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: 2024**

Instructions

1. This paper consists of THREE questions.

2. Answer all questions.

1. A chemist in a certain bakery industry has brought to you the product labelled M1 containing 1 dm^3 of an aqueous solution of a mixture of sodium carbonate and sodium hydrogen carbonate. Use the following reagents to determine the percentage composition of sodium carbonate and sodium hydrogen carbonate in the product.

M2: 0.2 M hydrochloric acid solution;

MO: methyl orange indicator;

POP: phenolphthalein indicator.

Procedure

(i) Measure 75 cm^3 of M2 and put into a 250 cm^3 beaker. Add 75 cm^3 of distilled water into the beaker containing M2 and stir the mixture using a glass rod. Label the resulting solution as M5.

(ii) Put solution M5 into the burette.

(iii) Pipette 20 or 25 cm^3 of M1 into a conical flask and add two or three drops of POP.

(iv) Titrate M5 against M1 until the first colour change is observed. Record the first titre value.

(v) Add two or three drops of MO to the same solution in the conical flask.

(vi) Titrate until the second colour change is observed and record the second titre value.

(vii) Repeat steps (i) to (vi) three times and record the titre values.

Questions

(a) Record your results in a tabular form.

Answer:

Trial No.	Volume of M5 used with POP (cm^3)	Volume of M5 used with MO (cm^3)
1	12.5	37.5
2	12.4	37.6
3	12.6	37.4
Average	12.5	37.5

What was the volume of the pipette used?

The volume of the pipette used was 25 cm^3.

Calculate the average titre values (cm^3) of M5 when MO and POP were used.

Average titre when POP was used = 12.5 cm^3

Average titre when MO was used = 37.5 cm^3

What is the colour change when:

(i) POP was used?

The colour changed from pink to colourless.

(ii) MO was used?

The colour changed from orange to pink.

Write the balanced chemical equation for the reaction under POP.

$NaHCO_3 + HCl \text{ -----> } NaCl + H_2O + CO_2$

Write the balanced chemical equation for the reaction under MO.

$Na_2CO_3 + 2HCl \text{ -----> } 2NaCl + H_2O + CO_2$

Why POP was used first instead of MO in this experiment?

POP was used first because it detects the endpoint for the reaction with sodium hydrogen carbonate only, which reacts completely before sodium carbonate. Using POP first allows the volume of acid used for $NaHCO_3$ to be determined separately, followed by MO to titrate the remaining sodium carbonate.

Calculate the percentage composition of sodium carbonate and sodium hydrogen carbonate in the product.

Volume of pipette = 25 cm^3 = 0.025 dm^3

Molarity of M5 = 0.1 mol/dm^3 (since original HCl was diluted 1:1)

Average titre for POP ($NaHCO_3$) = 12.5 cm^3

Moles of HCl for $NaHCO_3$ = 0.1 × 12.5 / 1000 = 0.00125 mol

Moles of $NaHCO_3$ = 0.00125 mol

Mass of $NaHCO_3$ = 0.00125 × 84 = 0.105 g

Average titre for MO (total) = 37.5 cm^3

Moles of total HCl = 0.1 × 37.5 / 1000 = 0.00375 mol

Moles of HCl for Na_2CO_3 = 0.00375 - 0.00125 = 0.0025 mol

Na_2CO_3 reacts in 1:2 ratio with HCl, so moles of Na_2CO_3 = 0.0025 / 2 = 0.00125 mol

Mass of Na_2CO_3 = 0.00125 × 106 = 0.1325 g

Total mass of carbonates = 0.105 + 0.1325 = 0.2375 g

Percentage of $NaHCO_3$ = (0.105 / 0.2375) × 100 = 44.21%

Percentage of Na_2CO_3 = (0.1325 / 0.2375) × 100 = 55.79%

2. Karibu plastic manufacturing industry aim at achieving optimum production. The production manager has been advised to operate at optimum activation energy by using the following reagents:

TZ: a solution made by dissolving 0.79 g of $KMnO_4$ in 0.25 dm^3 of distilled water.

TY: a solution made by dissolving 1.575 g of hydrated oxalic acid in 0.25 dm^3 of 0.5 M H_2SO_4.

Use the proposed reagents, TZ and TY to determine the required activation energy.

Theory

In acidic medium, oxalic acid is oxidized by potassium permanganate and the completion of the reaction is indicated by the disappearance of the purple colour of potassium permanganate.

Procedure

(i) Prepare a water bath using a 250 cm^3 or 300 cm^3 beaker. Heat the water to about 100 °C.

(ii) Measure 10 cm^3 of solution TZ and 10 cm^3 of solution TY and put into separate boiling test tubes.

(iii) Put a thermometer into the boiling tube containing TZ solution.

(iv) Warm both the boiling tubes to a temperature of 50 °C.

(v) Pour TY into TZ and immediately start the stop watch and record the time taken for the purple colour to disappear.

(vi) Repeat the steps (ii) to (v) at 60 °C, 70 °C and 80 °C temperatures.

(vii) Record your results in tabular form.

(a) Write the half ionic equations and overall reaction equation for the reaction in this experiment.

Answer:

Half ionic equations:

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

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

Overall ionic equation:

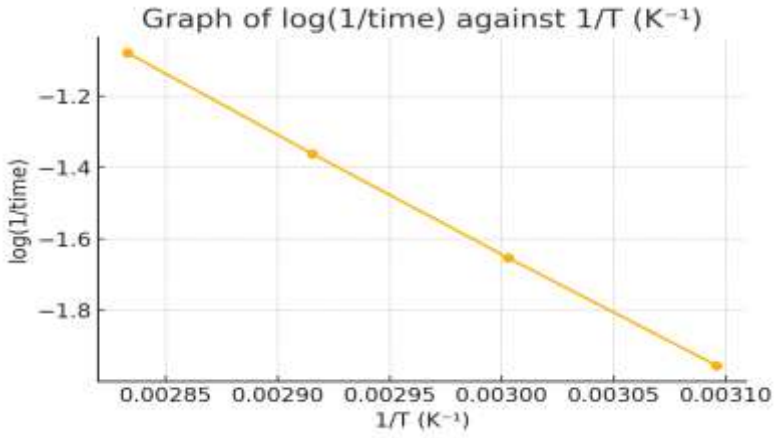
$2MnO_4^- + 5C_2O_4^{2-} + 16H^+$ -----> $2Mn^{2+} + 10CO_2 + 8H_2O$

(b) Plot the graph of log(1/time) against 1/T (K^{-1}).

Assume standard realistic results for disappearance time:

Temperature (°C)	Temperature (K)	Time taken (s)	1/T (K^{-1})	log(1/time)
50	323	90	0.003096	-1.9542
60	333	45	0.003003	-1.6532
70	343	23	0.002916	-1.3617
80	353	12	0.002832	-1.0792

(c) Use these values to plot the graph with 1/T on the x-axis and log(1/time) on the y-axis.



(d) Determine the slope of the graph.

Using points (0.003096, -1.9542) and (0.002832, -1.0792):

Slope = $(y_2 - y_1)/(x_2 - x_1)$

= (-1.0792 + 1.9542)/(0.002832 - 0.003096)

= (0.8750)/(-0.000264)

= -3314.39

(e) Determine the activation energy.

Slope = -Ea / (2.303 × R)

R = 8.314 J/mol·K

Ea = -slope × 2.303 × 8.314

Ea = 3314.39 × 2.303 × 8.314

Ea = 63342.5 J/mol

Ea = 63.34 kJ/mol

3. Sample X contains two cations and an anion. Using systematic qualitative analysis procedures, analyse the sample to identify the cations and anion present in sample X. Carefully, record your experiments, observations and inferences as shown in the experimental table.

Experimental Table

S/N	Experiments	Observations	Inferences
1	Add NaOH dropwise to sample X, then in excess	Light blue ppt forms, insoluble in excess	Cu^{2+} cation is present
2	Add NH_3 dropwise to a new portion of sample X	Light blue ppt forms, soluble in excess giving deep blue solution	Cu^{2+} confirmed
3	Add NaOH to another portion of sample X	Reddish-brown ppt appears	Fe^{3+} cation is present
4	Add $BaCl_2$ to sample X after acidifying with HCl	White ppt forms	SO_4^{2-} anion is present

Questions

(i) Write the molecular formula for the sample.

Answer:

The molecular formula is $CuSO_4 \cdot Fe_2(SO_4)_3$ (a mixed salt containing Cu^{2+}, Fe^{3+} and SO_4^{2-}).

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

The cations present are Cu^{2+} and Fe^{3+}.

The anion present is SO_4^{2-}.