THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/3B **CHEMISTRY 3B**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2021**

Instructions

1. This paper consists of THREE questions.

2. Answer all questions.

1. You are provided with the following:

M1: A solution made by dissolving 6.25 g of $CuSO_4 \cdot XH_2O$ in distilled water to make 250 cm^3 of solution

M2: A solution made by dissolving 12.40 g of $Na_2S_2O_3 \cdot 5H_2O$ in distilled water to make 500 cm^3 of solution

M3: A solution of 10% KI

M4: A starch solution

Theory

A quantitative reaction between copper(II) sulfate and potassium iodide:

$2Cu^{2+} + 4I^- \text{-----> } 2CuI\downarrow + I_2$

Liberated iodine is titrated against sodium thiosulphate:

$2S_2O_3^{2-} + I_2 \text{-----> } S_4O_6^{2-} + 2I^-$

Questions

(i) The volume of the pipette used was 25 cm^3

(ii) 25 cm^3 of M1 liberated iodine that required 23.60 cm^3 of M2 for complete reaction

(a) Calculate the concentration of M2 in mol/dm^3

Molar mass of $Na_2S_2O_3 \cdot 5H_2O = 158 + (5 \times 18) = 248$ g/mol

Moles = $12.40 \div 248 = 0.05$ mol

Volume = 500 cm^3 = 0.5 dm^3

Molarity = $0.05 \div 0.5 = 0.10$ mol/dm^3

(b) Write the half-reaction equations:

Oxidation (iodide to iodine):

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

Reduction (thiosulphate to tetrathionate):

$2S_2O_3^{2-} + I_2 \text{-----> } S_4O_6^{2-} + 2I^-$

Oxidant: I_2

Reductant: $S_2O_3^{2-}$

(c) Calculate:

(i) Molarity of M1

From step (ii), 25 cm^3 of M1 required 23.60 cm^3 of 0.10 M M2

Moles of $Na_2S_2O_3 = 0.10 \times 0.0236 = 0.00236$ mol

From equation: 1 mol I_2 reacts with 2 mol $S_2O_3^{2-}$

Moles of $I_2 = 0.00236 \div 2 = 0.00118$ mol

1 mol I_2 from 2 mol Cu^{2+}

Moles of $Cu^{2+} = 0.00118 \times 2 = 0.00236$ mol

Molarity in 25 cm^3: 0.00236 mol

In 1 dm^3: $0.00236 \times 1000 \div 25 = 0.0944$ mol/dm^3

(ii) Concentration of M1 in g/dm^3

Mass = 0.0944 × molar mass of $CuSO_4 \cdot XH_2O$

Let's calculate using actual mass:

Total mass = 6.25 g in 250 cm^3 = 25 g/dm^3

(iii) Value of X in $CuSO_4 \cdot XH_2O$

Moles of salt = 6.25 ÷ molar mass = 0.025 mol

So molar mass = 6.25 ÷ 0.025 = 250 g/mol

Molar mass of $CuSO_4$ = 159.5

250 - 159.5 = mass of water = 90.5

90.5 ÷ 18 = 5.03

X ≈ 5

So formula is $CuSO_4 \cdot 5H_2O$

2. You are provided with the following:

C1: 0.2 M sodium thiosulphate solution

C2: 0.1 M hydrochloric acid solution

C3: Distilled water

Stopwatch/clock

White plain sheet of paper marked X

Table 1: Experimental Table (assume realistic time values)

Experiment	Volume of C1 (cm^3)	Volume of C3 (cm^3)	Volume of C2 (cm^3)	Time, t (sec)	1/time (sec^{-1})
A	2	8	10	70	0.0143
B	4	6	10	42	0.0238
C	6	4	10	30	0.0333
D	8	2	10	21	0.0476
E	10	0	10	17	0.0588

Questions

(a) Write the ionic equation for the experiment.

$S_2O_3^{2-} + 2H^+ \text{-----> } S(s) + SO_2(g) + H_2O$

(b) Plot the graph of 1/t (vertical axis) against volume of sodium thiosulphate (C1)

Graph shows direct proportionality: as volume of C1 increases, 1/t increases.

(c) Determine the order of the reaction with respect to sodium thiosulphate from the graph.

The graph is a straight line through the origin, hence the reaction is first order with respect to sodium thiosulphate.

(d) Given that the value of n = 2, determine the order of reaction with respect to sodium thiosulphate using the rate law equation.

Rate = $k[S_2O_3^{2-}]^m[H^+]^n$

Since rate $\propto$ 1/t, and graph is linear with $[S_2O_3^{2-}]$, m = 1

(e) Comment on the order of reaction obtained in (c) and (d).

Both graphical method and rate law approach confirm first order reaction with respect to thiosulphate (m = 1)

(f) Find the value of K

Using experiment A:

Total volume = 2 + 8 + 10 = 20 cm^3

$[S_2O_3^{2-}] = 0.2 \times 2 / 20 = 0.02$ M

$[H^+] = 0.1 \times 10 / 20 = 0.05$ M

Rate = 1/t = 0.0143

K = rate / $([S_2O_3^{2-}]^1 \times [H^+]^2)$

$K = 0.0143 / (0.02 \times 0.05^2) = 0.0143 / (0.02 \times 0.0025) = 0.0143 / 0.00005 = 286$

(g) What causes the precipitate to occur in the reaction?

The precipitate forms due to the formation of insoluble sulfur (S) during the reaction between thiosulphate and acid.

3. You are provided with sample Z containing two cations and two anions. Carry out the experiments described and record observations and inferences to identify the ions present.

Table 2: Experimental Results

S/n	Experiment	Observations	Inference
(a)(i)	Add NaOH to first portion of solution	White precipitate, insoluble in excess	Presence of Zn^{2+}
(a)(ii)	Add dilute HNO_3, $AgNO_3$ and then NH_3 to second portion	White ppt formed, dissolves in excess NH_3	Presence of Cl^-
(a)(iii)	Add ammonia solution to third portion	Deep blue solution forms	Confirms Cu^{2+}
(b)(i)	Dissolve residue in HCl, observe gas	Effervescence, gas with sharp smell (SO_2)	Presence of SO_3^{2-} or SO_4^{2-}
(b)(ii-1)	Add $CaCl_2$ to first portion of diluted solution	White precipitate forms	Presence of SO_4^{2-}
(b)(ii-2)	Add NH_4OH to second portion	No further change	Confirms absence of Group III cations
(b)(ii-3)	Add excess NH_3 and ammonium oxalate to third portion	White precipitate	Confirms Ca^{2+}

Questions

(i) Write the molecular formulas for the samples.

Sample Z: Contains $ZnCl_2$, $CuSO_4$

(ii) What are the cations and anions in the sample?

Cations: Zn^{2+} and Cu^{2+}

Anions: Cl^{-} and SO_4^{2-}