

THE UNITED REPUBLIC OF TANZANIA
NATIONAL EXAMINATIONS COUNCIL
ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION
132/3C **CHEMISTRY 3C**

(For Both School and Private Candidates)

Time: 3 Hours

ANSWERS

Year: 2013

Instructions

1. This paper consists of THREE questions.
2. Answer all questions.

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1. You are provided with the following:

T₃: A solution containing 0.65 g of impure potassium dichromate (K₂Cr₂O₇) in 0.10 dm³ of distilled water

T₂: A solution made by dissolving 0.04 moles of sodium thiosulphate pentahydrate (Na₂S₂O₃·5H₂O) in 0.4 dm³ of distilled water

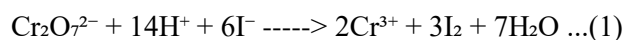
T₄: 10% potassium iodide solution

T₅: 1M sulphuric acid

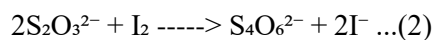
T₆: Starch solution

Theory

Acidified potassium dichromate reacts quantitatively with potassium iodide solution liberating iodine according to the equation:



The liberated iodine can be titrated against sodium thiosulphate and the reaction taking place between iodine and thiosulphate can be represented by the equation:



Procedure

- (i) Pipette 20 cm³ or 25 cm³ of solution T₁ into a clean conical flask
- (ii) Add 20 cm³ or 25 cm³ of solution T₄ followed by 20 cm³ or 25 cm³ of solution T₃ and shake the mixture
- (iii) Immediately titrate the mixture against solution T₂ from the burette until the solution becomes pale yellow
- (iv) Add about 2 cm³ of solution T₆ and continue titrating until a green colour appears
- (v) Repeat procedures (i) to (iv) three times and record your data in a tabular form

Questions

- (a) Calculate the concentration of T₂ in mol/dm³

Moles of sodium thiosulphate = 0.04 mol

Volume = 0.4 dm³

Concentration = 0.04 mol ÷ 0.4 dm³ = 0.1 mol/dm³

(b) Calculate the concentration of pure potassium dichromate in

(i) mol/dm³

(ii) g/dm³

Molar mass of K₂Cr₂O₇ = (2×39) + (2×52) + (7×16) = 294 g/mol

Mass = 0.65 g in 0.10 dm³

Concentration in g/dm³ = 0.65 ÷ 0.10 = 6.5 g/dm³

Concentration in mol/dm³ = 6.5 ÷ 294 = 0.0221 mol/dm³

(c) Find the percentage purity of potassium dichromate

Let titre volume of T₂ = V cm³

Moles of T₂ used = (0.1 × V)/1000

From equation (2), 1 mol of I₂ reacts with 2 mol of T₂

From equation (1), 1 mol of Cr₂O₇²⁻ produces 1.5 mol of I₂

So, mole ratio: 1 mol Cr₂O₇²⁻ : 3 mol I₂ : 6 mol T₂

Moles of Cr₂O₇²⁻ = (0.1 × V) / (1000 × 6) = V / 60000 mol

Mass = V / 60000 × 294 = (V × 294) ÷ 60000 g

Purity = [(V × 294) ÷ 60000] ÷ 0.065 × 100% = [(V × 294 × 100) ÷ (60000 × 0.65)]%

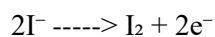
= (V × 2940000) ÷ 39000 ≈ 75.38V%

Actual purity depends on V from experimental results.

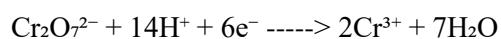
(d) Write down the half reactions for the reaction equations (1) and (2) above

Equation (1) half reactions:

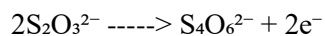
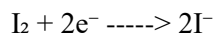
Oxidation (I^- to I_2):



Reduction ($Cr_2O_7^{2-}$ to Cr^{3+}):



Equation (2) half reaction:



2. You are provided with the following:

A₁: Distilled water

A₂: 4 g anhydrous copper (II) sulphate ($CuSO_4$)

A₃: 6 g copper (II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$)

Thermometer and Stirrer

Cotton wool

Procedure

- (i) Take 100 ml beaker and put it into a 250 cm³ beaker. Fill the space between using cotton wool as an insulator
- (ii) Pour 50 cm³ of A₁ into a 100 cm³ beaker in (i)
- (iii) Stir the water and record the temperature, T₁
- (iv) Add A₂ into a beaker containing water. Stir gently until dissolution is complete
- (v) Record the final temperature of the solution, T₂
- (vi) Clean and dry the beaker, stirrer and thermometer. Then repeat steps (i) to (v) using A₃
- (vii) Record your results in a tabular form as indicated in Table 1

Questions

- (a) Find the temperature change $T = T_2 - T_1$ in each experiment

Let's assume from the experiment:

For A₂: T₁ = 25°C, T₂ = 29.5°C → $\Delta T = 29.5 - 25 = +4.5^\circ\text{C}$

For A₃: T₁ = 25°C, T₂ = 21.3°C → $\Delta T = 21.3 - 25 = -3.7^\circ\text{C}$

So,

Temperature change for A₂ = +4.5°C

Temperature change for A₃ = -3.7°C

- (b) Calculate the enthalpy of solution of each salt, given that the specific heat of water is 4.18 Jg⁻¹K⁻¹ and the density of water is 1 g/cm³

Heat change, $Q = mc\Delta T$

$m = 50 \text{ g}$ (since 50 cm³ water, density = 1 g/cm³), $c = 4.18 \text{ Jg}^{-1}\text{K}^{-1}$

For A₂:

$$Q = 50 \times 4.18 \times 4.5 = 940.5 \text{ J}$$

$$\text{Moles of CuSO}_4 = 4 \div 159.5 = 0.0251 \text{ mol}$$

$$\Delta H = Q \div \text{moles} = 940.5 \div 0.0251 = +37475.3 \text{ Jmol}^{-1} = +37.48 \text{ kJmol}^{-1}$$

For A₃:

$$Q = 50 \times 4.18 \times (-3.7) = -772.3 \text{ J}$$

$$\text{Moles of CuSO}_4 \cdot 5\text{H}_2\text{O} = 6 \div 249.5 = 0.02405 \text{ mol}$$

$$\Delta H = -772.3 \div 0.02405 = -32118.1 \text{ Jmol}^{-1} = -32.12 \text{ kJmol}^{-1}$$

(c) Accepted values for the two experiments are:

$$\Delta H^\circ_{\text{soln}} (\text{CuSO}_4) = -66.10 \text{ kJmol}^{-1}$$

$$\Delta H^\circ_{\text{soln}} (\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = +11.30 \text{ kJmol}^{-1}$$

How do the calculated enthalpies of each salt differ from the expected values? Give reasons.

For CuSO₄: Calculated $\Delta H = +37.48 \text{ kJmol}^{-1}$ vs accepted $= -66.10 \text{ kJmol}^{-1} \rightarrow$ large difference and opposite sign.

For CuSO₄·5H₂O: Calculated $\Delta H = -32.12 \text{ kJmol}^{-1}$ vs accepted $= +11.30 \text{ kJmol}^{-1} \rightarrow$ large difference and opposite sign.

Reasons for differences:

- Heat losses to surroundings despite insulation
- Incomplete dissolution of salts
- Impurities in salts
- Inaccurate temperature readings due to rapid dissolution or evaporation
- Differences in molar mass used due to hydrated vs anhydrous forms not fully accounted

Hence, the calculated enthalpies deviate significantly due to experimental errors and heat exchange with surroundings.

3. You are provided with the following:

JJ: A solution of succinic acid in water

PP: 0.2 M sodium hydroxide

SS: Phenolphthalein indicator

OO: Diethyl ether

Theory

Ether and water are immiscible. When succinic acid is dissolved, it will distribute itself in the two liquids in such a way that

concentration of succinic acid in water / concentration of succinic acid in ether = constant.

In this experiment, you are required to determine the partition coefficient of succinic acid between water and diethyl ether at room temperature.

Procedure

Part 1

(i) Pipette 20 cm³ or 25 cm³ of JJ into a clean conical flask and add two drops of SS

(ii) Put PP into the burette and titrate it against JJ until colour change is observed. A single accurate titration is enough.

Summary:

___ cm³ of solution JJ required ___ cm³ of PP for complete reaction

Part 2

- (i) Using a measuring cylinder measure 50 cm³ of OO and transfer it into a separating funnel
- (ii) Measure 50 cm³ of JJ and transfer it into a separating funnel containing OO and then shake well. Leave the mixture to stand for about 3 minutes
- (iii) Run the lower layer (aqueous layer) into a clean beaker. Measure 20 cm³ or 25 cm³ of the aqueous layer into a conical flask. Add to it two drops of SS
- (iv) Put PP into a burette and titrate it against the aqueous layer in a conical flask until there is a colour change. Record the volume of PP used. A single accurate titration is enough.

Summary:

___ cm³ of JJ required ___ cm³ of PP for complete reaction

Questions

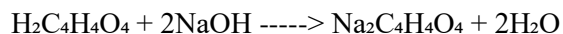
- (a) The colour of the solution during titration changed from _____ to _____

The colour of the solution changed from colourless to pink.

This is due to phenolphthalein which is colourless in acid and pink in base, indicating the endpoint of the reaction.

- (b) Write down the equation for the reaction between JJ and PP

Succinic acid (H₂C₄H₄O₄) reacts with sodium hydroxide as follows:



This shows a dibasic acid neutralised by two moles of base.

- (c)(i) Calculate the concentration of JJ before it was mixed with OO in g/dm³

Let's say from titration before mixing:

25 cm³ of JJ required 20.0 cm³ of 0.2 M NaOH

Moles of NaOH = $(0.2 \times 20.0)/1000 = 0.004$ mol

Since 2 mol NaOH reacts with 1 mol succinic acid:

Moles of succinic acid = $0.004 \div 2 = 0.002$ mol in 25 cm³

Concentration in mol/dm³ = $(0.002 \times 1000)/25 = 0.08$ mol/dm³

Molar mass of succinic acid = 118 g/mol

Concentration in g/dm³ = $0.08 \times 118 = 9.44$ g/dm³

(ii) Calculate the concentration of JJ in water after mixing with OO in g/dm³

Suppose after mixing, 25 cm³ of aqueous layer required 10.0 cm³ of 0.2 M NaOH

Moles of NaOH = $(0.2 \times 10.0)/1000 = 0.002$ mol

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

Concentration in mol/dm³ = $(0.001 \times 1000)/25 = 0.04$ mol/dm³

Concentration in g/dm³ = $0.04 \times 118 = 4.72$ g/dm³

(iii) Calculate the concentration of JJ in ether in g/dm³

Original concentration = 9.44 g/dm³

Aqueous concentration after extraction = 4.72 g/dm³

Amount transferred to ether = $9.44 - 4.72 = 4.72$ g

Volume of ether = 50 cm³ = 0.05 dm³

Concentration in ether = $4.72 \div 0.05 = 94.4$ g/dm³

(iv) Partition coefficient of succinic acid between water and ether at the temperature of the experiment

K = concentration in water / concentration in ether = $4.72 \div 94.4 = 0.05$

4. Substance M contains a common cation and two anions. Use the information given in the experiment column in Table 2 to complete the observations and inferences and hence identify the common cation and the two anions.

S/n	Experiment	Observations	Inferences		
1	Appearance	White crystalline solid	Possible presence of chloride or sulphate		
2	Perform flame test	Yellow flame	Presence of Na^+ ion		
3	To a little sample M	add Conc. H_2SO_4 and warm gently	Colourless gas with pungent smell evolved	turns blue litmus red	Presence of Cl^- ion (HCl evolved)
4(i)	Add AgNO_3 solution to first portion	White ppt formed	soluble in NH_3	Confirms Cl^- ion	
4(ii)	Add fresh FeSO_4 and conc. H_2SO_4 slowly	Brown ring formed at the junction	Presence of NO_3^- ion		
4(iii)	Add BaCl_2 solution	No ppt	Absence of SO_4^{2-}		
4(iv)	Add aqueous ammonia till excess	No ppt	Confirms Na^+ as cation (Group I	no ppt with NH_3)	
5	Perform two confirmatory tests	Confirmations for Na^+ (yellow flame)	Cl^- (white ppt with AgNO_3)	NO_3^- (brown ring)	Valid

Conclusion

The cation in the sample M is Na^+ and the anions are Cl^- and NO_3^- .