

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.

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1. You are provided with the following solutions:

KO: Solution containing 3.35 g of pure sodium oxalate in 0.50 dm³ of solution

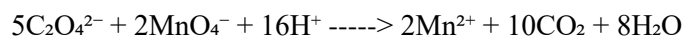
DM: Solution containing 3.20 g of impure potassium permanganate in 1 dm³ of solution

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:



Procedure

- (i) Pipette 25 cm³ or 20 cm³ of solution KO into a 250 cm³ titration flask
- (ii) Add 60 cm³ 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:

___ cm³ of solution KO require ___ cm³ of solution DM for completion of the reaction

Questions

- (a) Calculate the concentration of KO in moles per litre (dm³)

Molar mass of Na₂C₂O₄ = 134 g/mol

$$\text{Moles} = 3.35 \div 134 = 0.025 \text{ mol}$$

$$\text{Volume} = 0.50 \text{ dm}^3$$

$$\text{Concentration} = 0.025 \div 0.5 = 0.05 \text{ mol/dm}^3$$

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

$$\text{Molar mass of KMnO}_4 = 158 \text{ g/mol}$$

$$\text{Moles} = 3.20 \div 158 = 0.02025 \text{ mol}$$

$$\text{Volume} = 1 \text{ dm}^3$$

$$\text{Concentration} = 0.02025 \text{ mol/dm}^3$$

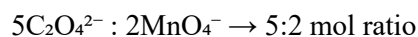
$$\text{(ii) Concentration in g/dm}^3 = 3.20 \text{ g/dm}^3$$

(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

$$\text{Moles of oxalate} = 25.0 \div 1000 \times 0.05 = 0.00125 \text{ mol}$$

From balanced equation:



$$\text{Moles of KMnO}_4 = (0.00125 \times 2)/5 = 0.0005 \text{ mol}$$

$$\text{Mass} = 0.0005 \times 158 = 0.079 \text{ g}$$

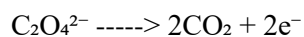
$$\text{Volume of DM} = 25.0 \text{ cm}^3 = 0.025 \text{ dm}^3$$

$$\text{Mass per dm}^3 = 0.079 \times (1000 \div 25) = 3.16 \text{ g/dm}^3$$

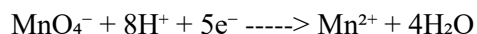
$$\text{Purity} = (3.16 \div 3.20) \times 100 = 98.75\%$$

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

Oxidation ($\text{C}_2\text{O}_4^{2-}$ to CO_2):



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



$\text{C}_2\text{O}_4^{2-}$ 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 ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)

Procedure

- Set up the apparatus as shown
- Pour 50 cm³ of distilled water into the polystyrene cup and measure its temperature
- Tip the solid PQ into water and stir gently until complete dissolution
- Record the maximum temperature
- Repeat using MQ

Results:

Let's assume:

Initial temperature = 25°C

Final temp with PQ = 30.4°C → $\Delta T = +5.4^\circ\text{C}$

Final temp with MQ = 21.8°C → $\Delta T = -3.2^\circ\text{C}$

Questions

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

(i) PQ

$$\text{Moles} = 1.6 \div 159.5 = 0.01003 \text{ mol}$$

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

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

(ii) MQ

$$\text{Moles} = 2.5 \div 249.5 = 0.01002 \text{ mol}$$

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

$$\Delta H = -672 \div 0.01002 = -67066.87 \text{ J/mol} = -67.07 \text{ kJ/mol}$$

(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:

W₁: 0.1 M sodium hydroxide

W₂: Solution of succinic acid

W₃: Phenolphthalein indicator

W₄: 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 cm³ or 20 cm³ of W₂ into a clean conical flask. Add to it 2-3 drops of W₃
- (ii) Put W₁ into the burette
- (iii) Titrate very carefully solution W₂ against W₁ till there is a colour change. Record the volume of W₁ used.

(a) Results

- (i) The volume of pipette used was ____ cm³
- (ii) Volume of W₁ used was ____ cm³

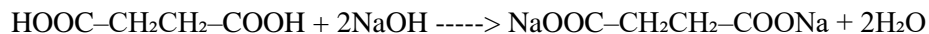
Procedure 2

- (i) Measure 100 cm³ of W₄ using a measuring cylinder and place it into a separating funnel
- (ii) Add 100 cm³ of W₂ 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 cm³ of the aqueous layer into a clean conical flask. Titrate very carefully this aliquot against W₁ using W₃ as an indicator. Record the volume of W₁ used.

(b) Results

- (i) Volume of aqueous layer taken was ____ cm³
- (ii) Volume of W₁ used was ____ cm³

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



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 = $(0.1 \times 20)/1000 = 0.002 \text{ mol}$

Since 2 mol NaOH react with 1 mol succinic acid:

Moles of succinic acid = $0.002 \div 2 = 0.001 \text{ mol}$

Concentration of W_2 = $(0.001 \times 1000) \div 25 = 0.04 \text{ mol/dm}^3$

Molar mass = 118 g/mol

Concentration in g/dm^3 = $0.04 \times 118 = 4.72 \text{ g/dm}^3$

(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 = $(0.1 \times 10)/1000 = 0.001 \text{ mol}$

Moles of succinic acid = $0.001 \div 2 = 0.0005 \text{ mol}$

Concentration = $(0.0005 \times 1000)/25 = 0.02 \text{ mol/dm}^3$

Concentration in g/dm^3 = $0.02 \times 118 = 2.36 \text{ g/dm}^3$

(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 = $100 \text{ cm}^3 = 0.1 \text{ dm}^3$

Concentration = $2.36 \div 0.1 = 23.6 \text{ g/dm}^3$

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

$K_d = \text{concentration in aqueous} / \text{concentration in ether}$

$K_d = 2.36 \div 23.6 = 0.1$

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