THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/3A **CHEMISTRY 3A**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2011**

Instructions

1. This paper consists of THREE questions.

2. Answer all questions.

1. You are provided with the following solutions:

KO: Solution containing 3.35 g of pure sodium oxalate in 0.50 dm^3 of solution

DM: Solution containing 3.20 g of impure potassium permanganate in 1 dm^3 of solution

GS: 3M sulphuric acid

Theory

An acidified oxalate solution warmed at 70°C–80°C is titrated against permanganate solution. From the titration results, the purity of the potassium permanganate can be calculated.

Balanced equation:

$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \text{-----> } 2Mn^{2+} + 10CO_2 + 8H_2O$

Procedure

(i) Pipette 25 cm^3 or 20 cm^3 of solution KO into a 250 cm^3 titration flask

(ii) Add 60 cm^3 of solution GS

(iii) Heat the mixture to about 80°C

(iv) Titrate the hot solution with the permanganate solution DM until complete colour change is observed

(v) Repeat titration and record all results

Summary:

___ cm^3 of solution KO require ___ cm^3 of solution DM for completion of the reaction

Questions

(a) Calculate the concentration of KO in moles per litre (dm^3)

Molar mass of $Na_2C_2O_4$ = 134 g/mol

Moles = 3.35 ÷ 134 = 0.025 mol

Volume = 0.50 dm^3

Concentration = 0.025 ÷ 0.5 = 0.05 mol/dm^3

(b)(i) Calculate the concentration of solution DM in moles per litre

Molar mass of $KMnO_4$ = 158 g/mol

Moles = 3.20 ÷ 158 = 0.02025 mol

Volume = 1 dm^3

Concentration = 0.02025 mol/dm^3

(ii) Concentration in g/dm^3 = 3.20 g/dm^3

(c) Calculate the percentage purity of potassium permanganate

Suppose average titre = 25.0 cm^3 of DM required for 25.0 cm^3 of KO

Moles of oxalate = 25.0 ÷ 1000 × 0.05 = 0.00125 mol

From balanced equation:

$5C_2O_4^{2-} : 2MnO_4^- \rightarrow$ 5:2 mol ratio

Moles of $KMnO_4$ = (0.00125 × 2)/5 = 0.0005 mol

Mass = 0.0005 × 158 = 0.079 g

Volume of DM = 25.0 cm^3 = 0.025 dm^3

Mass per dm^3 = 0.079 × (1000 ÷ 25) = 3.16 g/dm^3

Purity = (3.16 ÷ 3.20) × 100 = 98.75%

(d) Give the half reaction equations and indicate which species are oxidized or reduced

Oxidation ($C_2O_4^{2-}$ to CO_2):

$C_2O_4^{2-}$ -----> $2CO_2 + 2e^-$

Reduction (MnO_4^- to Mn^{2+}):

$MnO_4^- + 8H^+ + 5e^-$ -----> $Mn^{2+} + 4H_2O$

$C_2O_4^{2-}$ is oxidized, MnO_4^- is reduced.

2. You are provided with the following:

PQ: 1.6 g of anhydrous copper sulphate

MQ: 2.5 g of hydrated copper sulphate ($CuSO_4 \cdot 5H_2O$)

Procedure

(a) Set up the apparatus as shown

(b) Pour 50 cm^3 of distilled water into the polystyrene cup and measure its temperature

(c) Tip the solid PQ into water and stir gently until complete dissolution

(d) Record the maximum temperature

(e) Repeat using MQ

Results:

Let's assume:

Initial temperature = 25°C

Final temp with PQ = 30.4°C → ΔT = +5.4°C

Final temp with MQ = 21.8°C → ΔT = -3.2°C

Questions

(a) Calculate the enthalpy of solution of the two forms of the salt

(i) PQ

Moles = 1.6 ÷ 159.5 = 0.01003 mol

$Q = mc\Delta T = 50 \times 4.2 \times 5.4 = 1134$ J

$\Delta H = 1134 \div 0.01003 = 113037$ J/mol = +113.04 kJ/mol

(ii) MQ

Moles = 2.5 ÷ 249.5 = 0.01002 mol

$Q = 50 \times 4.2 \times (-3.2) = -672$ J

$\Delta H = -672 \div 0.01002 = -67066.87$ J/mol = −67.07 kJ/mol

(b) Explain the difference in the values of enthalpy of solution obtained for the two forms of the salt

PQ is anhydrous, so it releases energy when it hydrates in water (exothermic), resulting in a higher enthalpy change.

MQ is already hydrated, so its dissolution absorbs energy to break the hydration shell (endothermic), giving a negative enthalpy.

Thus, the difference is due to the hydration energy already present in MQ but absent in PQ.

3. You are provided with the following:

W_1: 0.1 M sodium hydroxide

W_2: Solution of succinic acid

W_3: Phenolphthalein indicator

W_4: Diethyl ether

Theory

At constant temperature succinic acid dissolves in both water and diethyl ether while maintaining a constant ratio of concentration in solvents under consideration.

Procedure 1

(i) Pipette 25 cm^3 or 20 cm^3 of W_2 into a clean conical flask. Add to it 2-3 drops of W_3

(ii) Put W_1 into the burette

(iii) Titrate very carefully solution W_2 against W_1 till there is a colour change. Record the volume of W_1 used.

(a) Results

(i) The volume of pipette used was ____ cm^3

(ii) Volume of W_1 used was ____ cm^3

Procedure 2

(i) Measure 100 cm^3 of W_4 using a measuring cylinder and place it into a separating funnel

(ii) Add 100 cm^3 of W_2 by means of measuring cylinder into the funnel in (i) above, shake well and allow the system to stand for a few minutes

(iii) Run off the aqueous layer into a clean beaker. Using measuring cylinder put 25 cm^3 of the aqueous layer into a clean conical flask. Titrate very carefully this aliquot against W_1 using W_3 as an indicator. Record the volume of W_1 used.

(b) Results

(i) Volume of aqueous layer taken was ____ cm^3

(ii) Volume of W_1 used was ____ cm^3

(c) Write a balanced chemical equation representing the reaction taking place in procedures (1) and (2) above

$HOOC–CH_2CH_2–COOH + 2NaOH \text{ -----> } NaOOC–CH_2CH_2–COONa + 2H_2O$

Succinic acid reacts with two moles of sodium hydroxide in neutralization.

(d) Calculate the following:

(i) Initial concentration of W_2 in water before mixing

Let volume of W_2 used = 25 cm^3

Volume of W_1 used = 20 cm^3

Concentration of W_1 = 0.1 mol/dm^3

Moles of NaOH = (0.1 × 20)/1000 = 0.002 mol

Since 2 mol NaOH react with 1 mol succinic acid:

Moles of succinic acid = 0.002 ÷ 2 = 0.001 mol

Concentration of W_2 = (0.001 × 1000) ÷ 25 = 0.04 mol/dm^3

Molar mass = 118 g/mol

Concentration in g/dm^3 = 0.04 × 118 = 4.72 g/dm^3

(ii) Final concentration of W_2 in the aqueous layer

Suppose 25 cm^3 of aqueous layer required 10 cm^3 of W_1

Moles of NaOH = (0.1 × 10)/1000 = 0.001 mol

Moles of succinic acid = 0.001 ÷ 2 = 0.0005 mol

Concentration = (0.0005 × 1000)/25 = 0.02 mol/dm^3

Concentration in g/dm^3 = 0.02 × 118 = 2.36 g/dm^3

(e) Deduce the concentration of W_2 in the organic layer

Total acid before mixing = 4.72 g

Aqueous concentration after = 2.36 g

Acid in organic = 4.72 − 2.36 = 2.36 g

Volume of ether = 100 cm^3 = 0.1 dm^3

Concentration = 2.36 ÷ 0.1 = 23.6 g/dm^3

(f) Calculate the partition coefficient of W_2 between water and diethyl ether W_4

K_d = concentration in aqueous / concentration in ether

K_d = 2.36 ÷ 23.6 = 0.1

This means succinic acid is ten times more soluble in ether than in water under the given conditions.