

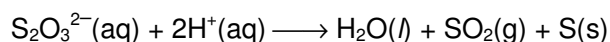
Name: () CT Group: Date:

Raffles Institution
Year 6 H2 Chemistry Practical 2014

Experiment 11: Reaction Kinetics

Worksheet Title: To determine the orders of reaction with respect to $\text{S}_2\text{O}_3^{2-}$ and H^+ using a clock reaction.

The experiment below involves the following reaction:



The rate equation can be expressed as: $\text{rate} = k [\text{S}_2\text{O}_3^{2-}]^x [\text{H}^+]^y$

where x and y are the orders of reaction with respect to thiosulfate and hydrogen ions respectively.

The aim of this experiment is to determine the

- (i) effect of changing the concentration of reactants on the rate of the reaction
- (ii) orders of reaction with respect to $\text{S}_2\text{O}_3^{2-}$ and H^+

The following is provided:

FA1 0.20 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3$ solution

FA2 2.00 mol dm^{-3} HCl solution
 deionised water

Procedure

1. Add 20.00 cm^3 of **FA1** into a 250 cm^3 beaker by means of a burette and stand it over the printed text on the insert.
2. Measure 20 cm^3 of **FA2** using a measuring cylinder provided.
3. Pour the 20 cm^3 of **FA2** into the beaker containing **FA1**, SIMULTANEOUSLY starting a stopwatch. Note the time taken, to the **nearest second**, for the printed text to become completely obscured by the sulfur produced during the reaction. (DO NOT SWIRL THE SOLUTION IN THE BEAKER)
4. Record your result in table 1.1 provided on page 2.
5. Rinse the beaker and transfer 10.00 cm^3 of **FA1** into it from the burette, together with 10 cm^3 of distilled water from another measuring cylinder.
6. Measure a further 20 cm^3 of **FA2** into the other measuring cylinder and pour this into the beaker, noting the time taken for the printed text to be completely obscured as before. Record your result in the table.
7. Repeat the experiment once more using the volumes of **FA1**, **FA2** and distilled water shown in the table, again noting the time taken for the printed text to be completely obscured by the sulfur produced.

Table 1.1 – Table of Results

Experiment	Volume of FA1 (cm ³)	Volume of FA2 (cm ³)	Volume of distilled water (cm ³)	Time taken for printed text to be completely obscured, t (s)	1/t (s ⁻¹)
1	20.00	20	0	21	0.0476
2	10.00	20	10	44	0.0227
3	20.00	10	10	22	0.0455

Answer the following questions.

- (a) Show how the concentration of thiosulfate ions in mol dm⁻³ is directly proportional to the volume of the thiosulfate ions taken for the experiment.

$$[\text{S}_2\text{O}_3^{2-}] \text{ after mixing} = (0.20 \times V_{\text{thiosulfate}}) / 0.04 = 5 V_{\text{thiosulfate}}$$

$$\Rightarrow [\text{S}_2\text{O}_3^{2-}] \text{ after mixing} \propto V_{\text{thiosulfate}}$$

Note: This relationship is kept true when total volume of reaction mixture is kept constant for all experiments (at 40 cm³ in this case).

- (b) Show how the concentration of hydrogen ions in mol dm⁻³ is directly proportional to the volume of the hydrochloric acid taken for the experiment.

$$[\text{H}^+] \text{ after mixing} = (2.00 \times V_{\text{acid}}) / 0.04 = 50 V_{\text{acid}}$$

$$\Rightarrow [\text{H}^+] \text{ after mixing} \propto V_{\text{acid}}$$

Note: This relationship is kept true when total volume of reaction mixture is kept constant for all experiments (at 40 cm³ in this case).

- (c) Show how the rate of reaction is inversely proportional to the time taken for the printed text to be obscured.

In this experiment, we are monitoring rate using the following relationship: $\text{rate} \propto \frac{d[\text{pdt}]}{dt}$

$$\text{Rate} = (\text{change in conc of S}) / (\text{time taken})$$

Since the same beaker and same total volume was used for every experiment (same depth), the concentration of sulfur required to obscure the printed text is constant.

$$\text{Rate} = \text{constant} / \text{time taken} \Rightarrow \text{Rate} \propto 1/\text{time taken}$$

- (d) Explain why it was necessary to add water in some experiments.

Water was added to keep total volume constant at 40 cm³ for all experiments.

This is to ensure that:

- Concentration \propto volume of reactants
- The depth is constant so that rate \propto 1/t

- (e) Determine the values of x and y , the orders with respect to $\text{S}_2\text{O}_3^{2-}$ and H^+ ions respectively, using your results in **Table 1.1**.

From (a), (b) and (c) above, volume of reactant added is proportional to concentration of reactant, and $1/t$ is proportional to rate.

Comparing experiments 1 and 2, when the volume of $\text{S}_2\text{O}_3^{2-}$ is doubled ($\frac{20.00}{10.00} = 2$), $1/t$ doubles ($\frac{0.0476}{0.0227} \approx 2$), and hence reaction is first order with respect to $\text{S}_2\text{O}_3^{2-}$.
 $\Rightarrow \underline{x = 1}$

Comparing experiments 1 and 3, when the volume of H^+ is doubled ($\frac{20.00}{10.00} = 2$), $1/t$ remains constant ($\frac{0.0476}{0.0455} \approx 1$), and hence reaction is zero order with respect to H^+ .
 $\Rightarrow \underline{y = 0}$

Calculate the values of ($V_{\text{FA1}} \times t$) and ($V_{\text{FA1}}^2 \times t$) for experiments 1 and 2 in **Table 1.2** below. Repeat the procedure (on page 1) for **experiment 4** and record your results in the table.

Table 1.2 – Table of Results

Experiment	Volume of FA1 (cm ³)	Volume of FA2 (cm ³)	Volume of distilled water (cm ³)	Time taken for printed text to be completely obscured, t (s)	$V_{\text{FA1}} \times t$ (cm ³ s)	$V_{\text{FA1}}^2 \times t$ (cm ⁶ s)
1	20.00	20	0	21	420	8400
2	10.00	20	10	44	440	4400
4	15.00	20	5	28	420	6300

Answer the following questions.

- (f) What can you deduce if
- (i) the time taken, t , for all three experiments are constant.

If the order of reaction w.r.t. $\text{S}_2\text{O}_3^{2-}$ is zero, then $\text{rate} = k[\text{S}_2\text{O}_3^{2-}]^0$

Since rate is inversely proportional to time taken, t , hence

$1/t = k'$ (where k' is a constant)

$t = 1/k' = \text{constant}$

Deduction: Reaction is zero order w.r.t. $\text{S}_2\text{O}_3^{2-}$ when the time taken, t , for all experiments are constant.

(ii) the values of $V_{FA1} \times t$ for all three experiments are constant.

If the order of reaction w.r.t. $S_2O_3^{2-}$ is 1, then rate = $k[S_2O_3^{2-}]$

Since concentration of $S_2O_3^{2-}$ is proportional to its volume, V_{FA1} , and rate is inversely proportional to time taken, t , hence

$$1/t = k'V_{FA1} \text{ (where } k' \text{ is a constant)}$$

$$V_{FA1}t = 1/k' = \text{constant}$$

Deduction: Reaction is first order w.r.t. $S_2O_3^{2-}$ when the values of $V_{FA1} \times t$ for all experiments are constant.

(iii) the values of $V_{FA1}^2 \times t$ for all three experiments are constant.

If the order of reaction w.r.t. $S_2O_3^{2-}$ is 2, then rate = $k[S_2O_3^{2-}]^2$

Since concentration of $S_2O_3^{2-}$ is proportional to its volume, V_{FA1} , and rate is inversely proportional to time taken, t , hence

$$1/t = k'V_{FA1}^2 \text{ (where } k' \text{ is a constant)}$$

$$V_{FA1}^2t = 1/k' = \text{constant}$$

Deduction: Reaction is second order w.r.t. $S_2O_3^{2-}$ when the values of $V_{FA1}^2 \times t$ for all experiments are constant.

(g) Deduce the order of reaction with respect to $S_2O_3^{2-}$ using your results in **Table 1.2**.

It is first order with respect to $S_2O_3^{2-}$ as the values of $V_{FA1} \times t$ are approximately constant.