer: (C)**

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Q13.

**Solution****Concept:**

The reducing power of an element is a measure of its ability to act as a reducing agent by donating electrons to another species, thereby undergoing oxidation itself. In electrochemistry, this property is quantitatively evaluated using standard reduction potentials ( $E^\circ$ ). A lower or more negative standard reduction potential indicates that the species has a lower tendency to be reduced and a conversely higher tendency to lose electrons and become oxidized. Therefore, the lower the standard reduction potential of a metallic element, the stronger its reducing power in aqueous solutions.

**Solution:**

- (a) Gather and compare the given standard reduction potential ( $E^\circ$ ) values for the three metallic elements:

$$E_A^\circ = +0.80 \text{ V}$$

$$E_B^\circ = -2.37 \text{ V}$$

$$E_C^\circ = -0.44 \text{ V}$$

- (b) Arrange the elements in decreasing order of their standard reduction potentials (from most positive to most negative):

$$+0.80 \text{ V (A)} > -0.44 \text{ V (C)} > -2.37 \text{ V (B)}$$

- (c) Correlate the reduction potentials with the reducing power: Since reducing power is inversely related to the standard reduction potential, the element with the most positive value (A) will be the weakest reducing agent, while the element with the most negative value (B) will be the strongest reducing agent. Thus, the correct increasing order of reducing power is:

$$A < C < B$$

This perfectly matches option (C).

**Final Answer:** The correct increasing order of their reducing power is  $A < C < B$ .

**Answer: (C)**

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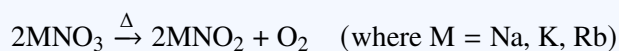
Q14.

**Solution****Concept:**

The thermal stability and decomposition behavior of alkali metal nitrates depend heavily on the size and polarizing power of the alkali metal cation. Most alkali metal nitrates ( $\text{NaNO}_3$ ,  $\text{KNO}_3$ ,  $\text{RbNO}_3$ , and  $\text{CsNO}_3$ ) are relatively stable due to the large size of their cations, which have low charge density and low polarizing power. Upon strong heating, these nitrates undergo mild thermal decomposition to yield the corresponding metal nitrites and oxygen gas. However, lithium (Li) exhibits a diagonal relationship with magnesium (Mg) due to its exceptionally small ionic radius and exceptionally high charge density.

**Solution:**

- (a) Examine the decomposition reaction for standard alkali metal nitrates like potassium, sodium, and rubidium nitrates: When  $\text{NaNO}_3$ ,  $\text{KNO}_3$ , or  $\text{RbNO}_3$  are strongly heated, they release oxygen but preserve the nitrogen-oxygen core as a nitrite:



These compounds leave behind a stable alkali metal nitrite.

- (b) Examine the anomalous behavior of lithium nitrate ( $\text{LiNO}_3$ ): Because the  $\text{Li}^+$  cation is extremely small, it has a high polarizing power that strongly distorts the electron cloud of the large nitrate ion ( $\text{NO}_3^-$ ). This severe distortion weakens the bonds within the anion, causing complete breakdown of the nitrate structure at elevated temperatures. Instead of forming a nitrite, it decomposes into a highly stable, transition-like lattice oxide, lithium oxide ( $\text{Li}_2\text{O}$ ), along with nitrogen dioxide and oxygen gases:



The residue left behind is lithium oxide ( $\text{Li}_2\text{O}$ ), which matches option (C).

**Final Answer:** Lithium nitrate ( $\text{LiNO}_3$ ) leaves behind a metal oxide upon strong thermal decomposition.

**Answer: (C)**

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Q15.

**Solution****Concept:**

Orthoboric acid ( $\text{H}_3\text{BO}_3$ ) is a weak, monobasic Lewis acid of boron. In its monomeric gas phase, it features a planar trigonal structure where the central boron atom is  $\text{sp}^2$  hybridized and bonded to three hydroxyl groups. However, when it solidifies into a crystalline form, its physical layout and structural properties are entirely dominated by intermolecular interactions. The hydrogen atoms of the  $-\text{OH}$  groups form strong hydrogen bonds with the oxygen atoms of adjacent orthoboric acid units, organizing the substance into a complex network.

**Solution:**

- Analyze the structural configuration in the solid state: In solid crystalline  $\text{H}_3\text{BO}_3$ , each planar trigonal  $\text{B}(\text{OH})_3$  unit is linked to neighboring units through extensive, highly directional hydrogen bonds. Each oxygen atom acts as both a hydrogen donor and a hydrogen acceptor.
- Describe the resulting arrangement: This continuous hydrogen bonding network spreads out in two dimensions, creating a stable, layered planar sheet-like architecture. The individual layers are held together by relatively weak van der Waals forces, which allows the layers to slide over one another easily, giving solid boric acid a characteristic soapy, slippery touch similar to graphite.
- Evaluate the given choices: Option (A) is incorrect because the units are planar trigonal, not tetrahedral. Option (C) is incorrect because it forms a two-dimensional sheet, not a linear chain. Option (D) is incorrect because orthoboric acid is a monobasic Lewis acid, not a tribasic acid, and it does not have a cage structure. Option (B) accurately portrays the layered two-dimensional hydrogen-bonded network.

**Final Answer:** Orthoboric acid forms a layered two-dimensional network stabilized by extensive hydrogen bonding in its solid crystalline form.

**Answer: (B)**

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Q16.

**Solution****Concept:**

White phosphorus ( $P_4$ ) is a highly reactive allotrope of phosphorus that exists as discrete tetrahedral molecules in both the liquid and gaseous phases, as well as in its crystalline solid form. The structural features of this molecule can be explained by examining the hybridization of the phosphorus atoms. Each phosphorus atom has five valence electrons and uses three of them to form single covalent bonds with the other three phosphorus atoms in the tetrahedron, leaving one lone pair on each atom. This spatial arrangement creates a regular tetrahedral geometry where all the vertices are occupied by phosphorus atoms.

**Solution:**

- (a) Determine the total number of single P-P covalent bonds in a  $P_4$  molecule: A regular tetrahedron has 4 vertices, 4 faces, and 6 edges. Since each edge of the tetrahedron represents a single covalent bond between two phosphorus atoms, we can determine the number of bonds by counting the edges. The edges connect vertex 1-2, 1-3, 1-4, 2-3, 2-4, and 3-4. Therefore, there are exactly 6 single P-P covalent bonds present within a single white phosphorus molecule.
- (b) Determine the precise P-P-P bond angle: In a perfect geometric tetrahedron, the interior angle formed between any two edges meeting at a vertex is exactly  $60^\circ$ . However, the normal bonding angle for an  $sp^3$  hybridized atom with a lone pair is approximately  $107^\circ$  to  $109.5^\circ$ . Because the phosphorus atoms are forced into a rigid  $60^\circ$  bond angle to maintain the tetrahedral shape, the orbital overlap is severely constrained. This deviation creates tremendous angular strain (ring strain) within the molecule, which accounts for the thermodynamic instability and high reactivity of white phosphorus, making it catch fire spontaneously in air. This matches option (A).

**Final Answer:** The precise P-P-P bond angle is  $60^\circ$  and the total number of single P-P covalent bonds is 6.

**Answer: (A)**

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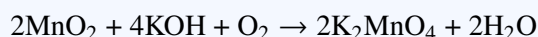
Q17.

**Solution****Concept:**

This problem concerns the industrial and laboratory chemical preparation of potassium permanganate ( $\text{KMnO}_4$ ), which begins with the oxidative fusion of the mineral pyrolusite, consisting primarily of manganese dioxide ( $\text{MnO}_2$ ). When a transition metal oxide like  $\text{MnO}_2$  is fused with an alkali metal hydroxide in the presence of a strong oxidizing agent, the manganese atom undergoes an increase in its oxidation state, transforming from a stable oxide into a water-soluble oxoanion salt.

**Solution:**

- (a) Analyze the chemical reaction taking place during the oxidative fusion process: Manganese dioxide ( $\text{MnO}_2$ ), where manganese is in a +4 oxidation state, is treated with molten potassium hydroxide ( $\text{KOH}$ ) and an oxidizing source like potassium nitrate ( $\text{KNO}_3$ ) or atmospheric oxygen ( $\text{O}_2$ ). The balanced chemical equation for this fusion reaction is:



- (b) Determine the nature of the product formed: The compound synthesized during this stage is potassium manganate ( $\text{K}_2\text{MnO}_4$ ). In the manganate ion ( $\text{MnO}_4^{2-}$ ), the manganese atom has an oxidation state of +6. The dark green color of the solution is a characteristic optical property of the paramagnetic  $\text{MnO}_4^{2-}$  ion, which contains one unpaired electron ( $3d^1$  configuration).
- (c) Differentiate between the choices: Option (A),  $\text{KMnO}_4$ , contains the purple permanganate ion where manganese is in a +7 state, which is produced in a subsequent electrolytic or chemical oxidation step. Option (B),  $\text{K}_2\text{MnO}_4$ , is the correct formula for the green fusion intermediate, matching choice (B).

**Final Answer:** The chemical composition of the dark green solution is  $\text{K}_2\text{MnO}_4$ .

**Answer: (B)**

[Go Back to Question 17](#)



Q18.

### Solution

#### Concept:

The brown ring test is a classic qualitative laboratory procedure used to detect the presence of nitrate ions ( $\text{NO}_3^-$ ) in an aqueous sample. The coordination complex formed at the junction of the two liquid layers is  $[\text{Fe}(\text{H}_2\text{O})_5(\text{NO})]\text{SO}_4$ . To find the oxidation state of the central iron atom and the number of unpaired electrons, we analyze its electronic structure and magnetic properties using Crystal Field Theory (CFT) and the spin-only magnetic moment formula:  $\mu = \sqrt{n(n+2)}$  BM, where  $n$  is the total number of unpaired d-electrons.

#### Solution:

- (a) Use the observed spin-only magnetic moment to solve for the number of unpaired electrons ( $n$ ):

$$\mu = 3.87 \text{ BM} \implies \sqrt{n(n+2)} = 3.87$$

Squaring both sides gives:

$$n(n+2) = (3.87)^2 \approx 15 \implies n^2 + 2n - 15 = 0 \implies (n+5)(n-3) = 0$$

Since  $n$  must be positive,  $n = 3$ . The complex contains exactly 3 unpaired electrons.

- (b) Determine the electronic configuration and oxidation state of iron: In this specific complex, the nitric oxide molecule acts as a positive charge donor ligand ( $\text{NO}^+$ ), transfers an electron to the iron center, and binds as a strong-field ligand. This means the overall complex charge balance is:

$$\text{Oxidation state of Fe} + 5(0) + 1(+1) = +2 \implies \text{Oxidation state of Fe} = +1$$

Iron(+1) has an atomic number of 26, giving it a  $3d^7$  configuration. Water ( $\text{H}_2\text{O}$ ) is a weak-field ligand that forms a high-spin octahedral complex. In an octahedral crystal field, the seven d-electrons fill the orbitals as  $t_{2g}^5 e_g^2$ , which yields exactly 3 unpaired electrons, perfectly matching the magnetic data. This confirms option (A).

**Final Answer:** The oxidation state of iron is +1 and the number of unpaired electrons is 3.

**Answer: (A)**

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Q19.

**Solution****Concept:**

Air pollutants are broadly categorized into two major classes based on their origin: primary pollutants and secondary pollutants. Primary pollutants, such as carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), and nitric oxide (NO), are emitted directly into the atmosphere from identifiable sources like automotive exhaust or industrial facilities. Secondary pollutants are not emitted directly; instead, they form in the atmosphere through chemical or photochemical reactions between primary pollutants and normal atmospheric gases. Photochemical smog is a specific type of air pollution that develops when solar ultraviolet radiation interacts with hydrocarbons and nitrogen oxides.

**Solution:**

- Identify the components involved in the formation of photochemical smog: Automobile engines release primary pollutants like nitric oxide (NO) and unburned volatile hydrocarbons into the air. In the atmosphere, NO is oxidized to nitrogen dioxide (NO<sub>2</sub>), which absorbs sunlight and splits into nitric oxide and highly reactive nascent oxygen atoms (O).
- Trace the secondary reactions that yield lacrimatory agents: The free oxygen atoms react with molecular oxygen to generate ozone (O<sub>3</sub>). Ozone and oxygen radicals then attack the unburned hydrocarbons to produce various oxidized secondary intermediates. Among these products, the reaction between peroxyacyl radicals and nitrogen dioxide synthesizes peroxyacetyl nitrate (CH<sub>3</sub>COONO<sub>2</sub>, abbreviated as PAN).
- Evaluate the physiological effects: While ozone causes respiratory issues, PAN is highly toxic to eyes and acts as a powerful lacrimatory agent, inducing intense eye irritation and tearing at very low concentrations. This aligns with option (C).

**Final Answer:** The primary secondary pollutant responsible for these effects is peroxyacetyl nitrate (PAN).

**Answer: (C)**

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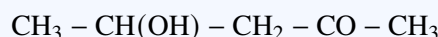
Q20.

**Solution****Concept:**

To determine the correct systematic IUPAC name of an organic compound, we follow a set of definitive rules established by the International Union of Pure and Applied Chemistry. First, we identify the principal functional groups present in the molecule to establish the hierarchy of priority. When a molecule contains more than one functional group, the group with the highest priority is designated as the principal functional group, which defines the suffix of the parent chain name. All other functional groups are treated as substituents and are cited as prefixes in alphabetical order along with their numerical locants.

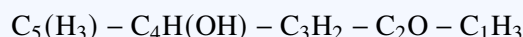
**Solution:**

- (a) Identify the functional groups in the given molecule:



The molecule contains a secondary alcohol group ( $-\text{OH}$ ) on the second carbon from the left and a ketone carbonyl group ( $-\text{CO}-$ ) on the second carbon from the right.

- (b) Apply the priority rules: According to IUPAC nomenclature priority guidelines, a ketone group has a higher priority than a hydroxyl group (Ketone > Alcohol). Therefore, the ketone defines the principal suffix as "-one", and the hydroxyl group will be designated as a prefix using the term "hydroxy".
- (c) Number the longest continuous carbon chain containing both groups: The parent chain contains 5 carbon atoms, so the root word is "pentan". We number the chain from right to left to give the principal functional group (ketone) the lowest possible locant:



This numbering places the ketone at position 2 and the hydroxy substituent at position 4. Combining these terms gives "4-hydroxypentan-2-one", matching option (B).

**Final Answer:** The correct IUPAC name of the organic compound is 4-hydroxypentan-2-one.

**Answer: (B)**

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Q21.

**Solution****Concept:**

The thermodynamic stability of a carbocation is determined by how effectively its positive charge is dispersed across the molecular structure. This electron delocalization primarily occurs via two major electronic pathways: resonance effects and hyperconjugation. Resonance delocalization involves the overlap of the empty p-orbital of the carbocation with adjacent pi-electron systems, such as a benzene ring or a double bond, which allows the positive charge to shift across multiple atoms. Hyperconjugation involves the stabilizing overlap of adjacent sigma C-H bonds with the empty p-orbital, and its strength depends on the total number of alpha-hydrogen atoms.

**Solution:**

- (a) Analyze the structural layout of each carbocation: Option (A) represents the tert-butyl carbocation,  $(\text{CH}_3)_3\text{C}^+$ . It is a tertiary alkyl carbocation stabilized by 9 alpha-hydrogens via hyperconjugation, but it completely lacks resonance stabilization. Option (B) is the benzyl carbocation,  $\text{C}_6\text{H}_5 - \text{CH}_2^+$ , which is stabilized by resonance delocalization through the pi-cloud of a single aromatic benzene ring. Option (D) is the allyl carbocation,  $\text{CH}_2 = \text{CH} - \text{CH}_2^+$ , which is stabilized by resonance with a single double bond.
- (b) Analyze Option (C), the triphenylmethyl (trityl) carbocation,  $(\text{C}_6\text{H}_5)_3\text{C}^+$ : In the trityl carbocation, the positive charge resides on a central carbon atom that is directly bonded to three separate phenyl rings. The empty p-orbital of this central carbon is perfectly aligned to interact with the extensive pi-electron systems of all three aromatic rings simultaneously. This allows the positive charge to be distributed across several ortho and para positions throughout the entire molecular framework, producing a large number of highly stable resonance contributors. This extensive delocalization makes the trityl carbocation remarkably stable, allowing it to exist as a stable salt in solution. This corresponds to option (C).

**Final Answer:** The carbocation that exhibits the highest thermodynamic stability is  $(\text{C}_6\text{H}_5)_3\text{C}^+$ .

**Answer: (C)**

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Q22.

**Solution****Concept:**

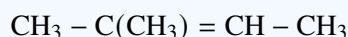
Ozonolysis is an important organic reaction that involves the oxidative cleavage of carbon-carbon double bonds in alkenes using ozone ( $O_3$ ). When followed by a reductive workup using zinc dust and water ( $Zn/H_2O$ ), the reaction breaks both the sigma and pi components of the double bond and replaces them with carbon-oxygen double bonds (carbonyl groups), producing aldehydes or ketones. This reaction is a classic diagnostic tool used to determine the exact position of a double bond in an unknown alkene. To reconstruct the identity of the original alkene, we align the carbonyl groups of the two products face-to-face, remove the oxygen atoms, and join the remaining carbon fragments with a double bond.

**Solution:**

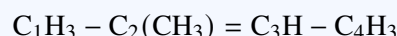
- (a) Identify and write out the chemical structures of the given ozonolysis products: The first product is propanone (acetone):  $CH_3 - CO - CH_3$ . The second product is ethanal (acetaldehyde):  $CH_3 - CHO$  or  $CH_3 - CH = O$ .
- (b) Align the two carbonyl molecules facing each other to visualize the reconstruction:



- (c) Connect the two carbonyl carbons with a carbon-carbon double bond while eliminating the oxygens:



- (d) Determine the systematic IUPAC name of the reconstructed alkene X: The longest continuous carbon chain containing the double bond has 4 carbon atoms, making the parent alkene "butene". Number the parent chain from left to right to give the double bond the lowest possible position number:



This numbering places the double bond at carbon-2 and a methyl substituent at carbon-2. Combining these designations gives the systematic name 2-methylbut-2-ene, which corresponds to option (A).

**Final Answer:** The systematic IUPAC name of alkene X is 2-methylbut-2-ene.

**Answer: (A)**

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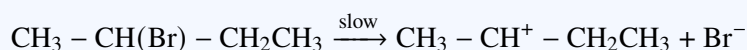
Q23.

**Solution****Concept:**

Nucleophilic substitution reactions can proceed via two main pathways:  $S_N1$  (substitution nucleophilic unimolecular) or  $S_N2$  (substitution nucleophilic bimolecular). The  $S_N1$  pathway is a two-step mechanism that begins with the slow, rate-determining heterolytic cleavage of the carbon-leaving group bond. This step results in the departure of the leaving group and the formation of a planar,  $sp^2$ -hybridized carbocation intermediate. Because this intermediate is completely flat, an incoming nucleophile can attack the vacant p-orbital with equal probability from either the front side or the back side.

**Solution:**

- (a) Trace the mechanism for the reaction of an optical isomer of 2-bromobutane via the  $S_N1$  pathway: The starting material, 2-bromobutane ( $CH_3 - CHBr - CH_2 - CH_3$ ), contains a chiral carbon center. In the first step, the bromide ion leaves, generating a planar sec-butyl carbocation intermediate:



- (b) Analyze the nucleophilic attack step: The hydroxide nucleophile ( $OH^-$ ) can attack the flat carbocation from the front face (leading to retention of configuration) or from the back face (leading to inversion of configuration). If the carbocation were completely free and long-lived, this would produce an exact 50:50 mixture of enantiomers, resulting in complete racemization.
- (c) Account for real-world deviations: In practice, the leaving halide ion often remains loosely associated with the newly formed carbocation as an asymmetric ion pair for a brief moment. This departing anion sterically shields the front face of the carbocation, making a back-side attack slightly more favorable. As a result, the reaction typically shows predominant racemization accompanied by a small excess of configuration inversion, which matches option (C).

**Final Answer:** The configuration of the resulting product shows predominant racemization with slight inversion.

**Answer: (C)**

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Q24.



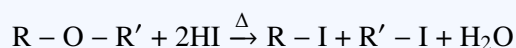
## Solution

### Concept:

When organic dialkyl ethers ( $R - O - R'$ ) are treated with excess hot, concentrated hydroiodic acid (HI), both of the carbon-oxygen bonds undergo nucleophilic cleavage. The reaction begins with the protonation of the ether oxygen atom to create a good leaving group (an oxonium ion). This intermediate is then attacked by iodide ions ( $I^-$ ) via  $S_N1$  or  $S_N2$  pathways, breaking the first ether linkage to form an alcohol and an alkyl iodide. Under the continuing hot, acidic conditions, the alcohol product is rapidly protonated and undergoes a second substitution reaction with another equivalent of iodide, converting it into a second alkyl iodide.

### Solution:

- (a) Write the general reaction scheme for ether cleavage with excess HI:



If the groups R and R' are different (an unsymmetrical ether), the reaction produces a mixture of two distinct alkyl iodides. For a single alkyl iodide to form as the sole organic product, the ether must be completely symmetrical ( $R = R'$ ).

- (b) Evaluate the given ether choices based on symmetry: Option (A): Anisole ( $C_6H_5OCH_3$ ) is an unsymmetrical aryl alkyl ether. Cleavage produces iodomethane ( $CH_3I$ ) and phenol ( $C_6H_5OH$ ). Phenol does not undergo further substitution because the  $sp^2$  carbon-oxygen bond is remarkably strong. Option (C): Methyl ethyl ether ( $CH_3OCH_2CH_3$ ) is unsymmetrical and yields a mixture of iodomethane and iodoethane. Option (D): Tert-butyl methyl ether is unsymmetrical and yields a mixture of tert-butyl iodide and iodomethane. Option (B): Diethyl ether ( $CH_3CH_2OCH_2CH_3$ ) is fully symmetrical, where  $R = R' = \text{ethyl}$ . Cleavage of both sides produces two moles of iodoethane ( $CH_3CH_2I$ ) as the single organic product, matching option (B).

**Final Answer:** The structural layout that matches compound Y is diethyl ether.

**Answer: (B)**

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Q25.

**Solution****Concept:**

The Cannizzaro reaction is a redox disproportionation reaction that occurs when aldehydes are treated with a concentrated strong base (50% aqueous NaOH or KOH). For an aldehyde to undergo this reaction, it must completely lack alpha-hydrogens (hydrogen atoms bound to the carbon directly adjacent to the carbonyl carbon). In this mechanism, one molecule of the aldehyde acts as a hydride donor and is oxidized to a carboxylic acid salt, while a second molecule accepts the hydride ion and is reduced to a primary alcohol. If an aldehyde possesses any alpha-hydrogens, the strong base will instead deprotonate the acidic alpha-carbon, triggering rapid aldol condensation pathways.

**Solution:**

- (a) Examine the structural layouts of the given aldehydes to check for alpha-hydrogens: Option (A): Formaldehyde (HCHO) consists of a carbonyl group bound only to hydrogens. It has no alpha-carbon, so it has zero alpha-hydrogens and readily undergoes the Cannizzaro reaction. Option (B): Benzaldehyde (C<sub>6</sub>H<sub>5</sub>CHO) has its carbonyl group attached to a benzene ring carbon that forms three single bonds and one double bond, leaving it with zero alpha-hydrogens. It undergoes the Cannizzaro reaction. Option (D): Trimethylacetaldehyde [(CH<sub>3</sub>)<sub>3</sub>CCHO] features a quaternary alpha-carbon bonded to three methyl groups, meaning it has zero alpha-hydrogens. It also undergoes the Cannizzaro reaction.
- (b) Analyze Option (C), acetaldehyde (CH<sub>3</sub>CHO): Acetaldehyde features a methyl group directly bound to the carbonyl group. The alpha-carbon has three alpha-hydrogen atoms. When treated with a concentrated base, the base rapidly abstracts one of these acidic alpha-hydrogens to form a nucleophilic enolate ion. This ion then attacks another acetaldehyde molecule, leading to aldol condensation rather than the Cannizzaro reaction. This aligns with option (C).

**Final Answer:** Acetaldehyde will not undergo a self-condensation Cannizzaro reaction.

**Answer: (C)**

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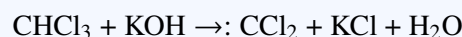
Q26.

**Solution****Concept:**

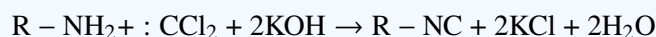
The chemical process described in this question is the Hoffmann carbylamine reaction, which serves as an important diagnostic laboratory test to identify primary amines. This reaction is specific to aliphatic and aromatic primary amines and does not give positive results with secondary or tertiary amines. When a primary amine is heated with chloroform ( $\text{CHCl}_3$ ) and an ethanolic solution of potassium hydroxide (KOH), it undergoes an alpha-elimination driven condensation sequence to yield an exceptionally foul-smelling functional group compound.

**Solution:**

- (a) Trace the mechanistic pathway of the carbylamine transformation: In the first stage, the strong base ( $\text{OH}^-$ ) abstracts an acidic proton from chloroform ( $\text{CHCl}_3$ ), yielding a trichloromethyl carbanion intermediate ( $\text{CCl}_3^-$ ). This carbanion rapidly eliminates a chloride ion ( $\text{Cl}^-$ ) to generate dichlorocarbene ( $:\text{CCl}_2$ ), which acts as a highly reactive, electrophilic intermediate.



- (b) Describe the subsequent nucleophilic attack and elimination steps: The unshared lone pair on the nitrogen atom of the primary amine ( $\text{R}-\text{NH}_2$ ) attacks the empty orbital of the dichlorocarbene intermediate. This nucleophilic addition is followed by successive base-mediated deprotonations and the elimination of two more chloride ions, culminating in the creation of a triple bond between the carbon and nitrogen atoms:



- (c) Identify the functional group responsible for the intense odor: The resulting substance is an alkyl or aryl isocyanide ( $\text{R}-\text{NC}$ ), also called a carbylamine. The structure possesses a coordinate covalent bond pointing from the nitrogen to the carbon atom ( $-\text{N}^+ \equiv \text{C}^-$ ). Its characteristic repulsive smell enables quick qualitative confirmation of a primary amine, matching option (A).

**Final Answer:** The functional group present in this foul-smelling substance is Isocyanide ( $-\text{NC}$ ).

**Answer: (A)**

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Q27.

**Solution****Concept:**

Disaccharides are carbohydrates formed by the condensation of two monosaccharide units with the elimination of a water molecule. The linkage connecting the two units is known as a glycosidic linkage, which is an oxo-bridged ether bond formed between the hydroxyl group of the anomeric carbon of one sugar and a hydroxyl group of another sugar. A reducing sugar requires a free anomeric carbon (hemiacetal or hemiketal group) that can open into a straight-chain form with a reactive aldehyde or ketone group. In a non-reducing disaccharide like sucrose, both anomeric carbons are locked inside the glycosidic linkage.

**Solution:**

- (a) Identify the monosaccharide components of sucrose: Sucrose is a non-reducing disaccharide composed of one D-glucose unit and one D-fructose unit.
- (b) Analyze the nature of the glycosidic bond in sucrose: In D-glucose, the anomeric carbon is located at position 1 ( $C_1$ ), which initially exists in the  $\alpha$  stereochemical configuration. In D-fructose, the anomeric carbon is located at position 2 ( $C_2$ ), which exists in the  $\beta$  stereochemical configuration. To form sucrose, the hemiacetal hydroxyl group at  $C_1$  of  $\alpha$ -D-glucopyranose undergoes condensation directly with the hemiketal hydroxyl group at  $C_2$  of  $\beta$ -D-fructofuranose.
- (c) Correlate the structure with the options: Because both reactive anomeric carbons ( $C_1$  of glucose and  $C_2$  of fructose) are involved in forming the glycosidic bridge, neither ring can open into an open-chain form containing a free carbonyl group. Consequently, sucrose does not reduce Tollens or Fehling reagents, making it a non-reducing sugar. This specific structural linkage is written as  $C_1 - \alpha - D\text{-glucopyranoside} - C_2 - \beta - D\text{-fructofuranoside}$ , which matches option (B).

**Final Answer:** The structural linkage connecting the monosaccharide units within sucrose is  $C_1 - \alpha - D\text{-glucopyranoside} - C_2 - \beta - D\text{-fructofuranoside}$ .

**Answer: (B)**

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Q28.

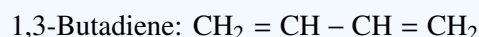
### Solution

#### Concept:

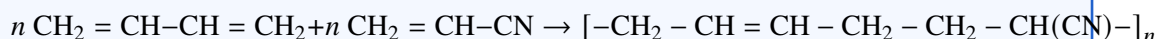
Polymers are macromolecular networks built by linking together small repeating molecular units called monomers. Based on their synthesis pathway, they are classified into addition polymers and condensation polymers. Addition polymerization occurs when unsaturated monomer molecules react together without releasing any secondary side products. Synthetic elastomers, often called synthetic rubbers, are addition copolymers engineered to have exceptional elastic properties under mechanical stress. A prime example is Buna-N, where "Buna" indicates butadiene and sodium (Natrium) catalyst, and "N" signifies the specific nitrile component.

#### Solution:

- (a) Examine the monomer composition of Buna-N: Buna-N is a synthetic copolymer manufactured through the radical-initiated addition copolymerization of 1,3-butadiene and acrylonitrile. The reactants are typically mixed in a controlled stoichiometric ratio of approximately 3 parts 1,3-butadiene to 1 part acrylonitrile.
- (b) Trace the polymerization reaction structure: The chemical formulas for the two monomers are:



When mixed with an initiator, the pi bonds break and rearrange to link the units together into a long chain:



- (c) Evaluate the remaining choices to rule them out: Option (A) defines Buna-S rubber. Option (B) contains chloroprene, which forms neoprene rubber. Option (D) describes the synthesis of Nylon-6,6. Thus, option (C) is the correct monomer combination.

**Final Answer:** The synthetic elastomer Buna-N is a copolymer produced from 1,3-butadiene and acrylonitrile.

**Answer: (C)**

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Q29.

**Solution****Concept:**

The solubility of an ionic salt in water depends on a delicate thermodynamic competition between two major opposing energetic factors: lattice energy and hydration energy. Lattice energy ( $\Delta H_{\text{lattice}}$ ) is the energy required to completely break apart one mole of an ionic solid into its gaseous constituent ions. Hydration energy ( $\Delta H_{\text{hyd}}$ ) is the amount of energy released when these isolated gaseous ions interact with polar water molecules. For an ionic compound to dissolve spontaneously, the hydration energy must be large enough to overcome the stable lattice energy of the crystal grid.

**Solution:**

- (a) Analyze the trends in ionic dimensions down Group 2: As we move down the alkaline earth metal group from  $\text{Mg}^{2+}$  to  $\text{Ba}^{2+}$ , the ionic radius of the metal cation increases substantially ( $\text{Mg}^{2+} < \text{Ca}^{2+} < \text{Sr}^{2+} < \text{Ba}^{2+}$ ). The sulfate anion ( $\text{SO}_4^{2-}$ ), however, is a large, bulky polyatomic ion whose size is much greater than that of the cations.
- (b) Apply the principles of electrostatic forces to lattice energy: Because the sulfate ion is quite large, the total interionic distance in the crystal lattice is dominated by the size of the anion. Consequently, the increase in the size of the cation down the group causes only a small fractional increase in the total bond distance, leading to a slow and minor decrease in lattice energy down the group.
- (c) Apply the principles of electrostatic forces to hydration energy: Hydration energy is inversely proportional to the radius of the ion ( $\Delta H_{\text{hyd}} \propto \frac{1}{r}$ ). Because the cations are relatively small compared to sulfate, the increase in the radius of the metal cation from  $\text{Mg}^{2+}$  to  $\text{Ba}^{2+}$  causes a rapid decrease in charge density. This leads to a rapid decrease in hydration energy down the group. Because hydration energy drops much faster than lattice energy, dissolution becomes less energetically favorable, decreasing solubility down the group. This matches option (B).

**Final Answer:** The decrease in solubility is fundamentally due to a rapid decrease in hydration energy down the group.

**Answer: (B)**

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**Q30.**



## Solution

### Concept:

The kinetic molecular theory of gases states that the gas molecules are in constant, random motion and collide elastically with each other and the walls of their container. The distribution of molecular velocities is described by the Maxwell-Boltzmann distribution law. The root-mean-square velocity ( $v_{\text{rms}}$ ) is a statistical measure of particle speed defined as the square root of the average of the squares of the individual molecular speeds. It is derived from kinetic principles and is expressed as  $v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$ , where  $R$  is the universal gas constant,  $T$  is the absolute temperature in Kelvin, and  $M$  is the molar mass of the gas species in kilograms per mole.

### Solution:

- (a) Set up the expression for the root-mean-square velocity of hydrogen gas ( $\text{H}_2$ ): The molar mass of  $\text{H}_2$  is  $2 \text{ g mol}^{-1}$  and the temperature is given as  $50 \text{ K}$ .

$$v_{\text{rms, H}_2} = \sqrt{\frac{3 \cdot R \cdot 50}{2}}$$

- (b) Set up the expression for the root-mean-square velocity of oxygen gas ( $\text{O}_2$ ): The molar mass of  $\text{O}_2$  is  $32 \text{ g mol}^{-1}$  and the temperature is given as  $800 \text{ K}$ .

$$v_{\text{rms, O}_2} = \sqrt{\frac{3 \cdot R \cdot 800}{32}}$$

- (c) Simplify the fraction inside the square root for the oxygen gas calculation:

$$\frac{800}{32} = \frac{100}{4} = 25$$

So, the oxygen velocity simplifies to:

$$v_{\text{rms, O}_2} = \sqrt{3 \cdot R \cdot 25}$$

- (d) Simplify the fraction inside the square root for the hydrogen gas calculation:

$$\frac{50}{2} = 25$$

So, the hydrogen velocity simplifies to:

$$v_{\text{rms, H}_2} = \sqrt{3 \cdot R \cdot 25}$$

- (e) Compute the ratio of the two velocities:

$$\text{Ratio} = \frac{v_{\text{rms, H}_2}}{v_{\text{rms, O}_2}} = \frac{\sqrt{3 \cdot R \cdot 25}}{\sqrt{3 \cdot R \cdot 25}} = \frac{1}{1} = 1 : 1$$

This shows that the higher temperature of the oxygen sample is exactly balanced by its larger molar mass, resulting in the same root-mean-square velocity as the colder, lighter hydrogen gas, matching option (A).

**Final Answer:** The ratio of the root-mean-square velocities of the two gases is  $1 : 1$ .

**Answer: (A)**



collegedunia



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Q31.



## Solution

### Concept:

This quantitative chemistry problem focuses on the thermal dehydration of a crystalline hydrated metal chloride salt. Crystalline salts frequently lock a precise stoichiometric ratio of water molecules within their solid crystal lattice, known as the water of crystallization. When a hydrated salt sample is heated thoroughly to a constant mass, these volatile water molecules are driven off into the vapor phase, leaving behind a completely dry, anhydrous solid residue. By applying the fundamental law of conservation of mass, the mass loss observed during the heating process corresponds directly to the total mass of water evaporated.

### Solution:

- (a) Calculate the mass of the water of crystallization lost during heating:

$$\text{Mass of hydrated salt (MCl}_x \cdot 2\text{H}_2\text{O)} = 2.44 \text{ g}$$

$$\text{Mass of anhydrous residue (MCl}_x) = 2.08 \text{ g}$$

$$\text{Mass of water lost} = 2.44 \text{ g} - 2.08 \text{ g} = 0.36 \text{ g}$$

- (b) Determine the number of moles of water evaporated: The molar mass of water ( $\text{H}_2\text{O}$ ) is  $2 \times 1 + 16 = 18 \text{ g mol}^{-1}$ .

$$\text{Moles of water} = \frac{0.36 \text{ g}}{18 \text{ g mol}^{-1}} = 0.02 \text{ moles}$$

- (c) Relate the moles of water to the moles of the anhydrous salt based on stoichiometry: From the chemical formula  $\text{MCl}_x \cdot 2\text{H}_2\text{O}$ , we know that 1 mole of the hydrated salt releases exactly 2 moles of water. Therefore, the number of moles of the anhydrous salt ( $\text{MCl}_x$ ) remaining must be exactly half the number of moles of water lost:

$$\text{Moles of MCl}_x = \frac{\text{Moles of water}}{2} = \frac{0.02}{2} = 0.01 \text{ moles}$$

- (d) Calculate the molar mass of the anhydrous salt ( $\text{MCl}_x$ ):

$$\text{Molar mass of MCl}_x = \frac{\text{Mass of residue}}{\text{Moles of residue}} = \frac{2.08 \text{ g}}{0.01 \text{ moles}} = 208 \text{ g mol}^{-1}$$

- (e) Determine the value of the stoichiometric variable  $x$ : The molar mass of the anhydrous salt is equal to the atomic mass of the metal plus  $x$  times the atomic mass of chlorine:

$$\text{Molar mass of MCl}_x = \text{Mass of M} + x \cdot \text{Mass of Cl}$$

$$208 = 137 + x \cdot (35.5) \implies 35.5x = 208 - 137 = 71 \implies x = \frac{71}{35.5} = 2$$

The value of  $x$  is 2, which identifies the salt as barium chloride dihydrate ( $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ ), matching option (B).

**Final Answer:** The value of the stoichiometric variable  $x$  is 2.

**Answer: (B)**

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Q32.

### Solution

#### Concept:

An electrochemical cell operating under non-standard ion concentrations deviates from its standard state potential ( $E^\circ$ ). The precise electromotive force ( $E_{\text{cell}}$ ) of such a chemical system can be determined quantitatively using the Nernst equation. For a general redox reaction, the equation is written as  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{2.303RT}{nF} \log Q$ , where  $n$  represents the total number of moles of electrons transferred during the balanced chemical process, and  $Q$  is the reaction quotient representing the mathematical ratio of the concentrations of product ions to reactant ions.

#### Solution:

- (a) Write out the standard reduction reactions and establish the overall balanced cell reaction:  
 Anode half-cell (Oxidation):  $\text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2e^-$  Cathode half-cell (Reduction):  
 $\text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s)$  Overall redox reaction:  $\text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s)$   
 This confirms that the number of electrons transferred per cycle is  $n = 2$ .

- (b) Calculate the standard cell potential ( $E_{\text{cell}}^\circ$ ) using the given reduction potentials:

$$E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ = E_{\text{Cu}^{2+}/\text{Cu}}^\circ - E_{\text{Zn}^{2+}/\text{Zn}}^\circ$$

$$E_{\text{cell}}^\circ = +0.34 \text{ V} - (-0.76 \text{ V}) = +1.10 \text{ V}$$

- (c) Set up the expression for the reaction quotient ( $Q$ ): Since solid metals have an effective thermodynamic activity of 1, the reaction quotient depends only on the concentrations of the dissolved ions in the solution:

$$Q = \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = \frac{0.1 \text{ M}}{0.01 \text{ M}} = \frac{10^{-1}}{10^{-2}} = 10$$

- (d) Substitute these parameters directly into the Nernst equation:

$$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{n} \log Q$$

$$E_{\text{cell}} = 1.10 - \frac{0.0591}{2} \log(10)$$

Since  $\log(10) = 1$ , the expression simplifies to:

$$E_{\text{cell}} = 1.10 - 0.02955 = 1.07045 \text{ V} \approx 1.070 \text{ V}$$

This calculated electromotive force perfectly corresponds to option (C).

**Final Answer:** The precise electromotive force ( $E_{\text{cell}}$ ) of this chemical system is 1.070 V.

**Answer: (C)**

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Q33.

**Solution****Concept:**

An oxidizing agent, also known as an oxidant, is a chemical species that causes the oxidation of another substance while simultaneously undergoing reduction itself by gaining electrons. In an aqueous electrochemical environment, the relative strength of various oxidizing agents can be determined by evaluating their standard reduction potentials ( $E^\circ$ ). A higher, more positive standard reduction potential value indicates a stronger thermodynamic driving force for that species to accept electrons and be reduced. Therefore, the tripositive metal ion with the most positive reduction potential for the  $M^{3+}/M^{2+}$  couple will act as the strongest oxidizing agent.

**Solution:**

- (a) List and compare the given standard reduction potentials ( $E^\circ$ ) for the trivalent-to-divalent transitions:

$$E^\circ(\text{Cr}^{3+}/\text{Cr}^{2+}) = -0.41 \text{ V}$$

$$E^\circ(\text{Fe}^{3+}/\text{Fe}^{2+}) = +0.77 \text{ V}$$

$$E^\circ(\text{Mn}^{3+}/\text{Mn}^{2+}) = +1.57 \text{ V}$$

$$E^\circ(\text{Co}^{3+}/\text{Co}^{2+}) = +1.97 \text{ V}$$

- (b) Arrange the metal ions in increasing order of their reduction potential values:

$$-0.41 \text{ V} (\text{Cr}^{3+}) < +0.77 \text{ V} (\text{Fe}^{3+}) < +1.57 \text{ V} (\text{Mn}^{3+}) < +1.97 \text{ V} (\text{Co}^{3+})$$

- (c) Correlate the potential values with the oxidizing ability of the ions: The highly positive value of +1.97 V for cobalt means that the  $\text{Co}^{3+}$  ion has an exceptional thermodynamic tendency to gain an electron and convert into the more stable divalent state ( $\text{Co}^{2+}$ ). This high stability is driven by the relaxation of electronic repulsions when shifting out of the highly unstable cobaltic state. Consequently,  $\text{Co}^{3+}$  will act as the strongest oxidizing agent among the choices, easily oxidizing water or other species in solution, which aligns with option (D).

**Final Answer:** The tripositive metal ion that acts as the strongest oxidizing agent is  $\text{Co}^{3+}$ .

**Answer: (D)**

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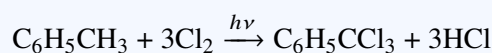
Q34.

**Solution****Concept:**

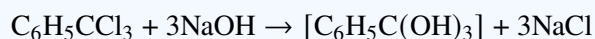
This problem involves a sequence of organic transformations starting with the alkyl-aromatic hydrocarbon toluene ( $C_7H_8$ ). When toluene is treated with an excess of chlorine gas under the influence of intense ultraviolet light or boiling conditions, it undergoes a free-radical side-chain substitution reaction. This light-driven halogenation occurs selectively at the benzylic position, replacing the aliphatic hydrogens sequentially without affecting the aromatic ring. The resulting chlorinated intermediate containing three chlorine atoms on a single carbon atom is then subjected to nucleophilic alkaline hydrolysis followed by acidification.

**Solution:**

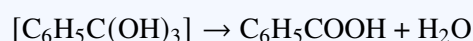
- (a) Trace the free-radical side-chain chlorination stage: Toluene ( $C_6H_5CH_3$ ) reacts with excess chlorine gas ( $Cl_2$ ) under intense UV light. All three benzylic hydrogen atoms are sequentially replaced by chlorine radicals, yielding benzotrichloride as the chlorinated intermediate:



- (b) Trace the alkaline hydrolysis stage: When benzotrichloride ( $C_6H_5CCl_3$ ) is treated with boiling aqueous sodium hydroxide (NaOH), all three chlorine atoms undergo nucleophilic substitution by hydroxyl groups ( $-OH$ ). This yields a highly unstable intermediate containing three hydroxyl groups attached to the same carbon atom:



- (c) Complete the transformation via elimination and acidification: Organic compounds containing multiple hydroxyl groups on a single carbon atom are thermodynamically unstable and immediately undergo spontaneous elimination of a water molecule. The loss of water from this gem-triol intermediate generates a stable carboxyl group, forming benzoic acid:



In the basic solution, this exists as sodium benzoate, which upon final acidification precipitates out as crystalline benzoic acid, matching option (C).

**Final Answer:** The molecular structure of this final organic product is Benzoic acid.

**Answer: (C)**

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Q35.

### Solution

#### Concept:

This problem concerns the chemical phenomenon of salt hydrolysis, which describes how the pH of an aqueous solution is altered by the reaction of dissolved salt ions with water. The sodium salt of a weak monoprotic acid (NaA) dissociates completely in water to yield sodium cations ( $\text{Na}^+$ ) and conjugate base anions ( $\text{A}^-$ ). While the sodium ion remains inert, the conjugate base anion undergoes anionic hydrolysis by accepting a proton from water molecules:  $\text{A}^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HA}(aq) + \text{OH}^-(aq)$ . This equilibrium releases excess hydroxide ions, making the solution basic ( $\text{pH} > 7$ ).

#### Solution:

(a) Identify the given variables and establish the relevant equations: The concentration of the salt solution is  $c = 0.10 \text{ M}$ . The acid dissociation constant of the parent weak acid is  $K_a = 1.0 \times 10^{-5}$ . The ionic product of water at 298 K is  $K_w = 1.0 \times 10^{-14}$ .

(b) Calculate the hydrolysis constant ( $K_h$ ) of the conjugate base anion:

$$K_h = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-5}} = 1.0 \times 10^{-9}$$

(c) Determine the concentration of hydroxide ions ( $[\text{OH}^-]$ ) produced at equilibrium: Since the extent of hydrolysis is typically very small, we can apply the simplified approximation formula:

$$[\text{OH}^-] = \sqrt{K_h \cdot c} = \sqrt{(1.0 \times 10^{-9}) \cdot (0.10)} = \sqrt{1.0 \times 10^{-10}} = 1.0 \times 10^{-5} \text{ M}$$

(d) Calculate the pOH of the solution:

$$\text{pOH} = -\log[\text{OH}^-] = -\log(1.0 \times 10^{-5}) = 5.0$$

(e) Convert the pOH value into the absolute pH scale:

$$\text{pH} = 14.0 - \text{pOH} = 14.0 - 5.0 = 9.0$$

Alternatively, using the direct salt hydrolysis pH formula gives:

$$\text{pH} = 7 + \frac{1}{2}\text{p}K_a + \frac{1}{2}\log c = 7 + \frac{1}{2}(5) + \frac{1}{2}(-1) = 7 + 2.5 - 0.5 = 9.0$$

This result confirms that the solution is basic, matching option (C).

**Final Answer:** The absolute pH of the 0.10 M sodium salt solution is 9.0.

**Answer: (C)**

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Q36.

### Solution

#### Concept:

According to Molecular Orbital Theory (MOT), the magnetic properties of homonuclear diatomic molecules are dictated by the presence or absence of unpaired electrons in their molecular orbitals. For lighter elements (atomic number  $Z \leq 7$ ), the ordering of molecular orbitals follows the sequence:  $\sigma_{1s} < \sigma_{1s}^* < \sigma_{2s} < \sigma_{2s}^* < (\pi_{2p_x} = \pi_{2p_y}) < \sigma_{2p_z} < (\pi_{2p_x}^* = \pi_{2p_y}^*) < \sigma_{2p_z}^*$ . For heavier elements like oxygen ( $Z = 8$ ), the  $\sigma_{2p_z}$  orbital drops below the  $\pi_{2p}$  orbitals. A chemical species is paramagnetic if it possesses one or more unpaired electrons, and diamagnetic if all electrons are completely spin-paired.

#### Solution:

- (a) Analyze  $B_2$  (10 electrons): The configuration follows the lighter element sequence:  $\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \pi_{2p_x}^1 \pi_{2p_y}^1$ . According to Hund's rule, the two highest energy electrons occupy the degenerate  $\pi_{2p}$  orbitals singly with parallel spins. Because it contains two unpaired electrons,  $B_2$  is paramagnetic, making option (A) correct.
- (b) Analyze  $C_2$  (12 electrons): The configuration is  $\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \pi_{2p_x}^2 \pi_{2p_y}^2$ . All twelve electrons are fully paired within the bonding molecular orbitals, making this species diamagnetic. Thus, option (B) is incorrect.
- (c) Analyze  $O_2$  (16 electrons): Using the oxygen sequence, the configuration is  $\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \sigma_{2p_z}^2 \pi_{2p_x}^2 \pi_{2p_y}^2 \pi_{2p_x}^{*1} \pi_{2p_y}^{*1}$ . The two highest energy electrons occupy the degenerate antibonding  $\pi^*$  orbitals singly, imparting a triplet paramagnetic ground state with two unpaired electrons. Thus, option (C) is correct.
- (d) Analyze  $N_2^{2-}$  (16 electrons): The parent nitrogen molecule has 14 electrons. Adding two extra electrons to form the dianion gives a total of 16 electrons. Filling the lighter element orbital ladder gives:  $\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \pi_{2p_x}^2 \pi_{2p_y}^2 \sigma_{2p_z}^2 \pi_{2p_x}^{*1} \pi_{2p_y}^{*1}$ . Similar to oxygen, it retains two unpaired electrons in its degenerate antibonding pi orbitals, meaning it is paramagnetic. Thus, option (D) is correct.

**Final Answer:** A, C, D

**Answer:** (A, C, D)

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Q37.

**Solution****Concept:**

The structural and electronic layout of a coordination complex is explained by Crystal Field Theory (CFT) and Valence Bond Theory (VBT). Oxalate ( $\text{ox} = \text{C}_2\text{O}_4^{2-}$ ) is a bidentate chelating ligand that coordinates to a central metal atom through two distinct oxygen donor atoms. In the presence of a trivalent metal center like  $\text{Co}^{3+}$ , oxalate exerts a strong crystal field splitting energy ( $\Delta_o$ ), which forces the d-electrons of the central metal ion to undergo pairing within the low-energy  $t_{2g}$  orbitals. Optical activity in octahedral coordination complexes occurs when the molecule lacks an improper axis of rotation, rendering its mirror image non-superimposable.

**Solution:**

- (a) Determine the oxidation state and coordination number: Let  $x$  be the oxidation state of cobalt:  $x + 3(-2) = -3 \implies x = +3$ . Cobalt has an atomic number of 27, so a free  $\text{Co}^{3+}$  ion has a  $3d^6$  valence configuration. Since oxalate is bidentate and there are three ligands, the coordination number is  $3 \times 2 = 6$ , ruling out statement (D).
- (b) Analyze orbital hybridization and magnetic behavior: The strong field environment of the chelating oxalates pairs up the 6 valence electrons into the three  $t_{2g}$  orbitals:  $t_{2g}^6 e_g^0$ . This leaves the two higher energy  $e_g$  orbitals ( $d_{x^2-y^2}$  and  $d_{z^2}$ ) completely vacant. These two empty 3d orbitals combine with the 4s and three 4p orbitals to form six  $d^2sp^3$  hybrid orbitals. This establishes an inner-orbital octahedral geometry, making statement (A) correct. Because all 6 d-electrons are fully paired, the complex is completely diamagnetic, making statement (B) correct.
- (c) Analyze stereochemistry and optical activity: The tris-chelate coordination geometry creates a propeller-like layout belonging to the  $D_3$  point group. Because it completely lacks a plane of symmetry ( $\sigma$ ) or an inversion center ( $i$ ), it forms non-superimposable mirror images. This gives rise to a pair of optically active dextrorotatory (d) and levorotatory (l) enantiomers, making statement (C) correct.

**Final Answer:** A, B, C**Answer:** (A, B, C)[Go Back to Question 37](#)

Q38.

**Solution****Concept:**

Thermodynamics characterizes macroscopic gas transformations using foundational equations. An adiabatic process is one in which the system is thermally isolated from its surroundings, preventing any transfer of thermal energy as heat ( $q = 0$ ). For a process to be perfectly reversible, it must progress through an infinite sequence of equilibrium states, meaning the entropy change of the system is given directly by  $\Delta S = \int \frac{dq_{\text{rev}}}{T}$ . According to the first law of thermodynamics,  $\Delta U = q + w$ . For an ideal gas, internal energy depends only on temperature, where  $\Delta U = nC_v\Delta T$ .

**Solution:**

- (a) Evaluate the heat and entropy conditions: By definition, an adiabatic system permits no heat transfer with the environment, which directly implies that  $q = 0$ , making statement (B) correct. Since the adiabatic expansion is carried out in a perfectly reversible manner, substituting  $dq_{\text{rev}} = 0$  into the definition of entropy yields  $\Delta S_{\text{system}} = 0$ . This means the process is isentropic, making statement (A) correct.
- (b) Analyze the work and internal energy variations: In an expansion process, the gas volume increases ( $\Delta V > 0$ ), meaning the system performs mechanical work on its surroundings. In chemical thermodynamics, work done by the system is mathematically negative ( $w < 0$ ). This contradicts statement (D).
- (c) Analyze the temperature change: Substitute the parameters  $q = 0$  and  $w < 0$  into the first law of thermodynamics:

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

Since  $w < 0$ , it follows that  $\Delta U < 0$ . For an ideal gas, a decrease in internal energy means the temperature must drop:

$$nC_v\Delta T < 0 \implies \Delta T < 0$$

This drop in temperature shows that the gas cools down as it consumes its own internal kinetic energy to perform mechanical expansion work, making statement (C) correct.

**Final Answer:** A, B, C

**Answer:** (A, B, C)

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Q39.

**Solution****Concept:**

The iodoform test is a diagnostic organic reaction used to identify the presence of specific structural units within a molecule. For a compound to yield a positive iodoform test, it must contain either a methyl ketone group ( $-\text{CO} - \text{CH}_3$ ) or a secondary alcohol structure that can be oxidized under the reaction conditions to a methyl ketone ( $-\text{CH}(\text{OH}) - \text{CH}_3$ ). When treated with iodine ( $\text{I}_2$ ) and sodium hydroxide ( $\text{NaOH}$ ), the alpha-methyl group undergoes consecutive halogenations to form a triiodomethyl intermediate, which is then cleaved by a hydroxide ion to precipitate yellow iodoform ( $\text{CHI}_3$ ).

**Solution:**

- (a) Analyze Pentan-2-one ( $\text{CH}_3 - \text{CO} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$ ): This molecule has a carbonyl group located at carbon-2, which is directly bound to a terminal methyl group. Because it contains the required methyl ketone structural unit, it reacts with the alkaline iodine solution to give a positive test. Thus, statement (A) is correct.
- (b) Analyze Pentan-3-one ( $\text{CH}_3 - \text{CH}_2 - \text{CO} - \text{CH}_2 - \text{CH}_3$ ): The carbonyl group is positioned symmetrically between two ethyl fragments. Because it lacks a methyl group directly attached to the carbonyl carbon, it cannot form the triiodomethyl intermediate and does not undergo haloform cleavage. Thus, statement (B) is incorrect.
- (c) Analyze Ethanol ( $\text{CH}_3 - \text{CH}_2 - \text{OH}$ ): Ethanol is a primary alcohol, but it features a methyl group adjacent to the hydroxyl-bearing carbon. The alkaline iodine solution acts as a mild oxidizing agent that converts ethanol into ethanal (acetaldehyde,  $\text{CH}_3 - \text{CHO}$ ). Since ethanal contains the necessary methyl group bound directly to the carbonyl group, it goes on to form iodoform. Thus, statement (C) is correct.
- (d) Analyze Propan-2-ol ( $\text{CH}_3 - \text{CH}(\text{OH}) - \text{CH}_3$ ): This secondary alcohol is oxidized by the reagent into propan-2-one (acetone,  $\text{CH}_3 - \text{CO} - \text{CH}_3$ ). The resulting acetone contains two methyl ketone structures, which react to produce a bright yellow precipitate of iodoform. Thus, statement (D) is correct.

**Final Answer:** A, C, D**Answer:** (A, C, D)[Go Back to Question 39](#)

Q40.

**Solution****Concept:**

A chemical reaction is classified as an intramolecular redox thermal decomposition if a single complex compound breaks down upon heating due to internal electron transfers between different elements within the same formula unit. In such a process, one element within the reactant undergoes oxidation (loses electrons and increases its oxidation state) while another element within the same reactant molecule undergoes reduction (gains electrons and decreases its oxidation state). If the oxidation states of all atoms remain completely unchanged during thermal cleavage, the reaction is a non-redox thermal dissociation.

**Solution:**

- (a) Analyze equation (A)  $[2\text{KClO}_3 \xrightarrow{\Delta} 2\text{KCl} + 3\text{O}_2]$ : In potassium chlorate, potassium is +1, chlorine is +5, and oxygen is -2. In the products, chlorine in KCl is reduced to -1 ( $\Delta\text{OS} = -6$ ), while oxygen in  $\text{O}_2$  is oxidized to 0 ( $\Delta\text{OS} = +2$ ). Since electron transfer occurs internally between chlorine and oxygen within the same starting material, this is a true intramolecular redox decomposition. Thus, statement (A) is correct.
- (b) Analyze equation (B)  $[\text{NH}_4\text{NO}_2 \xrightarrow{\Delta} \text{N}_2 + 2\text{H}_2\text{O}]$ : Ammonium nitrite contains two distinct nitrogen environments. In the ammonium cation ( $\text{NH}_4^+$ ), nitrogen has an oxidation state of -3. In the nitrite anion ( $\text{NO}_2^-$ ), nitrogen has an oxidation state of +3. Upon heating, both nitrogens compromise into a neutral oxidation state of 0 in elemental  $\text{N}_2$  gas. The ammonium nitrogen is oxidized ( $-3 \rightarrow 0$ ), and the nitrite nitrogen is reduced ( $+3 \rightarrow 0$ ). This internal redox process confirms statement (B) is correct.
- (c) Analyze equation (C)  $[\text{CaCO}_3 \xrightarrow{\Delta} \text{CaO} + \text{CO}_2]$ : In calcium carbonate, the oxidation states are  $\text{Ca} = +2$ ,  $\text{C} = +4$ , and  $\text{O} = -2$ . Looking at the products, calcium oxide (CaO) and carbon dioxide ( $\text{CO}_2$ ) retain these exact same oxidation states. This is a non-redox thermal decomposition, ruling out statement (C).
- (d) Analyze equation (D)  $[\text{NH}_4\text{Cl} \xrightarrow{\Delta} \text{NH}_3 + \text{HCl}]$ : Ammonium chloride dissociates into ammonia and hydrogen chloride gases. The oxidation states of nitrogen (-3), hydrogen (+1), and chlorine (-1) remain constant. This is a reversible acid-base thermal dissociation rather than a redox process, ruling out statement (D).

**Final Answer:** A, B**Answer:** (A, B)[Go Back to Question 40](#)

## Answer Key

| Q  | Ans     | Q  | Ans     | Q  | Ans     | Q  | Ans     | Q  | Ans  |
|----|---------|----|---------|----|---------|----|---------|----|------|
| 1  | B       | 2  | A       | 3  | D       | 4  | C       | 5  | C    |
| 6  | C       | 7  | A       | 8  | B       | 9  | A       | 10 | B    |
| 11 | C       | 12 | C       | 13 | C       | 14 | C       | 15 | B    |
| 16 | A       | 17 | B       | 18 | A       | 19 | C       | 20 | B    |
| 21 | C       | 22 | A       | 23 | C       | 24 | B       | 25 | C    |
| 26 | A       | 27 | B       | 28 | C       | 29 | B       | 30 | A    |
| 31 | B       | 32 | C       | 33 | D       | 34 | C       | 35 | C    |
| 36 | A, C, D | 37 | A, B, C | 38 | A, B, C | 39 | A, C, D | 40 | A, B |

