

Calculating Reaction Rate Between Sodium Thiosulphate and Hydrochloric Acid Coursework

In this experiment I will be seeing how the concentration of Sodium Thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$, and Hydrochloric Acid, HCl , affects the rate of the reaction. In this reaction the solution turns milky yellow as sulphate is displaced and forms a solid precipitate.



The Rate of a reaction can be represented as: $\frac{\Delta \text{concentration}}{\Delta \text{time}}$ and so is the time taken for the reactants to be used up. Therefore I will be investigating if either:

$$\text{Rate} \propto [\text{Na}_2\text{S}_2\text{O}_3]^X \quad \text{or/and} \quad \text{Rate} \propto [\text{HCl}]^Y$$

where X and Y are the orders of the reaction.

To calculate the rate equation and orders of the reaction I am going to use the log function:

$$\begin{array}{ll} \text{As} & \text{Rate} \propto [\text{Na}_2\text{S}_2\text{O}_3]^X \quad \text{and} \quad \text{Rate} \propto [\text{HCl}]^Y \\ & \text{Rate} = k_1 \times [\text{Na}_2\text{S}_2\text{O}_3]^X \quad \text{Rate} = k_2 \times [\text{HCl}]^Y \end{array}$$

$$\begin{array}{ll} \text{Take logs} & \log \text{Rate} = \log k_1 + X \log [\text{Na}_2\text{S}_2\text{O}_3] \quad \log \text{Rate} = \log k_2 + Y \log [\text{HCl}] \\ \text{eq. of line} & Y = C + M X \quad Y = C + M X \end{array}$$

This shows how the power, and order of the reaction, can be found by drawing a graph of $\log \text{Rate}$ against $\log [\text{concentration}]$ and the gradient of the line will give the order of the reaction. The two equations can then be put together to give an overall rate equation:

$$\text{Rate} = k \times [\text{Na}_2\text{S}_2\text{O}_3]^X [\text{HCl}]^Y$$

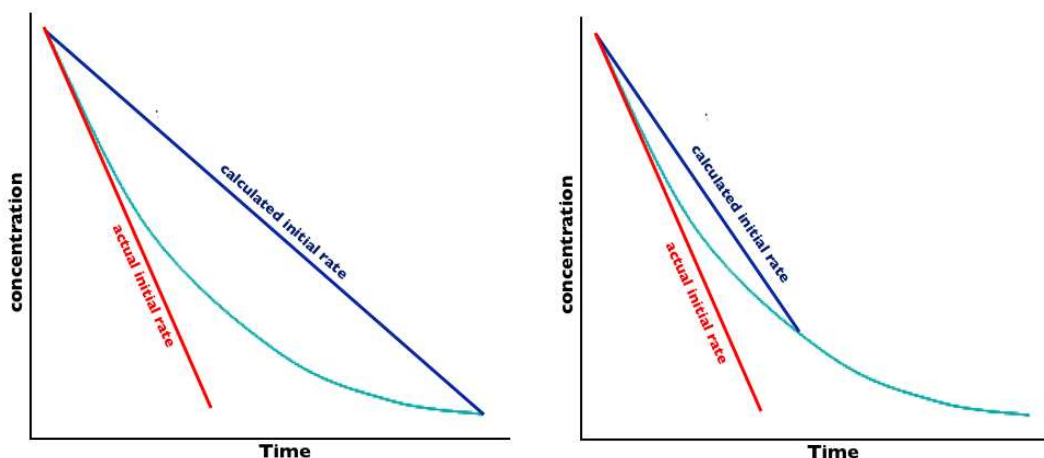
Experimentally I will be changing the concentrations of each of the reactants independently and then calculating the rate for each concentration. From these rates I will be able to draw a log graph of rate against concentrations and from my calculation I can find the orders for each of the reactants.

Variables

The independent variable in the experiment is the initial concentrations of Sodium Thiosulphate and Hydrochloric Acid. I will be changing this variable and seeing how it affects the time taken for the reaction to take place and therefore how the concentration affects the rate of the reaction. However as only one variable can be changed I will keep one reactant constant whilst changing the other to get a fair set of results. This will show me the effect of each reactant on the rate independently.

The dependent variable is the one that will be monitored in the reaction. The dependent variable is the time taken for the reaction to take place which can be used to calculate the rate of the reaction. The method I will be using is by seeing how long it takes for a black cross underneath the conical flask to disappear which will be the point in all the reactions where the concentration of the sulphur precipitate is equal and so will the rate can be fairly

calculated. To reduce errors I will need to use my preliminary results to find a volume that will give a long enough time to measure accurately, but not too long to affect the rate which is calculated by dividing initial concentration by time.



These graphs show how if the time taken for the reaction to reach a specific concentration is too long it will not be a true reflection on the actual initial rate of the reaction.

The first variable that must be controlled is the temperature of the reactions. This is because temperature will affect the rate of the reaction as a higher temperature will cause an increase in the rate. If the temperature varies between reactions it will have an effect on the results. To try and insure the same temperature is used I will have all reactants at room temperature and carry out all the reactions in one lesson. Another control is the volume of reactants used and the depth of the solution. If this is changed the amount of precipitate that will need to be observed through will change and therefore the concentration at which the cross 'disappears' will be different. To control this the same volumes will be used and the same conical flask will be used and therefore the depth will be the same. Similarly the cross used will need to be the same as a thicker cross would mean it will disappear at a different concentration of sulphur and the results will not be fair. Finally I will not shake or move the conical flask once the reactants have been put together as this again might affect the rate of the reaction.

Equipment

1. 200cm³ of Na₂S₂O₃
1. 200cm³ of HCl
2. 10 x 50cm³ beakers
3. 2 x Graduated Pipettes
4. Conical Flask
5. Stopwatch

Method

1. Start by making the concentrations, using a graduated pipette measure out the correct volumes of Sodium Thiosulphate and put into 5 small 50cm³ beakers. Then add the corresponding amounts of distilled water and label with the correct concentration.
2. Secondly draw a black cross onto a piece of paper which is no bigger than the base of the conical flask, place the conical flask on top of the flask.
3. Using another graduated pipette, place 25cm³ of 2M hydrochloric acid into the bottom of the conical flask.
4. Whilst standing above the conical flask, looking directly down, simultaneously pour the first concentration of Na₂S₂O₃ into the conical flask and start the stopwatch.
5. Keep observing and when the yellow precipitate causes the cross to completely disappear stop the stopwatch.
6. Record the time taken, wash out the conical flask thoroughly and repeat from step 3 but using the next dilution until all the concentrations have been reacted and recorded.
7. Repeat all results and average times .
8. Secondly replace the Sodium Thiosulphate with the HCl and copy above steps by measuring out correct concentrations and place into 5 more 50cm³ beakers.
9. This time add 25cm³ of Na₂S₂O₃ into the bottom of the conical flask before recording the time taken for the cross to disappear again, for all the concentrations.
10. Repeat all results again for HCl concentrations.

Initial Rates can then be calculated.

Dilution Tables

Na ₂ S ₂ O ₃ Concentration / moldm ⁻³	Na ₂ S ₂ O ₃ (1M) / cm ³	Distilled Water / cm ³
1.0	20	0
0.8	16	4
0.6	12	8
0.4	8	12
0.2	4	16

HCl Concentration / moldm ⁻³	HCl (2M) / cm ³	Distilled Water / cm ³
2.0	20	0

HCl Concentration / mol dm^{-3}	HCl (2M) / cm^3	Distilled Water / cm^3
1.6	16	4
1.2	12	8
0.8	8	12
0.4	4	16

Safety Points

As concentrated Hydrochloric acid will be used make sure eye and hand protection is worn. In case of contact, immediately flush skin with plenty of water for at least 15 minutes and with eye contact get medical attention immediately. Sulphur is also present so make sure the room is well ventilated to allow fumes to escape. Take care with glass wear, such as pipettes as they are fragile and may break easily. If broken clear up all glass immediately.

	Time Taken for Cross to Disappear / s					
Concentration of $\text{Na}_2\text{S}_2\text{O}_3$ / mol dm^{-3}	1	2	Average	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$	logRate / $\log \text{mol dm}^{-3} \text{s}^{-1}$	logconc. / $\log \text{mol dm}^{-3}$
1.0	9.21	9.46	9.34	0.107	-0.971	0.000
0.8	13.71	14.00	13.86	0.072	-1.142	-0.097
0.6	17.43	17.21	17.32	0.058	-1.237	-0.222
0.4	23.66	22.71	23.19	0.043	-1.367	-0.398
0.2	49.78	50.12	49.95	0.020	-1.699	-0.699

	Time Taken for Cross to Disappear / s			
Concentration of HCl / mol dm^{-3}	1	2	Average	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$
2	7.25	9.47	8.36	0.120
1.6	9.03	9.09	9.06	0.110
1.2	8.88	8.76	8.86	0.113
0.8	9.09	8.42	8.76	0.113
0.4	9.37	8.67	9.02	0.111

Analysis

After drawing a graph of logRate against logConcentration and using the calculations in my plan, the gradient of the line gave me a value of 0.957 which taking into account experimental error shows the order of the reaction of Sodium Thiosulphate is 1. Also when carrying out the investigation for how the rate changes with the concentration of HCl there is no noticeable change in rate when the concentration varies. Therefore I didn't draw a graph, as the table shows HCl concentration doesn't affect the rate of the reaction and must be zero order. I can therefore deduce that the rate equation for this reaction is:

$$\text{Rate} \propto [\text{Na}_2\text{S}_2\text{O}_3]^1 \quad \text{and} \quad \text{Rate} \propto [\text{HCl}]^0$$
$$\text{Rate} = C \times [\text{Na}_2\text{S}_2\text{O}_3]$$

where C is a constant which is proportional to the rate constant. The reason why the actual rate constant, k, can be calculated is because in the experiments the change in concentration cannot be calculated. However this always the same value as it is the concentration at which the cross disappeared and therefore the rate was proportional to 1/time. The intercept of the graph is equal to logC, -1.02, therefore $C = 10^{-1.02} = 0.095\text{s}^{-1}$.

To conclude the results show that the rate of the reaction between Sodium Thiosulphate and Hydrochloric Acid is directly proportional to the concentration of Sodium Thiosulphate. This gives evidence to the mechanism of the reaction. In most reactions the mechanism is not made up of one step but a series of intermediate stages where molecules form and break down. Each of these steps will have a rate which is due to how many molecules are colliding. For example if 2 molecules must collide to form one product the reaction will be 2nd order. However the overall order for the reaction cannot be calculated using the stoichiometry in the overall equation. This is because the rate is determined by the rate of the slowest step of the mechanism, known as the rate determining step. In this reaction although 2HCl molecules are needed for the reaction to take place; however from the kinetics that I found HCl has no effect on the rate and is zero order. Therefore the slowest step in this reaction is the breakdown of 1 Sodium Thiosulphate molecule as the reaction is 1st order.

Evaluation

I feel the results I obtained allowed me to draw a graph and come to valid conclusions and be confident about calculating the order and rate equation for this reaction. I didn't have any obvious anomalies from my graph however there are some variations that meant I couldn't calculate a rate of exactly 1. Also from my table of results for changing the concentration of HCl, where all the rates must be the same for different concentrations, there is an anomaly with the 2.0mol dm^{-3} concentration.

A limitation of my procedure was the way in which the rate was calculated using the disappearing cross method. This involves human judgement rather than a qualitative value that can be used to calculate the rate. There will also be an accuracy issue as there is a reaction time in realising the cross has disappeared and stopping the stopwatch. Another limitation of the procedure at the start of the timing and I had to add the chemicals together and start the stopwatch. This again causes an error in the actual time period taken for the cross to disappear. Another error is in the variation of temperature. As well as environmental variations in temperature the reaction was exothermic and heat is produced. When the temperature increases the k constant will increase, this is because the molecules have more kinetic energy and there is a higher probability that they will collide and react. This means it is hard to control this factor which is affecting the rate of the reaction.

There are also many accuracy errors caused by percentage error in measuring. There is a time error in the time taken when the cross disappears and the delay in stopping the time. When using the graduated cylinder there was an error of $0.05/20 = 0.25\%$ error, human reaction time is about $0.2/9.34 = 2.1\%$. To reduce this error I would choose another method of measuring the rate. Instead of using the cross method I would use a light intensity machine that could measure the change in colour over a period of time and stop and start timing when it had reached a certain value. This quantitative method of measuring should make the results more accurate. To control the temperature I could use a large water bath which could control the temperature throughout the reaction. Another method that could be used is to measure the products formed. The easiest would be using a gas syringe to measure the amount of SO_2 formed. This again would give more quantitative results and increase the accuracy and reliability.