

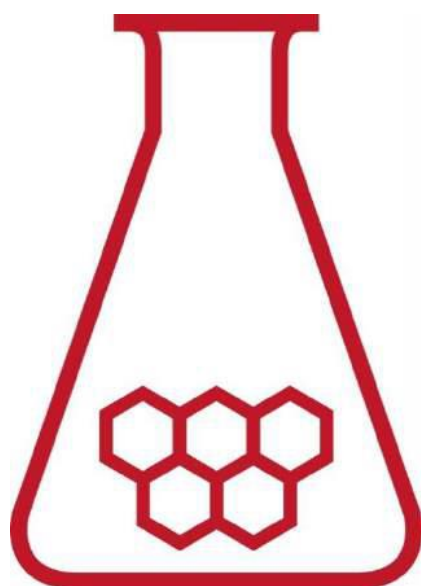
45th National Chemistry Olympiad

Maastricht University

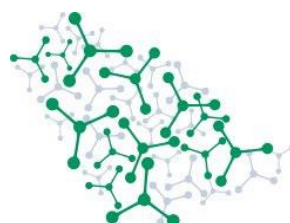
PRACTICAL TEST

Marking scheme

Thursday June 6, 2024



**SCHEIKUNDE
OLYMPIADE**



56th IChO International
Chemistry Olympiad
Saudi Arabia 2024



Maastricht University

Experiment 1 The determination of the amount of crystal water (x) in a mixture of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ and NaHCO_3

40 points

Maximum score 10

The following practical skills are assessed:

- safety, working clean and independence
- handling of the glassware

□1 Maximum score 8

- mass of the sample and the molarity of the hydrochloric acid 1
- burette readings read in two decimals 2
- difference between the two duplicates of the titrations 5

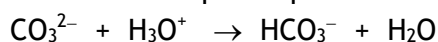
The score points for the differences between the two duplicates for each titration are determined as follows:

- If the difference in the used volume between the duplicates ≤ 0.10 mL 5
- If $0.10 \text{ mL} <$ the difference in the used volume between the duplicates ≤ 0.20 mL 4
- If $0.20 \text{ mL} <$ the difference in the used volume between the duplicates ≤ 0.30 mL 3
- If $0.30 \text{ mL} <$ the difference in the used volume between the duplicates ≤ 0.50 mL 2
- If $0.50 \text{ mL} <$ the difference in the used volume between the duplicates ≤ 0.70 mL 1
- If the difference in the used volume between the duplicates > 0.70 mL 0

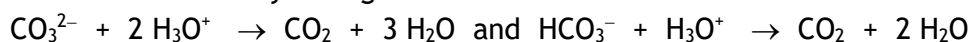
The final score is the average of the scores for both titrations.

□2 Maximum score 4

Titration with phenolphthalein:



Titration with methyl orange:



- correct reaction equation for the titration with phenolphthalein 1
- for the titration with methyl orange, correct reaction equation with the carbonate 2
- for the titration with methyl orange, correct reaction equation with the hydrogen carbonate 1

Remarks

- *When H^+ is used instead of H_3O^+ , in an otherwise correct equation, accept this as correct.*
- *When for the titration with methyl orange the equations $\text{CO}_3^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{HCO}_3^- + \text{H}_2\text{O}$ and $\text{HCO}_3^- + \text{H}_3\text{O}^+ \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$ are given, accept this as correct.*
- *When H_2CO_3 is written after the arrow in the equations for the titration with methyl orange, do not penalize this.*

□3 Maximum score 10

From the titration with phenolphthalein follows that $V_1 \times 0.1000$ mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ were present in 25.00 mL of the solution from the volumetric flask,

So $\frac{V_1 \times 0.1000}{25.00} \times 250.00$ mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ were present in the sample.

$V_2 \times 0.1000$ mmoles of H_3O^+ reacted in the titration with methyl orange. Of this amount $2 \times V_1 \times 0.1000$ mmoles reacted with $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, so the amount of mmoles of NaHCO_3 in 25.00 mL of the solution of the sample from the volumetric flask was

$V_2 \times 0.1000 - 2 \times V_1 \times 0.1000$, so $\frac{V_2 \times 0.1000 - 2 \times V_1 \times 0.1000}{25.00} \times 250.00$ mmoles of NaHCO_3

were present in the sample.

- calculation of the amount of mmoles of H_3O^+ that reacted in both titrations:
 $V_1 \times 0.1000$ and $V_2 \times 0.1000$, respectively 1
- calculation of the amount of mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ in the 25.00 mL solution:
equals $V_1 \times 0.1000$ 1
- notion that in the titration with methyl orange $2 \times V_1 \times 0.1000$ mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$
reacted 1
- calculation of the amount of mmoles of NaHCO_3 in the 25.00 mL solution 1
- conversion from the amount of mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ and NaHCO_3 in the 25.00 mL
solution to the amount of mmoles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ and NaHCO_3 in the sample: divide by
25.00 and multiply by 250.00 1
- results 5

□4 Maximum score 4

The amount of mg of H_2O in the sample is

$$m_{\text{sample}} - m_{\text{Na}_2\text{CO}_3} - m_{\text{NaHCO}_3} = m_{\text{sample}} - \text{mmoles of Na}_2\text{CO}_3 \times 105.99 - \text{mmoles of NaHCO}_3 \times 84.007$$

Thus, the amount of mmoles of H_2O in the sample is:

$$\frac{m_{\text{sample}} - \text{mmol Na}_2\text{CO}_3 \times 105.99 - \text{mmol NaHCO}_3 \times 84.007}{18.015}$$

$$\text{And } x = \frac{\text{amount of mmoles of H}_2\text{O}}{\text{amount of mmoles of Na}_2\text{CO}_3}$$

- calculation of the amount of mg of Na_2CO_3 in the sample and of the amount of mg of
 NaHCO_3 in the sample 1
- calculation of the amount of mg of H_2O in the sample 1
- calculation of the amount of mmoles of H_2O in the sample 1
- calculation of x 1

□5 Maximum score 4

An example of a correct answer is:

A solution of barium hydroxide can be used. Then HCO_3^- from the NaHCO_3 as well as CO_3^{2-} from the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ will react to BaCO_3 . In that case the titration with methyl orange does not have to be executed.

- use of a solution of barium hydroxide 1
- CO_3^{2-} from $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ reacts to BaCO_3 1
- HCO_3^- from NaHCO_3 reacts to BaCO_3 1
- conclusion 1

If an answer is given as: „A solution of barium chloride can be used. Then, CO_3^{2-} from $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ reacts to BaCO_3 . The titration with fenolftalein does not have to be executed.”

2

Remark

When an answer is given as: „A solution of barium chloride can be used. Then, CO_3^{2-} from $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ reacts to BaCO_3 . Because of that, the equilibrium of HCO_3^- will completely shift into the direction of CO_3^{2-} , that will be converted into BaCO_3 thereafter. Thus, the titration with methyl orange does not have to be executed.”, do not penalize this.

Experiment 2 Kinetic study of the decomposition of tris-(oxalato)-manganese(III) ion

40 points

Maximum score 10

The following practical skills are assessed:

- safety, working clean and independence
- handling of the glassware

□6 Maximum score 2

- times noted in sec
- absorbances noted

1

1

□7 Maximum score 2

- calculation of ΔA and Δt in both variants
- calculation of s_I and s_{II}

1

1

□8 Maximum score 8

- calculation of $\log s_1$ and $\log s_2$
- calculation of $\log [\{\text{Mn}(\text{C}_2\text{O}_4)_3\}^{3-}]_I$ and $\log [\{\text{Mn}(\text{C}_2\text{O}_4)_3\}^{3-}]_{II}$
- calculation of n
- result

1

1

1

5

□9 Maximum score 2

- answer in accordance with the calculated value of n
- motivation

1

1

□10 Maximum score 3

- calculation of ΔA , three times
- calculation of Δt , three times
- calculation of s , three times

1

1

1

□11 Maximum score 9

- calculation of the concentration of the complex at the start of each time interval
- calculation of the value of k , four times
- calculation of the average k
- correct dimension for k
- result

1

1

1

1

5

□12 Maximum score 4

An example of a correct answer is:

$(4.0 \times 0.020 =) 0.080$ mmoles of MnO_4^- and $(2.0 \times 0.20 =) 0.40$ mmoles of Mn^{2+} and $(14.0 \times 0.20 =) 28$ mmoles of $\text{H}_2\text{C}_2\text{O}_4$ are added together.

So the amount of MnO_4^- (is the limiting factor and) determines the amount of the complex ion that is formed.

So $5 \times 0.080 = 0.40$ mmol complex is formed in $(4.0 + 2.0 + 14.0 =) 20.0$ mL solution.

The concentration is $\frac{0.40}{20} = 0.020$ mol L⁻¹.

- calculation of the amount of mmoles of MnO_4^- , Mn^{2+} and $\text{H}_2\text{C}_2\text{O}_4$
- conclusion that the amount of mmoles of MnO_4^- determines the amount of mmoles of complex ion that is formed
- calculation of the amount of mmoles of complex ion that is formed
- calculation of the concentration of the complex ion at $t = 0$

1

1

1

1