CHRISTIAN SOCIAL SERVICES COMMISSION (CSSC)
NORTHERN ZONE JOINT EXAMINATIONS SYNDICATE (NZ-JES)

FORM SIX PRE-NATIONAL EXAMINATIONS 2026
132/2 CHEMISTRY 2

MARKING SCHEME

1. **(a) Steam Distillation**

(i) Definition:

Steam distillation is a separation technique used to purify temperature-sensitive compounds by co-distilling them with water. This process allows the compound to evaporate at a lower temperature than its normal boiling point, preventing decomposition.

(ii) Applications of Steam Distillation:

- **Extraction of essential oils** from plant materials, such as eucalyptus and lavender oils.
- **Purification of high-boiling organic compounds** like aniline and nitrobenzene.
- **Isolation of natural flavoring compounds** such as those from citrus peels.

(b) Molecular Weight of Bromobenzene

Given data:

- **Boiling point of the mixture** = 95°C
- **Mass ratio of bromobenzene to water in distillate** = 1.6
- **Vapor pressure of water at 95°C** = 640 mmHg
- **Vapor pressure of bromobenzene at 95°C** = 120 mmHg
- **Molecular weight of water (H_2O)** = 18 g/mol

Step 1: Use Dalton's Law for Partial Pressures

The moles of each component in vapor phase is proportional to their vapor pressure:

$$\frac{\text{Bromobenzene}}{\text{Water}} = \frac{\text{Bromobenzene}}{\text{Water}} = \frac{120}{640} = 0.1875$$

Step 2: Use Mass Ratio to Find Molecular Weight of Bromobenzene ($M_{\beta r}$)

Since **mass = moles × molecular weight**,

$0.1875_{\text{Bromobenzene}}$

Solving for $_{\text{Bromobenzene}}$:

$= 1.6$

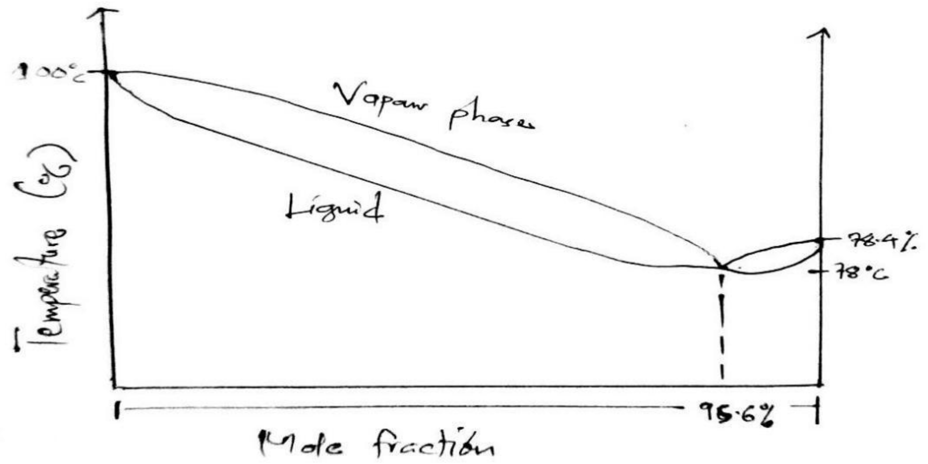
18

$$M_{\text{Bromobenzene}} = 1.6 \times 18 \div 0.1875 = 153.6\, g/mol$$

Thus, the **molecular weight of bromobenzene** is **153.6 g/mol**.

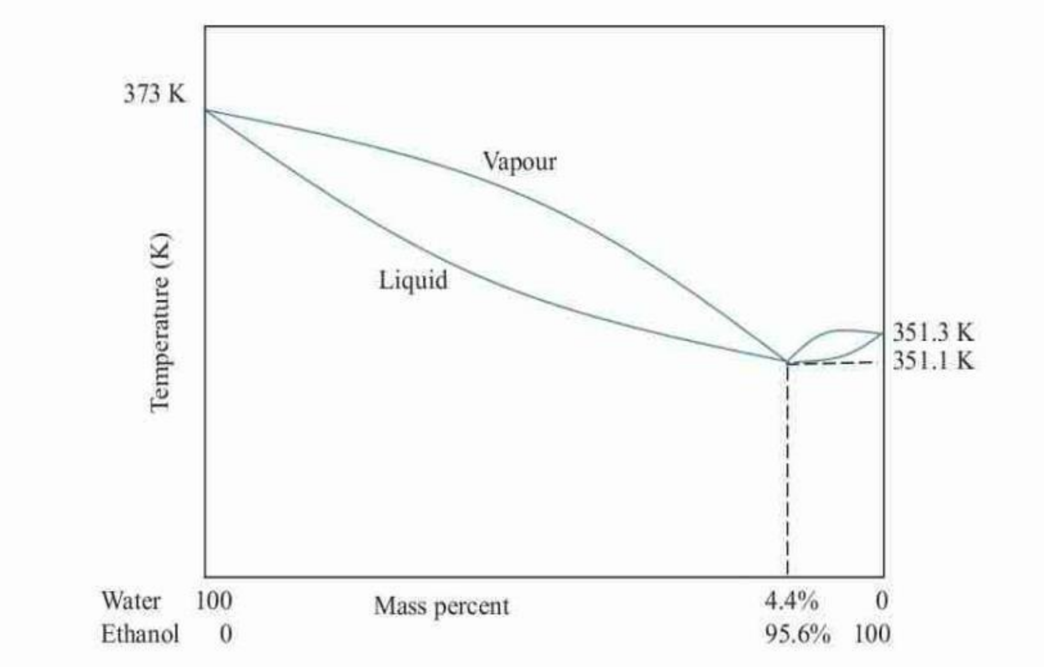
(c) Azeotropic Mixture of Ethanol and Water

(i) Temperature vs. Mole Fraction Diagram:



- A labeled diagram should show **two curves**:
    - **Boiling point curve (liquid phase)**
    - **Vapor phase curve**
    - The **azeotropic point** at 95.6% ethanol, 78°C.

(ii) Vapour Pressure vs. Composition Diagram:



- This graph should show:
    - **Raoult's Law deviation**
    - The **azeotropic point** where vapor and liquid compositions are identical.

(iii) Separation of Azeotropic Mixture:

- **Fractional distillation with an entrainer** (e.g., benzene or cyclohexane) to break the azeotrope.
- **Pressure variation distillation**, as changing pressure alters the azeotropic composition.
- **Membrane separation techniques** such as pervaporation.

(d) Distribution Law and Solute Dissociation

(i) Modification of the Distribution Law

When a solute dissociates in one solvent, its apparent concentration increases. The distribution law is modified as:

$$K_D = \frac{1}{C_2} \times \frac{1}{\alpha}$$

where **α** is the degree of dissociation.

(ii) Effect of Complete Dissociation in One Solvent

- If the solute completely dissociates in one solvent, the **actual concentration in that solvent increases**, disrupting equilibrium.
- The solute's distribution ratio is altered, leading to deviations from the original partition law.

2. **(a) Definitions**

(i) **Activation Energy:** The minimum energy required for a reaction to proceed.

(ii) **Rate Constant (k):** A proportionality constant that links the reaction rate to reactant concentrations in a rate equation.

(iii) **Half-life ($t_{1/2}$):** The time required for half of a reactant to be consumed in a reaction.

(iv) **Order of Reaction:** The sum of the exponents in the rate equation, indicating how reactant concentration affects reaction rate.

(b) Reaction Kinetics

Given:

- Initial concentration, $[A]_0 = 0.8$ mol/dm^3
- Rate constant, $k = 2.0 \times 10^{-3}$ sec^{-1}
- First-order reaction formula:

$$[A] = [A]_0 e^{-kt}$$

(i) Time for concentration to reach 0.355 mol/dm³

$$0.355 = 0.8e^{-\ 2.0\times10^{-3}\ t}$$

Taking natural log:

$$\ln \frac{0.355}{0.8} = -(2.0 \times 10^{-3})\ t$$

$$= \frac{\ln(0.355/0.8)}{-2.0 \times 10^{-3}}$$

Solving,

$$= 512.5 \text{ sec}$$

(ii) Concentration of A after 40 sec

$$[A] = 0.8e^{-\ 2.0\times10^{-3}\times40}$$

$$[A] = 0.8e^{-0.08} = 0.737 \text{ mol/dm}^3$$

(iii) Percentage of A reacted after 70 sec

$$\% \text{ reacted} = \frac{[A]_0 - [A]}{[\ \ ]_0} \times 100$$

Using $[A] = 0.8e^{-\ 2.0\times10^{-3}\times70}$,

$$[A] = 0.8e^{-0.14} = 0.674 \text{ mol/dm}^3$$

$$\% \text{ reacted} = \frac{0.8 - 0.674}{0.8} \times 100 = 15.75\%$$

(c) Electrochemical Cell Calculations

(i) Labeled Diagram:

- Zn electrode (anode) and Cu electrode (cathode)
- $ZnSO_4$ and $CuSO_4$ solutions
- Salt bridge connecting both half-cells

(ii) EMF Expression:

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

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

(iii) EMF at Given Concentrations (Nernst Equation):

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0591}{}\log\frac{[\ \ ^{2+}]}{[\ \ ^{2+}]}$$

$$E_{\text{cell}} = 1.10 - \frac{0.0591}{2}\log\frac{0.01}{1}$$

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

$$_{\text{cell}} = 1.10 + 0.0591 = 1.16$$

(d) Weak Acid Conductivity

Given:

- **Conductivity (κ)** = 2.64×10^{-2} Ω^{-1} m^{-1}
- **Molar conductivity at infinite dilution (Λ_0)** = 3.91×10^{-2} Ω^{-1} m^2/mol
- **Concentration (C)** = 0.025 mol/dm^3

(i) Hydrogen Ion Concentration:

$$= \frac{\quad}{_0} = \frac{2.64 \times 10^{-2}}{3.91 \times 10^{-2}}$$

$$= 0.675$$

$$[H^+] = \alpha \times C = 0.675 \times 0.025 = 0.0169 \text{ mol/dm}^3$$

(ii) Dissociation Constant (Ka):

$$Ka = \frac{\alpha^2 C}{1 - \alpha}$$

$$= \frac{(0.675)^2 \times 0.025}{1 - 0.675} = 1.55 \times 10^{-3} \text{ mol/dm}^3$$

3. **(a) Cell Notation and E.M.F Calculations**

The standard E.M.F of a galvanic cell is calculated using:

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

(i) S.H.E and Copper

- **Cell notation:**

$$\text{Pt} \mid H_2(g), H^+(aq) \parallel Cu^{2+}(aq) \mid Cu$$

- **E.M.F Calculation:**

$$E_{\text{cell}} = 0.34V - 0V = 0.34V$$

(ii) Zinc and Silver

- **Cell notation:**

$$\text{Zn} \mid Zn^{2+}(aq) \parallel Ag^+(aq) \mid Ag$$

- **E.M.F Calculation:**

$$E_{\text{cell}} = 0.80V - (-0.76V) = 1.56V$$

(iii) Mercury and Copper

- **Cell notation:**

$$\text{Hg} \mid Hg^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu$$

- **E.M.F Calculation:**

$$E_{\text{cell}} = 0.34V - 0.79V = -0.45V$$

Since the E.M.F is negative, the reaction is **not spontaneous** in the given direction.

(b) Percentage Purity of Iron (II) Salt

(i) Balanced Ionic Equation

$$\text{MnO}_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

(ii) Percentage Purity Calculation

- **Moles of $KMnO_4$ Used**

$$\text{Moles of } KMnO_4 = \text{Concentration} \times \text{Volume}$$

$$= 0.04 \times \frac{25}{1000} = 1.0 \times 10^{-3} \text{ moles}$$

- **Moles of Fe^{2+} in 20 cm³**

  Since **1 mole of $KMnO_4$ reacts with 5 moles of Fe^{2+}**:

  $$\text{Moles of } \mathrm{Fe}^{2+} = 5 \times 1.0 \times 10^{-3} = 5.0 \times 10^{-3} \text{ moles}$$

  Since this is for **20 cm³**, total moles in **200 cm³**:

  $$= 5.0 \times 10^{-3} \times \frac{200}{20} = 5.0 \times 10^{-2} \text{ moles}$$

- **Mass of Pure Iron Salt ($FeSO_4 \cdot 7H_2O$)**

  $$\text{Molar mass of } FeSO_4 \cdot 7H_2O = 278 \text{ g/mol}$$

  $$\text{Mass} = 5.0 \times 10^{-2} \times 278 = 13.9 \text{ g}$$

- **Percentage Purity**

  $$\%\text{Purity} = \frac{\text{Mass of pure salt}}{\text{Mass of impure salt}} \times 100$$

  $$= \frac{2.8}{} \times 100 = 28\%\ 10$$

(c) Reduction Potential at pH 14

Using **Nernst equation**:

$$E = E^\circ - \frac{0.0591}{} \log \left(\frac{1}{[\mathrm{Cu}^{2+}]} \right)$$

$$K_{sp} = [Cu^{2+}][OH^-]^2 = 1 \times 10^{-19}$$

At **pH = 14**,

$$[OH^-] = 10^{-14} \Rightarrow [Cu^{2+}] = \frac{1 \times 10^{-19}}{(10^{-14})^2} = 10^{-11} M$$

$$E = 0.34 - \frac{0.0591}{2} \log \frac{1}{10^{-11}}$$

$$E = 0.34 - 0.325 = 0.015 V$$

(d) Cyclopropane to Propene Reaction

(i) Concentration after 8.8 min

Using first-order kinetics:

$$[A] = [A]_0 e^{-kt}$$

Given:

- $k = 6.7 \times 10^{-4} s^{-1}$
- $t = 8.8 \times 60 = 528$ s

$$[A] = 0.25 e^{-\ 6.7 \times 10^{-4} \times 528}$$

$$[A] = 0.25 e^{-0.354} = 0.25 \times 0.702 = 0.176 \text{ M}$$

4. **(a) Explanations**

   (i) **Common reductants are useless for aluminium extraction**

      a. Aluminium has a very low reduction potential, so only **electrolysis** can reduce it.

   (ii) **Chlorine is more soluble in NaOH than in water**

      a. It reacts with NaOH to form **NaClO and NaCl**, increasing solubility.

   (iii) **Fluorine liberates oxygen from water**

   - Fluorine is so electronegative that it oxidizes water:

$$2F_2 + 2H_2O \rightarrow 4HF + O_2$$

(b) Aluminium Extraction

(i) ***Purification of Bauxite (Bayer Process)***

- Dissolve bauxite in **NaOH** to form **sodium aluminate**.
- Filter out **impurities** (Fe_2O_3, SiO_2).
- Precipitate **$Al(OH)_3$**, then calcine to **Al_2O_3**.

(ii) ***Electrolysis of Alumina (Hall-Héroult Process)***

- **Anode:** C (oxidized to CO_2).
- **Cathode:** Al^{3+} reduced to Al.
- **Cryolite (Na_3AlF_6)** lowers melting point.

(c) Complex Chemistry & Colour Changes

- **$[Pt(NH_3)_3Cl_2]Cl$ vs. $[Pt(NH_3)_2Cl_4]$**
  - The first **dissociates** in water, allowing $AgNO_3$ to react with **Cl^-**.
  - The second is **chelated**, preventing Cl^- release.
- **Colour of Co Complexes**
  - $[Co(CN)_6]^{3-}$: **Yellow** (strong ligand, large gap).
  - $[Co(NH_3)_6]^{3+}$: **Orange** (medium ligand, moderate gap).
  - $[Co(H_2O)_6]^{3+}$: **Blue** (weak ligand, small gap).
- **Dichromate (VI) Equilibrium**
  - In **acid**, orange $Cr_2O_7^{2-}$ dominates.
  - In **alkali**, yellow CrO_4^{2-} forms:

$$Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$$

- **Fe^{3+} Salts Are Acidic**
  - Fe^{3+} hydrolyzes in water, forming H_3O^+, making the solution acidic.

5. **(a) Identification of Liquid Y**

- **Given Data:**

  Empirical formula: C_3H_6O

  Molecular mass: 58

Possible molecular formula: $(C_3H_6O)_n = 58 \Rightarrow C_3H_6O$

Test Results and Interpretation

Test	Reagent	Observation	Interpretation
A	Sodium metal	No reaction	No acidic hydrogen → No alcohol or carboxylic acid
B	Bromine water	No reaction	No C=C double bond → Not an alkene
C	2,4-DNPH	Orange precipitate	Presence of a **carbonyl group** (aldehyde or ketone)
D	Ammoniacal silver nitrate	No reaction	No oxidation → Not an aldehyde (must be a **ketone**)

- **Test B alone:** No alkene (no C=C bond).
- **Test C alone:** Contains a **carbonyl group** (C=O).
- **Test D alone:** Not an aldehyde, so must be a **ketone**.
- **Test C & D together:** The compound is a **ketone** (not an aldehyde).

Molecular Formula and Structure of Y

- **Molecular formula: C_3H_6O**
- **Possible ketones:**
    a. **Propanone (acetone)**: **CH_3COCH_3**
    b. **Propanal (but ruled out as aldehyde)**

☑ **Final Answer: Propanone (CH_3COCH_3)**

(b) Compound M Identification

- **Elemental Composition:**
    - **C = 64.86%**, **H = 13.5%**, **O = 21.64%**
    - **Molecular mass = 74**

Step 1: Find Empirical Formula

Divide each percentage by atomic mass:

$$\frac{64.86}{12} = 5.405, \quad \frac{13.5}{1} = 13.5, \quad \frac{21.64}{16} = 1.352$$

Divide by the smallest (1.352):

$$= \frac{5.405}{1.352} = 4, \quad = \frac{13.5}{1.352} = 10, \quad = \frac{1.352}{1.352} = 1$$

$$\text{Empirical formula} = \ _4\ _{10}$$

Step 2: Determine the Molecular Formula

$$\text{Empirical formula mass} = (4 \times 12) + (10 \times 1) + (1 \times 16) = 74$$

Since empirical mass **matches** molecular mass, the **molecular formula is $C_4H_{10}O$**.

Step 3: Identify Possible Isomers

- **Reaction with PCl_5 → Forms compound O + Gas P (HCl)**
    - Suggests presence of **-OH (hydroxyl group) → Alcohol** or **Carboxylic Acid**

- **Reaction with I_2/NaOH → Triiodomethane test**
    - Presence of **CH_3CO- group → Must be a methyl ketone or ethanol derivative**
- **Possible Isomers (Alcohols and Ketones):**
- **Butan-2-one ($CH_3COCH_2CH_3$)** ☑
- **Butan-2-ol ($CH_3CHOHCH_2CH_3$)** ☑
- **2-Methylpropan-2-ol ($(CH_3)_3COH$)** ☑
- **Butan-1-ol ($CH_3CH_2CH_2CH_2OH$)** ☑
- **2-Methylpropan-1-ol ($CH_3CH(CH_3)CH_2OH$)** ☑

Chemical Reactions

- **Reaction with PCl_5:**

$$ROH + PCl_5 \rightarrow RCl + POCl_3 + HCl$$

- **Triiodomethane Reaction (only for Butan-2-one):**

$$CH_3COCH_2CH_3 + 3I_2 + 4NaOH \rightarrow CHI_3 (yellow ppt) + CH_3CH_2O^-Na^+ + 3NaI + 3H_2O$$

(c) Phenylamine Reactions

Reactant	Product	IUPAC Name
Ethanoic anhydride	**$CH_3CONHPh$**	**N-Phenylethanamide**
Aqueous bromine	**2,4,6-Tribromophenylamine**	**2,4,6-Tribromoaniline**
Ethanoic anhydride + Bromine	**2,4,6-Tribromo-N-phenylethanamide**	**2,4,6-Tribromo-N-phenylethanamide**
$NaNO_2$ + HCl (below 10°C)	**$C_6H_5N_2^+Cl^-$ (Benzene diazonium chloride)**	**Benzene diazonium chloride**

(d) Preparation of n-Propylamine ($CH_3CH_2CH_2NH_2$)

- **From n-Propyl Bromide ($CH_3CH_2CH_2Br$)**
    - **Reaction:**

$$CH_3CH_2CH_2Br + NH_3 \rightarrow CH_3CH_2CH_2NH_2 + HBr$$

- **From n-Propyl Alcohol ($CH_3CH_2CH_2OH$)**
    - **Convert to Alkyl Halide (Using PBr_3):**

$$CH_3CH_2CH_2OH + PBr_3 \rightarrow CH_3CH_2CH_2Br + H_3PO_3$$

    - **Then react with NH_3 as above**.
- **From n-Butyl Alcohol ($CH_3CH_2CH_2CH_2OH$)**
    - **Convert to Butyl Bromide, then react with KOH to form Butyl Cyanide:**

$$CH_3CH_2CH_2CH_2Br + KCN \rightarrow CH_3CH_2CH_2CH_2CN$$

    - **Hydrolyze to Butanoic Acid and Decarboxylate:**

$$CH_3CH_2CH_2CH_2CN + H_2O + HCl \rightarrow CH_3CH_2CH_2CH_2COOH$$

  - **Heat with Soda Lime to remove CO_2:**

$$CH_3CH_2CH_2CH_2COOH + NaOH \rightarrow CH_3CH_2CH_2NH_2 + Na_2CO_3$$

- **From n-Propanitrile (CH_3CH_2CN)**
  - **Reduction with $LiAlH_4$:**

$$CH_3CH_2CN + 4[H] \rightarrow CH_3CH_2CH_2NH_2$$

☑ **Final Answer Summary:**

- **Y is Propanone (Acetone)**
- **M is Butan-2-one ($C_4H_{10}O$)**
- **Phenylamine Reactions and Propylamine Preparation Covered**

6. **(a) Vulcanization and Plasticizers**

(i) **Vulcanization of Rubber:**

- It is the process of treating natural rubber with **sulfur** or other curatives to **increase its strength, elasticity, and durability**. The sulfur atoms form **cross-links** between polymer chains, making the rubber harder and more heat-resistant.

(ii) **Why Vulcanized Rubber is Suitable for Aircraft Tyres:**

- **Heat Resistance**: Aircraft tyres experience high friction and temperature during landing.
- **Elasticity & Strength**: Prevents deformation under heavy loads.
- **Abrasion Resistance**: Withstands wear and tear over time.

(iii) **Why Plasticizers are Used in Moulding of Plastics:**

- **Increase Flexibility**: Reduces intermolecular forces in polymers.
- **Enhances Processability**: Makes plastics easier to shape.
- **Prevents Brittleness**: Keeps plastic soft and durable.

(b) Cationic Polymerization and Electron-Donating Groups

- **Cationic polymerization** is preferred for vinylic monomers with **electron-donating groups ($-OCH_3$, $-CH_3$, $-NH_2$)** because:

Electron-donating groups **stabilize the carbocation intermediate**, making the reaction proceed more efficiently.

Example: **Polymerization of Isobutene ($CH_2{=}C(CH_3)_2$)**

$${}_2 = C(CH_3)_2 \xrightarrow{H^+} CH_3C^+H - CH_3 \Rightarrow \text{polymerization continues}$$

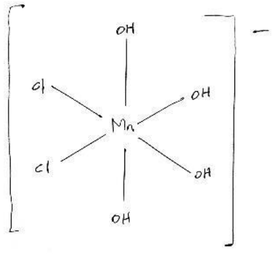
The **tertiary carbocation formed** is highly stabilized by **methyl groups**, making the polymerization process fast.

(c) Mn Complex: $[MnCl_2(OH_2)_4]$

- **Cis and Trans Structures**
  - The **cis-isomer** has the two chloride (Cl) ligands adjacent.
  - The **trans-isomer** has the chloride ligands opposite each other.

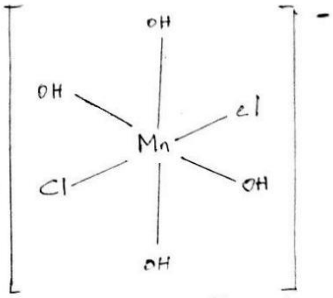
Structures:

- **Cis- $[MnCl_2(OH_2)_4]$**



Cis - $[MgCl_2(OH)_4]^-$

- **Trans- $[MnCl_2(OH_2)_4]$**



Trans - $[MnCl_2(OH)_4]^-$

- **Coordination Number of Manganese:**
  - The Mn^{2+} ion is surrounded by **six ligands** (**4 water molecules + 2 chloride ions**).
  - **Coordination number = 6**.
- **High Spin Electron Configuration of Mn^{2+}**
  - Mn^{2+} has **5 d-electrons (d^5)** in an **octahedral crystal field**.
  - In **high-spin configuration**, the electrons remain **unpaired** due to weak field ligands (Cl^-, H_2O).

Energy Level Diagram (Octahedral High Spin d^5):

↑ ↑ ↑ ↑ ↑

$_2$ (lower energy) (higher energy)

- **Why the Complex is Colored:**
  - The **Mn^{2+} ion undergoes d-d transitions** between split **t_2g and e_9 orbitals** in an **octahedral crystal field**.
  - Absorption of visible light causes electron excitation → **Color observed is due to the complementary color of absorbed light**.

(d) Isomers of Aliphatic Carboxylic Acid and Ester (Molecular Mass = 88)

Step 1: Determine the Molecular Formula

- Possible molecular formula: **$C_4H_8O_2$** (fits Molar Mass = 88)
- Functional groups: **Carboxylic Acid (-COOH) and Ester (-COO-).**

Step 2: Identify Isomers

Isomer	Structure	IUPAC Name
Carboxylic Acid 1	$CH_3CH_2CH_2COOH$	**Butanoic acid**
Carboxylic Acid 2	$(CH_3)_2CHCOOH$	**2-Methylpropanoic acid**
Ester 1	$CH_3CH_2COOCH_3$	**Methyl propanoate**

(d)(ii) Structure of Salicylic Acid and Aspirin

- **Salicylic Acid (2-Hydroxybenzoic Acid)**
    - Structure:

      OH
      |
      C6H4-COOH

    - Functional groups: **-OH (Phenol) and -COOH (Carboxylic acid)**
- **Aspirin (Acetylsalicylic Acid)**
    - Structure:

      OCOCH3
      |
      C6H4-COOH

    - The **-OH group in salicylic acid is esterified with acetic anhydride** to form **Aspirin**.