THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2022**

Instructions

1. This paper consists of a total of six questions
2. Answer five questions.

1. (a) (i) A solid Y is added to a mixture of benzene and water. After shaking well and allowing the mixture to equilibrate, 10 cm^3 of the benzene layer was found to contain 0.13 g of Y while 100 cm^3 of the aqueous layer contained 0.22 g of Y. Calculate the value of the distribution coefficient of Y between benzene and water.

The distribution coefficient (K_d) is the ratio of the concentration of Y in benzene to its concentration in water at equilibrium.

Concentration of Y in benzene:

Volume = 10 cm^3 = 0.01 dm^3

Mass = 0.13 g

[Y]_benzene = 0.13 / 0.01 = 13 g dm^{-3}

Concentration of Y in water:

Volume = 100 cm^3 = 0.1 dm^3

Mass = 0.22 g

[Y]_water = 0.22 / 0.1 = 2.2 g dm^{-3}

K_d = [Y]_benzene / [Y]_water = 13 / 2.2 ≈ 5.91

The distribution coefficient of Y between benzene and water is approximately 5.91.

(ii) Comment on the solubility of Y in benzene and water with respect to the distribution coefficient you have obtained in 1(a)(i).

The distribution coefficient K_d = 5.91 indicates that Y is more soluble in benzene than in water. Since K_d > 1, the concentration of Y in benzene is 5.91 times higher than in water, meaning Y prefers the organic solvent (benzene) over the aqueous phase. This suggests Y is likely a non-polar or weakly polar compound, as benzene is non-polar and water is polar.

Y is more soluble in benzene than in water, as the K_d of 5.91 shows a higher concentration in benzene, indicating a preference for the non-polar solvent.

(b)What are the two applications of fractional distillation? Explain briefly.

Separation of Crude Oil: Fractional distillation is used in the petroleum industry to separate crude oil into its components (e.g., gasoline, kerosene, diesel) based on their boiling points. The mixture is heated, and fractions are collected at different temperatures in a fractionating column.

Purification of Liquids: It is used to purify liquids with close boiling points, such as separating ethanol (boiling point 78°C) from water (100°C) in the production of spirits. The process involves repeated vaporization and condensation to enrich the more volatile component.

Fractional distillation is applied in separating crude oil into fractions like gasoline and kerosene, and in purifying liquids like ethanol from water by exploiting differences in boiling points.

(c) Calculate the percentage by mass of bromobenzene (C_6H_5Br) in the distillate when a mixture of bromobenzene and water distills in steam at 95°C. The vapour pressures of bromobenzene and water at 95°C are 1.59×10^4 and 8.50×10^4 N m^{-2} respectively.

For steam distillation of immiscible liquids, the total vapor pressure is the sum of the vapor pressures of the components:

P_total = P_bromobenzene + P_water = $1.59 \times 10^4 + 8.50 \times 10^4 = 1.009 \times 10^5$ N m^{-2}

The mole ratio of the components in the distillate is proportional to their vapor pressures:

n_bromobenzene / n_water = P_bromobenzene / P_water = $(1.59 \times 10^4) / (8.50 \times 10^4) = 0.187$

Molar masses:

Bromobenzene (C_6H_5Br) = (6 x 12) + (5 x 1) + 79.9 = 156.9 g mol^{-1}

Water (H_2O) = (2 x 1) + 16 = 18 g mol^{-1}

Mass ratio:

Mass_bromobenzene / Mass_water = (n_bromobenzene x M_bromobenzene) / (n_water x M_water)

= (n_bromobenzene / n_water) x (M_bromobenzene / M_water)

= 0.187 x (156.9 / 18) ≈ 0.187 x 8.717 ≈ 1.63

Percentage by mass of bromobenzene:

% bromobenzene = (Mass_bromobenzene / (Mass_bromobenzene + Mass_water)) x 100

= (1.63 / (1.63 + 1)) x 100 ≈ (1.63 / 2.63) x 100 ≈ 62%

The percentage by mass of bromobenzene in the distillate is approximately 62%.

(d) Heptane (C_7H_{16}) and octane (C_8H_{18}) form an ideal solution. At 373 K, the vapour pressures of pure heptane and octane were 105.2 kPa and 46.8 kPa respectively. Calculate the vapour pressure of the mixture of 26.0 g of heptane and 35.0 g of octane.

Moles of heptane:

Molar mass of C_7H_{16} = (7 x 12) + (16 x 1) = 100 g mol^{-1}

n_heptane = 26.0 / 100 = 0.26 mol

Moles of octane:

Molar mass of C_8H_{18} = (8 x 12) + (18 x 1) = 114 g mol^{-1}

n_octane = 35.0 / 114 ≈ 0.307 mol

Total moles = 0.26 + 0.307 = 0.567 mol

Mole fractions:

X_heptane = 0.26 / 0.567 ≈ 0.459

X_octane = 0.307 / 0.567 ≈ 0.541

For an ideal solution:

P_total = (P_heptane x X_heptane) + (P_octane x X_octane)

= (105.2 x 0.459) + (46.8 x 0.541)

= 48.3 + 25.3 ≈ 73.6 kPa

The vapor pressure of the mixture is approximately 73.6 kPa.

2.(a) Calculate the pH of a sample of pure water at 25°C. Given K_w = 10^{-14} mol^2 dm^{-6} at 25°C.

For pure water:

$H_2O \rightleftharpoons H^+ + OH^-$

K_w = $[H^+]$ x $[OH^-]$ = 10^{-14}

Since $[H^+] = [OH^-]$, let $[H^+]$ = x:

x x x = 10^{-14}

$x^2 = 10^{-14}$

x = 10^{-7} mol dm^{-3}

pH = -log$[H^+]$ = -log(10^{-7}) = 7

The pH of pure water at 25°C is 7.

(b) A 500 cm³ of 0.1 M aqueous solution of CH_3COOH (acetic acid) were mixed with 500 cm³ of 0.1 M HCl solution. If 3 g of NaOH are added to the mixture, calculate the pH of the mixture before and after addition of NaOH, assuming that no change in volume occurs on mixing.

Before addition of NaOH:

Total volume = 500 cm³ + 500 cm³ = 1000 cm³ = 1 dm³

HCl: A strong acid, fully dissociates:

$HCl \text{ ---->} H^+ + Cl^-$

Initial [HCl] = 0.1 M, but after mixing:

[HCl] = (0.1 x 0.5) / 1 = 0.05 M

$[H^+]$ from HCl = 0.05 M

CH_3COOH: A weak acid, partially dissociates:

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

Initial $[CH_3COOH]$ = 0.1 M, after mixing:

$[CH_3COOH]$ = (0.1 x 0.5) / 1 = 0.05 M

K_a of $CH_3COOH \approx 1.8 \times 10^{-5}$

Since HCl provides a high $[H^+]$, the dissociation of CH_3COOH is suppressed (common ion effect). Let's approximate $[H^+]$ from CH_3COOH:

$K_a = ([H^+] \times [CH_3COO^-]) / [CH_3COOH]$

$[H^+] \approx 0.05$ M (from HCl), $[CH_3COO^-] = x$, $[CH_3COOH] \approx 0.05$:

$1.8 \times 10^{-5} = (0.05 \times x) / 0.05$

$x = 1.8 \times 10^{-5}$ M

$[H^+]$ from CH_3COOH is negligible compared to 0.05 M.

Total $[H^+] \approx 0.05$ M

$pH = -\log(0.05) \approx 1.3$

After addition of NaOH:

Moles of NaOH:

Molar mass of NaOH = 40 g mol⁻¹

Moles of NaOH = 3 / 40 = 0.075 mol

Moles of H^+ from HCl:

Moles of HCl = 0.05 x 1 = 0.05 mol

Moles of CH_3COOH = 0.05 x 1 = 0.05 mol

NaOH reacts with H^+ from HCl first (strong acid):

$H^+ + OH^-$ ----> H_2O

0.05 mol of NaOH reacts with 0.05 mol of H^+ from HCl, neutralizing it completely.

Moles of NaOH remaining = 0.075 - 0.05 = 0.025 mol

Remaining NaOH reacts with CH_3COOH:

$CH_3COOH + OH^-$ ----> $CH_3COO^- + H_2O$

0.025 mol of NaOH reacts with 0.025 mol of CH_3COOH.

Moles of CH_3COOH remaining = 0.05 - 0.025 = 0.025 mol

Moles of CH_3COO^- formed = 0.025 mol

This forms a buffer solution:

$[CH_3COOH]$ = 0.025 / 1 = 0.025 M

$[CH_3COO^-]$ = 0.025 / 1 = 0.025 M

Use the Henderson-Hasselbalch equation:

$pH = pK_a + \log([CH_3COO^-] / [CH_3COOH])$

$pK_a = -\log(1.8 \times 10^{-5}) \approx 4.74$

pH = 4.74 + log(0.025 / 0.025) = 4.74 + 0 = 4.74

The pH before adding NaOH is approximately 1.3, and after adding NaOH, it is approximately 4.74.

(c) (i) Although lead(II) chloride is sparingly soluble in pure water, it is soluble in concentrated hydrochloric acid. Explain briefly.

Lead(II) chloride ($PbCl_2$) has a low solubility in water due to its small K_sp (1.7×10^{-5}):

$PbCl_2 \rightleftharpoons Pb^{2+} + 2Cl^-$

In pure water, the equilibrium favors the solid, with low $[Pb^{2+}]$ and $[Cl^-]$.

In concentrated HCl, the high $[Cl^-]$ shifts the equilibrium:

The common ion effect initially reduces solubility, but excess Cl^- forms soluble complexes:

$PbCl_2 + 2Cl^- \rightleftharpoons [PbCl_4]^{2-}$

The formation of $[PbCl_4]^{2-}$ increases the solubility of $PbCl_2$ in concentrated HCl.

$PbCl_2$ is sparingly soluble in water due to its low K_sp, but in concentrated HCl, high $[Cl^-]$ forms the soluble complex $[PbCl_4]^{2-}$, increasing its solubility.

(ii) A chemist wanted to separate Al^{3+} and Zn^{2+} using fractional precipitation method. In the first experiment, NH_4OH was added and both Al^{3+} and Zn^{2+} precipitated. In the second experiment, NH_4OH was added followed by addition of NH_4Cl and only Al^{3+} precipitated. Comment briefly on the results obtained in the second experiment.

First Experiment:

NH_4OH provides OH^-:

$Al^{3+} + 3OH^-$ ----> $Al(OH)_3$ (insoluble)

$Zn^{2+} + 2OH^-$ ----> $Zn(OH)_2$ (insoluble)

Both Al^{3+} and Zn^{2+} precipitate as hydroxides due to high $[OH^-]$.

Second Experiment:

$NH_4OH + NH_4Cl$ forms a buffer, controlling $[OH^-]$:

$NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$

The lower $[OH^-]$ is sufficient for $Al(OH)_3$ to precipitate (K_sp of $Al(OH)_3 \approx 1.3 \times 10^{-33}$), but not for $Zn(OH)_2$ (K_sp $\approx 3 \times 10^{-17}$). Additionally, NH_3 from NH_4OH forms a soluble complex with Zn^{2+}:

$Zn^{2+} + 4NH_3$ ----> $[Zn(NH_3)_4]^{2+}$

Thus, only Al^{3+} precipitates as $Al(OH)_3$, while Zn^{2+} remains in solution as $[Zn(NH_3)_4]^{2+}$.

In the second experiment, the NH_4OH-NH_4Cl buffer lowers $[OH^-]$, allowing $Al(OH)_3$ to precipitate while Zn^{2+} forms the soluble $[Zn(NH_3)_4]^{2+}$ complex, preventing its precipitation.

(d) Equal volumes of 0.025 mol dm^{-3} barium nitrate and 0.010 mol dm^{-3} sodium fluoride were mixed together. Show whether the solution is saturated, super saturated, or unsaturated. BaF_2 is 1.7×10^{-6} mol^3 dm^{-9}.

Reaction:

$Ba(NO_3)_2 + 2NaF \text{ ----> } BaF_2 + 2NaNO_3$

Initial concentrations (after mixing equal volumes, concentrations halve):

$[Ba^{2+}] = 0.025 / 2 = 0.0125$ M

$[F^-] = 0.010 / 2 = 0.005$ M

Ionic product (Q) for BaF_2:

$BaF_2 \rightleftharpoons Ba^{2+} + 2F^-$

$Q = [Ba^{2+}] \text{ x } [F^-]^2 = 0.0125 \text{ x } (0.005)^2 = 0.0125 \text{ x } 0.000025 = 3.125 \text{ x } 10^{-7}$

K_sp of $BaF_2 = 1.7 \text{ x } 10^{-6}$

Since Q ($3.125 \text{ x } 10^{-7}$) < K_sp ($1.7 \text{ x } 10^{-6}$), the solution is unsaturated.

The solution is unsaturated because the ionic product ($3.125 \text{ x } 10^{-7}$) is less than the K_sp ($1.7 \text{ x } 10^{-6}$), so no precipitate forms.

3. (a) Compound Q is commonly added to foods to give them the rum flavour. It has the following structural formula:

H

|

H—C—C—O

| ||

H   C—C—H

|| |

O   H

(i) To which class of organic compounds does the compound Q belong?

The structure is H—C(H)—C(O)—O—C(H)—C(H)—H, or $HCOOCH_2CH_3$ (ethyl formate).

It has the form RCOOR', which is an ester.

Compound Q belongs to the class of esters.

(ii) How can you synthesize compound Q from ethanol and methanol and any other suitable reagent?

Ethyl formate ($HCOOCH_2CH_3$) can be synthesized from ethanol (CH_3CH_2OH) and methanol (CH_3OH):

Oxidize methanol to formic acid ($HCOOH$) using a strong oxidizing agent like $KMnO_4$:

$CH_3OH + [O]$ ----> $HCOOH + H_2O$

Esterify formic acid with ethanol using a catalyst like H_2SO_4:

$HCOOH + CH_3CH_2OH$ ----> $HCOOCH_2CH_3 + H_2O$

$CH_3OH + [O]$ ----> $HCOOH + H_2O$

$HCOOH + CH_3CH_2OH$ ----> $HCOOCH_2CH_3 + H_2O$

(iii) What is the IUPAC name of compound Q?

The structure $HCOOCH_2CH_3$ has:

Formate (from $HCOO^-$) as the acid part.

Ethyl (from $CH_3CH_2^-$) as the alcohol part.

IUPAC name: ethyl methanoate.

The IUPAC name of compound Q is ethyl methanoate.

(iv) Compound Q can react with NaOH in presence of heat. How can you represent this reaction using a chemical equation?

Ethyl methanoate reacts with NaOH (saponification) to form the sodium salt of the acid and the alcohol:

$HCOOCH_2CH_3 + NaOH$ ----> $HCOONa + CH_3CH_2OH$

$HCOOCH_2CH_3 + NaOH$ ----> $HCOONa + CH_3CH_2OH$

(b)(i) The boiling point of ethanoic acid is higher than that of ethanol.

Ethanoic acid (CH_3COOH, 118°C) has a higher boiling point than ethanol (CH_3CH_2OH, 78°C) because:

Ethanoic acid forms hydrogen bonds via its -COOH group, and it can form dimers (two molecules linked by two H-bonds), leading to stronger intermolecular forces.

Ethanol forms hydrogen bonds via its -OH group but cannot form dimers, so its intermolecular forces are weaker.

Ethanoic acid has a higher boiling point than ethanol due to stronger hydrogen bonding and dimer formation in ethanoic acid.

(ii) Methylamine is a stronger base than ammonia. Trimethylamine and n-propylamine have the same molecular mass but the former boils at a lower temperature (276 K) than the latter (322 K).

Methylamine vs. ammonia: Methylamine (CH_3NH_2) is a stronger base than ammonia (NH_3) because the CH_3 group is electron-donating (+I effect), increasing electron density on N, making the lone pair more available to donate (pK_b of $CH_3NH_2 \approx 3.4$, $NH_3 \approx 4.75$).

Boiling points: Trimethylamine ($(CH_3)_3N$, 276 K) has a lower boiling point than n-propylamine ($CH_3CH_2CH_2NH_2$, 322 K) because:

n-Propylamine has two N-H bonds, allowing stronger hydrogen bonding (N-H…N).

Trimethylamine has no N-H bonds (all are N-CH_3), so it only has weaker dipole-dipole and London forces.

Methylamine is a stronger base than ammonia due to the +I effect of the CH_3 group, and trimethylamine boils at a lower temperature than n-propylamine because it lacks hydrogen bonding.

(c) (i) Complete the following organic reactions:

(i) $CH_3CH_2NH_2 + NaNO_2 + HCl$ ---->

(ii) $CH_3CH_2NH_2 + CHCl_3 + KOH$ ---->

(i) Primary amines with $NaNO_2/HCl$ at 0-5°C undergo diazotization:

$CH_3CH_2NH_2 + NaNO_2 + HCl$ ----> $CH_3CH_2OH + N_2 + NaCl + H_2O$

(ii) The carbylamine reaction with $CHCl_3$ and KOH forms an isocyanide:

$CH_3CH_2NH_2 + CHCl_3 + 3KOH$ ----> $CH_3CH_2NC + 3KCl + 3H_2O$

(i) $CH_3CH_2NH_2 + NaNO_2 + HCl$ ----> $CH_3CH_2OH + N_2 + NaCl + H_2O$

(ii) $CH_3CH_2NH_2 + CHCl_3 + 3KOH$ ----> $CH_3CH_2NC + 3KCl + 3H_2O$

(d) Arrange the following organic compounds in order of increasing basic strength:

$C_6H_5NH_2$, $(C_6H_5)_2NH$, $C_2H_5NH_2$, NH_3

Basic strength depends on the availability of the lone pair on N:

$C_6H_5NH_2$ (aniline): The lone pair on N is delocalized into the benzene ring via resonance, reducing basicity ($pK\_b \approx 9.4$).

$(C_6H_5)_2NH$ (diphenylamine): Two phenyl groups further delocalize the lone pair, making it even less basic ($pK\_b \approx 13$).

NH_3 (ammonia): No substituents to withdraw electrons ($pK\_b \approx 4.75$).

$C_2H_5NH_2$ (ethylamine): The C_2H_5 group is electron-donating (+I effect), increasing electron density on N, making it the most basic ($pK\_b \approx 3.4$).

Order: $(C_6H_5)_2NH < C_6H_5NH_2 < NH_3 < C_2H_5NH_2$

$(C_6H_5)_2NH < C_6H_5NH_2 < NH_3 < C_2H_5NH_2$

4. (a) During a tour to one of the emerging local industries in Tanzania, it was noticed that some of the machine parts made up of iron were corroding. What do you think would be the factors affecting the extent of corrosion?

Factors affecting iron corrosion:

Presence of Moisture: Water is needed for the electrochemical reaction of rusting ($Fe + O_2 + H_2O$ ----> $Fe_2O_3 \cdot nH_2O$).

Oxygen Availability: O_2 acts as an oxidizing agent in rusting.

Electrolytes: Salts (e.g., NaCl) in water increase conductivity, accelerating corrosion.

Temperature: Higher temperatures increase the rate of corrosion by speeding up the reaction.

pH: Acidic conditions (low pH) enhance corrosion by providing H^+ ions.

Surface Area: More exposed surface area increases the rate of corrosion.

The factors affecting iron corrosion include moisture, oxygen, electrolytes, temperature, pH, and surface area, all of which influence the electrochemical rusting process.

4. (b) By using half-reaction method, balance the following redox reaction if it takes place in an acidic medium:

$Cr_2O_7^{2-}(aq) + HNO_2(aq)$ ----> $Cr^{3+}(aq) + NO_3^-(aq)$

Oxidation half-reaction: HNO_2 ----> NO_3^-

Balance N: Already balanced.

Balance O by adding H_2O:

HNO_2 ----> $NO_3^- + 2H_2O$

Balance H by adding H^+:

$HNO_2 + H_2O$ ----> $NO_3^- + 3H^+$

Balance charge: Left (-1 + 0 = -1), Right (-1 + 3 = +2), add $3e^-$ to right:

$HNO_2 + H_2O$ ----> $NO_3^- + 3H^+ + 3e^-$ (1)

Reduction half-reaction: $Cr_2O_7^{2-}$ ----> Cr^{3+}

Balance Cr: $Cr_2O_7^{2-}$ ----> $2Cr^{3+}$

Balance O by adding H_2O:

$Cr_2O_7^{2-}$ ----> $2Cr^{3+} + 7H_2O$

Balance H by adding H^+:

$Cr_2O_7^{2-} + 14H^+$ ----> $2Cr^{3+} + 7H_2O$

Balance charge: Left (-2 + 14 = +12), Right (2 x 3 = +6), add $6e^-$ to left:

$Cr_2O_7^{2-} + 14H^+ + 6e^-$ ----> $2Cr^{3+} + 7H_2O$ (2)

Combine: Multiply (1) by 2 to balance electrons:

$2HNO_2 + 2H_2O$ ----> $2NO_3^- + 6H^+ + 6e^-$

Add to (2):

$Cr_2O_7^{2-} + 14H^+ + 6e^- + 2HNO_2 + 2H_2O$ ----> $2Cr^{3+} + 7H_2O + 2NO_3^- + 6H^+$

Simplify:

$Cr_2O_7^{2-} + 2HNO_2 + 8H^+$ ----> $2Cr^{3+} + 2NO_3^- + 5H_2O$

$Cr_2O_7^{2-} + 2HNO_2 + 8H^+$ ----> $2Cr^{3+} + 2NO_3^- + 5H_2O$

(c) Ethanedioic acid crystal, $H_2C_2O_4 \cdot 2H_2O$, weighing 0.9 g was dissolved in a 0.25 dm^3 distilled water. A 25.0 cm^3 of the resulting solution required 33.0 cm^3 of potassium permanganate(VII) solution for complete reaction during a titration experiment. Calculate the concentration of potassium permanganate(VII) solution.

Reaction (in acidic medium):

$5H_2C_2O_4 + 2MnO_4^- + 6H^+ \text{---->} 2Mn^{2+} + 10CO_2 + 8H_2O$

Moles of $H_2C_2O_4 \cdot 2H_2O$:

Molar mass = (2 x 1) + (2 x 12) + (4 x 16) + (2 x 18) = 126 g mol^{-1}

Moles = 0.9 / 126 ≈ 0.00714 mol

Concentration in 0.25 dm^3 = 0.00714 / 0.25 ≈ 0.0286 M

Moles in 25.0 cm^3 (0.025 dm^3):

Moles of $H_2C_2O_4$ = 0.0286 x 0.025 = 0.000715 mol

From the equation, 5 moles of $H_2C_2O_4$ react with 2 moles of MnO_4^-:

Moles of MnO_4^- = (2 / 5) x 0.000715 = 0.000286 mol

Volume of MnO_4^- = 33.0 cm^3 = 0.033 dm^3

Concentration of MnO_4^- = 0.000286 / 0.033 ≈ 0.00867 M

The concentration of the potassium permanganate solution is approximately 0.00867 M.

(d) With a reason, predict if the reaction will occur when iodine and bromine are added to a solution containing ions of iodide and bromide both maintained at 1 M. The electrode potential for the reactions are given as follows:

$2e^- + I_2 \text{---->} 2I^-$, $E^o = +0.54$ V

$2e^- + Br_2 \text{---->} 2Br^-$, $E^o = +1.08$ V

Calculate the cell potential:

$I_2 + 2Br^- \text{---->} 2I^- + Br_2$

E_cell = E_cathode - E_anode

Cathode (reduction): $Br_2 + 2e^- \text{---->} 2Br^-$ ($E^o = +1.08$ V)

Anode (oxidation): $2I^- \text{---->} I_2 + 2e^-$ ($E^o = +0.54$ V, so reverse is -0.54 V)

$E\_cell = 1.08 - 0.54 = 0.54$ V

Since $E\_cell > 0$, the reaction is spontaneous. Br_2 will oxidize I^- to I_2, while Br^- remains unreacted.

The reaction will occur because $E\_cell = 0.54$ V is positive, indicating spontaneity; Br_2 oxidizes I^- to I_2.

5 (a) (i) What is the difference between periodicity and diagonal relationship?

Periodicity refers to the repeating trends in properties of elements across periods and down groups in the periodic table, such as atomic size, ionization energy, and electronegativity.

Diagonal relationship refers to the similarities in properties between certain pairs of diagonally adjacent elements in the periodic table, especially in the second and third periods (e.g., lithium and magnesium, beryllium and aluminum). These similarities are due to similar charge density and electronegativity.

(ii) How is tin reduced by thermal method in the reverberatory furnace? Explain briefly while supporting your answer with appropriate chemical equations.

In a reverberatory furnace, tin oxide (SnO_2) is reduced by carbon or carbon monoxide at high temperature.

$SnO_2 + 2C$ ---> $Sn + 2CO$

or

$SnO_2 + 2CO$ ---> $Sn + 2CO_2$

The carbon or carbon monoxide acts as a reducing agent to convert tin oxide into metallic tin.

5 (b) "Lithium and magnesium relate diagonally in a periodic table of elements." By giving three reasons, briefly justify this statement.

- Both lithium and magnesium form nitrides (Li_3N and Mg_3N_2), unlike other elements in their respective groups.

- Both form sparingly soluble hydroxides and carbonates, unlike their group members which form more soluble compounds.

- Both exhibit similar polarizing power due to high charge density, leading to compounds with covalent character.

5 (c) The metallic characters of the elements change across the period. Illustrate this concept with reference to chlorides and hydrides of the elements of period 3.

Across period 3 from sodium to chlorine, metallic character decreases and non-metallic character increases.

- Sodium and magnesium form ionic chlorides ($NaCl$, $MgCl_2$), which are solids with high melting points and soluble in water.

- Aluminium forms covalent $AlCl_3$, which sublimes easily and is hydrolyzed in water.

- Silicon forms $SiCl_4$, a covalent liquid that fumes in moist air due to hydrolysis.

- Phosphorus, sulfur, and chlorine form covalent molecular chlorides (PCl_3, PCl_5, S_2Cl_2, Cl_2), which are volatile and hydrolyze easily.

Hydrides also show this trend:

- Sodium and magnesium form ionic hydrides (NaH, MgH_2)

- Aluminium to chlorine form covalent hydrides like AlH_3 (unstable), SiH_4, PH_3, H_2S, HCl — low boiling, reactive gases or liquids.

6 (a) By giving a reason, arrange the following complex compounds in order of increasing their magnetic properties: $[MnCl_4]^{2-}$; $[FeF_6]^{3-}$; $[Fe(CN)_6]^{4-}$

Magnetic property depends on the number of unpaired electrons.

- $[Fe(CN)_6]^{4-}$ is low spin due to strong field ligand CN^-, Fe^{2+} has 0 unpaired electrons.

- $[FeF_6]^{3-}$ is high spin, F^- is weak field ligand, Fe^{3+} has 5 unpaired electrons.

- $[MnCl_4]^{2-}$ is also high spin, Mn^{2+} has 5 unpaired electrons. However, tetrahedral field splitting is less than octahedral, so it still shows strong magnetic property.

Order of increasing magnetic properties:

$[Fe(CN)_6]^{4-} < [FeF_6]^{3-} \approx [MnCl_4]^{2-}$

6 (b) Briefly explain the following:

(i) A concentrated aqueous copper(II) chloride solution is bright green in color but changes to light blue when diluted with water.

In concentrated solution, Cu^{2+} exists as $[CuCl_4]^{2-}$ complex which is green due to presence of Cl^- ligands. Upon dilution, Cl^- ions are replaced by water molecules forming $[Cu(H_2O)_6]^{2+}$ which is light blue.

(ii) The d orbitals for both zinc and copper contain paired electrons, but copper is considered a transition element while zinc is not.

Copper has an incompletely filled d subshell in its +2 oxidation state ($3d^9$), so it meets the definition of a transition element. Zinc in +2 state has a completely filled d subshell ($3d^{10}$), so it does not show typical transition element properties like variable oxidation states or colored compounds.

6 (c) You have been employed as a chemist in a chemical industry which plan to use transition elements as catalysts in their production. Briefly, explain four applications/uses of transition elements as catalysts. Support your answer with one chemical equation in each case.

- Iron (Fe) in Haber process: $N_2 + 3H_2 \rightarrow 2NH_3$
- Vanadium(V) oxide (V_2O_5) in Contact process: $2SO_2 + O_2 \rightarrow 2SO_3$
- Nickel (Ni) in hydrogenation of oils: $C{=}C + H_2 \rightarrow C{-}C$
- Platinum (Pt) or rhodium (Rh) in catalytic converters: $2CO + 2NO \rightarrow 2CO_2 + N_2$

Transition elements work as catalysts due to their variable oxidation states and ability to form complexes with reactants.

6 (d) (i) With an example in each case, explain two types of polymers based on physical properties.

- Thermoplastics: Soften on heating, can be reshaped. Example: Polyethylene
- Thermosetting plastics: Harden permanently after heating, cannot be reshaped. Example: Bakelite

(ii) Why Tanzania government banned the use of polymers obtained from ethylene monomers? Briefly, explain.

Polyethylene is non-biodegradable and causes environmental pollution due to accumulation in soil and water bodies. It is resistant to decomposition and harms wildlife, leading to its regulation or ban.

(iii) How does the structural differences of High Density Polythene (HDP) and Low Density Polythene (LDP) account for their differences in behaviour and nature?

HDP has linear chains with minimal branching, resulting in higher crystallinity, density, strength, and melting point. LDP has highly branched chains, leading to lower density, weaker intermolecular forces, softer texture, and lower melting point.