Investigation of how the rate of a reaction changes with temperature:

To investigate how the rate of the reaction of sodium thiosulfate with hydrochloric acid changes as the temperature of the reaction is changed.

Student sheet

Sodium thiosulfate reacts with hydrochloric acid according to the equation

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + S(s)$$

The reaction produces a precipitate of sulfur. The rate of this reaction can be monitored by measuring the time taken for a fixed amount of sulfur to be produced. An easy method to do this is by timing how long it takes for a cross, marked under the bottom of the reaction vessel, to disappear as it is obscured by the sulfur precipitate.

Dilute hydrochloric acid will be added to sodium thiosulfate solution at different temperatures in a series of experiments.

This table shows the approximate temperatures for five experiments.

Experiment	1	2	3	4	5
Approximate temperature/°C	room*	~25	~35	~45	~55**

[* The temperature of the room is likely to be 15 to 18 °C]

[** The temperature must **not** exceed 55 °C]

It is not necessary for these exact temperatures to be used although the temperature used must **not** exceed 55 °C. However, the actual temperature at which each experiment is carried out must be known as accurately as possible. One way that this can be achieved is to measure both the initial temperature and the final temperature and then use a mean temperature when plotting your graph.

Requirements

You are provided with the following:

- thermometer
- 400 cm^3 beaker (for use as a water bath)
- plastic container with lid
- 2 glass tubes to hold 12–14 cm^3 of liquid
- 0.05 mol dm^{-3} sodium thiosulfate solution
- 1.0 mol dm^{-3} hydrochloric acid (or 0.5 mol dm^{-3} sulfuric acid)
- 10 cm^3 measuring cylinder
- plastic graduated pipette
- stopwatch
- graph paper.

Suggested method

a) Add about 10 cm^3 of 1 mol dm^{-3} hydrochloric acid (or 0.5 mol dm^{-3} sulfuric(VI) acid) to the 'acid' tube. Place this tube into the correct hole in the plastic container (ie the one without the cross under it).
b) Use a measuring cylinder to add 10.0 cm^3 of 0.05 mol dm^{-3} sodium thiosulfate solution to the second tube. Place this tube into the correct hole in the plastic container (ie the one with the cross under it) and carefully place a thermometer in this tube.
c) Note the start temperature and then add 1 cm^3 of the acid to the thiosulfate solution and start timing.
d) Look down through the tube from above and record the time for the cross to disappear from view.
e) Record the temperature of the reaction mixture. Pour the cloudy contents of the vial into the sodium carbonate solution (the 'stop bath').
f) Now add water from a very hot water tap (or kettle) to the plastic container. The water should be no hotter than 55 °C. Add cold water if necessary.
g) Measure another 10.0 cm^3 of 0.05 mol dm^{-3} sodium thiosulfate solution into a clean tube. Insert this tube into the correct hole in the plastic container (ie the one with the cross under it).
h) Leave the tube to warm up for about 3 minutes.
i) Repeat steps (c) to (e) above.
j) Repeat to obtain results for at least 5 different temperatures in total.

Analysing the data

In these experiments at different temperatures, the concentrations of all the reactants are the same. You are investigating the time taken to produce the same amount of sulfur at different temperatures. If you were to plot a graph of the amount of sulfur produced against time, it would initially be a straight line because the reaction has only just started. Therefore,

the initial rate of reaction = (amount of sulfur)/time

so the initial rate of reaction is proportional to 1/time ($\frac{1}{t}$).

AS analysis

- calculate the mean temperature of each reaction mixture
- for each of the five temperatures, calculate $\frac{1}{t}$ to 3 significant figures, where t is the time taken for the cross to be obscured
- plot a graph of $\frac{1}{t}$ on the *y*-axis against average temperature
- the plotting of the points may be more straightforward if you multiply all of the values for $\frac{1}{t}$ by a common factor (eg 10^4).

A-level analysis

The rate constant for a reaction varies with temperature according to the following equation, where T is the temperature in **kelvins**:

$$k = Ae^{-Ea/RT}$$

taking natural logarithms

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

In this experiment, the rate constant is directly proportional to $\frac{1}{t}$. Therefore

$$\ln \frac{1}{t} = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \text{constant}$$

- plot a graph of $\ln\frac{1}{t}$ on the *y*-axis against $\frac{1}{T}$
- the graph should be a straight line with gradient $-\frac{E_a}{R}$ so measure the gradient
- calculate a value for the activation energy and express your answer in kJ mol^{-1}
- R = 8.31 J K^{-1} mol^{-1}