Investigating the effect of concentration on the sodium thiosulfate clock reaction

TEACHERS’ AND TECHNICIANS’ NOTES

Specification reference: C2.4.1 Rates of reaction

(e) Increasing the concentration of reactants in solutions increases the frequency of collisions and so increases the rate of reaction.

Learning objective
- To investigate how changing the concentration of a reactant affects the rate of a reaction.

Description of activity
This is a practical activity that students can carry out in pairs or small groups to investigate how changing the concentration of a reactant affects the rate of a reaction.

Sodium thiosulfate reacts with acid to produce a precipitate of sulfur:

\[ \text{Na}_2\text{S}_2\text{O}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{SO}_2 + \text{S} \]

The reaction is not immediate, so timing how long it takes for the sulfur to obscure a cross marked on a piece of paper can be used to measure the reaction rate. Hence this is a ‘clock’ reaction.

A suggested method for the practical is provided on the accompanying worksheet.

The method could also be adapted to look at the effect of temperature on the rate of a reaction.

How Science Works

The following aspects can be addressed:
- Consider the precision of the measured data (4.3.2e)
- Choosing the most appropriate form of presentation (4.4.2c)
- Describing the relationship between two variables (4.5.2d)
- Evaluating methods of data collection (4.5.4d)

Resources
- Dilute hydrochloric acid (1.00 mol dm\(^{-3}\))
- Sodium thiosulfate solution (\(\text{Na}_2\text{S}_2\text{O}_3\cdot5\text{H}_2\text{O}\) at 40 g dm\(^{-3}\))
- 50 or 100 cm\(^3\) measuring cylinders (or syringes)
- 5 or 10 cm\(^3\) measuring cylinders (or syringes)
- 100 cm\(^3\) conical flasks (or beakers)
- Stopwatch

Practical tips
- If you are working with a group who can be trusted to use syringes safely, this can save a considerable amount of time.
- Separate measuring cylinders (or syringes) must be used for the hydrochloric acid and sodium thiosulfate solution to ensure that the reaction is not started prematurely.

Health and safety
- Both solutions are low risk at this low concentration, but should be regarded as potentially irritant.
Small amounts of sulfur dioxide gas are released but, at these low concentrations, should cause no problems.
Wash hands at the end of the practical.

Timing
Approximately 40 min

Different approaches
Support students by allowing them to simply record and plot the time taken for the cross to disappear. They could be provided with a blank graph on which the axes have already been scaled and labelled. Extend students by getting them to work out the rate of the reaction, and to plot this, with the appropriate units.

Answers to evaluation questions on the students' worksheet

Analysis
This is a continuous variable so a line graph should be drawn. The volume of sodium thiosulfate solution used is proportional to its concentration, so either the volume or concentration can be plotted in this analysis. (Concentrations can be determined from working out how much the original sodium thiosulfate solution has been diluted each time.)
- Plotting volume of sodium thiosulfate solution (or concentration) against time gives a smooth curve.
- Plotting volume of sodium thiosulfate solution (or concentration) against rate (1/time) gives a passable straight line.
  1. The volume (or concentration) of sodium thiosulfate solution
  2. Continuous
  3. The time it takes for cross to be no longer visible
  4. The temperature, total volume, depth of liquid, the volume (or concentration) of hydrochloric acid etc
  5. There are several ways that the student could describe this, but basically the solution goes cloudy, going from white through cream to yellow, obscuring the cross. There is also a sharp smell (due to the production of sulfur dioxide).

Answer to extension question
There are several ways that the student could describe this, but the most straightforward and safe way is to warm the sodium thiosulfate solution to different recorded starting temperatures before adding the hydrochloric acid. It is not practical to keep the reaction mixture at a specified temperature each time.

Useful links
http://www.chemguide.co.uk/physical/basicrates/concentration.html
This site gives a good overview of the effect of concentration on reaction rates.
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/chemreac/ratesrev1.shtml
BBC Bitesize provides some useful general information about rates of reaction.
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STUDENTS’ WORKSHEET

Aim
- To investigate how changing the concentration of a reactant affects the rate of a reaction.

Method
1. Wear eye protection.
2. Draw a bold cross on a piece of paper.
3. Place a 100 cm$^3$ conical flask on the cross.
4. Using a measuring cylinder pour 50 cm$^3$ of sodium thiosulfate solution into the flask.
5. Measure out 5 cm$^3$ of dilute hydrochloric acid in another measuring cylinder. Keep this measuring cylinder for use with only the hydrochloric acid.
6. At the same time, start the stopwatch and add the dilute hydrochloric acid to the flask. Quickly, swirl the flask to mix the contents. Put it back on the cross.
7. When it is just no longer possible to see the cross through the solution, stop the stopwatch.
8. Record the time in your results table.
9. Wash out your conical flask.
10. Repeat steps 4 – 9, but use 40 cm$^3$ of sodium thiosulfate solution and 10 cm$^3$ of distilled water.
11. Repeat steps 4 – 9, but use 30 cm$^3$ of sodium thiosulfate solution and 20 cm$^3$ of distilled water.
12. Repeat steps 4 – 9, but use 20 cm$^3$ of sodium thiosulfate solution and 30 cm$^3$ of distilled water.
13. Repeat steps 4 – 9, but use 10 cm$^3$ of sodium thiosulfate solution and 40 cm$^3$ of distilled water.
14. If time permits you could repeat each experiment and calculate a mean.

Health and safety
- Both solutions are low risk at this low concentration, but should be regarded as potentially irritant.
- Small amounts of sulfur dioxide gas are released but, at these low concentrations, should cause no problems.
- Wash hands at the end of the practical.

Results
Design a suitable results table to show your observations and the data you are going to record.

Analysis
Present your results using the most suitable form of chart or graph.

Evaluation questions
1. What is the independent variable in this investigation?
2. Is this variable categoric or continuous?
3. What is the dependent variable in this investigation?
4. Name one control variable you used.
5. Describe the observations that you made during the experiments.

Extension work
Suggest how this experiment could be modified to investigate the effect of temperature on the rate of this reaction.