# Chemistry PAG 8: Measuring rates of reaction

# Combined Science PAG C5: Measuring rates of reaction

# Suggested Activity 2: The disappearing cross

## Instructions and answers for teachers & technicians

These instructions cover the learner activity section which can be found on [page 12](#_Learner_Activity_1). This Practical activity supports OCR GCSE Chemistry and Combined Science.

**When distributing the activity section to the learners, either as a printed copy or as a Word file, you will need to remove the teacher instructions section.**

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| This is a **suggested** practical activity that can be used as part of teaching the GCSE (9-1) Gateway Science (A) and Twenty First Century Science (B) specifications.  These are **not controlled assessment tasks**, and there is **no requirement to use these particular activities**.  You may modify these activities to suit your learners and centre. Alternative activities are available from, for example, [Royal Society of Biology](https://www.rsb.org.uk/education/teaching-resources/secondary-schools), [Royal Society of Chemistry](http://www.rsc.org/learn-chemistry), [Institute of Physics](http://www.iop.org/education/teacher/resources/index.html), [CLEAPSS](http://science.cleapss.org.uk/) and [publishing companies](https://global.oup.com/education/content/secondary/key-issues/gcse_science_2016/?region=uk), or of your own devising.  Further details are available in the [specifications](http://www.ocr.org.uk/science) (Practical Skills Topics), and in these [videos](https://www.youtube.com/playlist?list=PLBD9B84FF4BD54AA4). |

**OCR recommendations:**

**Before carrying out any experiment or demonstration based on this guidance, it is the responsibility of teachers to ensure that they have undertaken a risk assessment in accordance with their employer’s requirements, making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.**

**CLEAPSS resources are useful for carrying out risk-assessments: (**<http://science.cleapss.org.uk>**).**

**Centres should trial experiments in advance of giving them to learners. Centres may choose to make adaptations to this practical activity, but should be aware that this may affect the Apparatus and Techniques covered by the learner.**

### Introduction

In this activity, learners can investigate the effect of concentration on the rate of reaction between hydrochloric acid and sodium thiosulfate. This is a commonly used practical that can cause concern due to the production of sulfur dioxide. This activity has been adapted from a CLEAPSS resource and has the following advantages:

* reduced scale – volumes about one fifth of those normally used
* use of a stop-bath – neutralises the acid and dissolves the sulfur dioxide
* experimental setup is constrained, minimising the chances of spills

This resource is adapted from the CLEAPSS experiment ‘The thiosulfate-acid reaction’– <http://science.cleapss.org.uk/Resource-Info/PP041-The-thiosulfate-acid-reaction-rate-and-concentration.aspx>

In addition to other practical activities [available from OCR](http://www.ocr.org.uk/qualifications/gcse-gateway-science-suite-chemistry-a-j248-from-2016/#resources), suggested practical activities that fit into PAG 8 include:

* [The rate of reaction of magnesium with hydrochloric acid](http://www.rsc.org/learn-chemistry/resource/res00001916/the-rate-of-reaction-of-magnesium-with-hydrochloric-acid?cmpid=CMP00006119) from the Nuffield Foundation / Royal Society of Chemistry Practical Chemistry Project
* [Exothermic or endothermic](http://www.rsc.org/learn-chemistry/resource/res00000406/exothermic-or-endothermic?cmpid=CMP00005103) from the Nuffield Foundation / Royal Society of Chemistry Practical Chemistry Project
* [The effect of temperature on reaction rate](http://www.rsc.org/learn-chemistry/resource/res00000448/the-effect-of-temperature-on-reaction-rate?cmpid=CMP00000518) from the Royal Society of Chemistry Classic Chemistry Experiments

### DfE Apparatus and Techniques covered

The codes used below match the OCR Practical Activity Learner Record Sheet ([**Chemistry**](https://www.ocr.org.uk/Images/295630-gcse-chemistry-student-record-sheet.doc) / [*Combined Science*](http://www.ocr.org.uk/Images/304431-gcse-combined-science-learner-record-sheet.doc)) and Trackers ([**Chemistry**](http://www.ocr.org.uk/Images/323481-gcse-chemistry-practical-tracker.zip) / [*Combined Science*](http://www.ocr.org.uk/Images/323483-gcse-combined-science-practical-tracker.zip)) available online. **There is no requirement to use these resources.**

**1** [*1*]: Use of appropriate apparatus to make and record a range of measurements accurately, including: **ii** [*iv*]) time; **iv** [*vi*]) volume of liquids

**3** [*8*]: Use of appropriate apparatus and techniques for: i) conducting and monitoring chemical reactions

**5** [*10*]: Making and recording of appropriate observations during chemical reactions including: iii) the measurement of rates of reaction by a variety of methods such as colour change

**6** [*11*]: Safe use and careful handling of gases, liquids and solids, including: i) careful mixing of reagents under controlled conditions; ii) using appropriate apparatus to explore chemical changes and/or products

### Aims

To investigate the effect of concentration on the rate of reaction between acid and sodium thiosulfate.

### Intended class time

20-25 minutes

### Links to Specifications:

### Gateway Science (Suite A) – including Working Scientifically (WS)

CM5.2i arithmetic computation, ratio when measuring rates of reaction

CM5.2iv proportionality when comparing factors affecting rate of reaction

C5.2a suggest practical methods for determining the rate of a given reaction

C5.2b interpret rate of reaction graphs

C5.2c describe the effect of changes in temperature, concentration, pressure, and surface area on rate of reaction

C5.2d explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles

C5.2f describe the characteristics of catalysts and their effect on rates of reaction

C5.2h explain catalytic action in terms of activation energy

WS1.1b use models to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts

WS1.2e evaluate methods and suggest possible improvements and further investigations

WS1.3a presenting observations and other data using appropriate methods

WS1.3b translating data from one form to another

WS1.3c carrying out and representing mathematical and statistical analysis

WS1.3e interpreting observations and other data

WS1.3f presenting reasoned explanations relating data to hypotheses

WS1.3g evaluating data in terms of accuracy, precision, repeatability and reproducibility

WS1.3h identifying potential sources of random and systematic error

WS1.4a use scientific vocabulary, terminology and definitions

WS1.4c use SI units and IUPAC chemical nomenclature unless inappropriate

WS1.4f use an appropriate number of significant figures in calculation

WS2a carry out experiments

WS2b make and record observations and measurements using a range of apparatus and methods

WS2c presenting observations using appropriate methods to include descriptive, tabular diagrammatic and graphically

### Twenty First Century Science (Suite B) – including Ideas about Science (IaS)

C6.2.1 describe the effect on rate of reaction of changes in temperature, concentration, pressure, and surface area

C6.2.2 explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles

C6.2.3 describe the characteristics of catalysts and their effect on rates of reaction

C6.2.6 explain catalytic action in terms of activation energy

C6.2.7 suggest practical methods for determining the rate of a given reaction including measurement of physical factors iv: formation of a precipitate

C6.2.8 interpret rate of reaction graphs

C6.2.9 interpret graphs of reaction conditions versus rate

C6.2.10 use arithmetic computation and ratios when measuring rates of reaction

C6.2.13 use proportionality when comparing factors affecting rate of reaction

IaS2.1 present observations and other data using appropriate formats

IaS2.2 when processing data use SI units where appropriate (e.g. kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate

IaS2.4 be able to translate data from one form to another

IaS2.6 when processing data use an appropriate number of significant figures

IaS2.7 when displaying data graphically select an appropriate graphical form, use appropriate axes and scales, plot data points correctly, draw an appropriate line of best fit, and indicate uncertainty (e.g. range bars)

IaS2.8 when analysing data identify patterns/trends, use statistics (range and mean) and obtain values from a line on a graph (including gradient, interpolation and extrapolation),

IaS2.9 in a given context evaluate data in terms of accuracy, precision, repeatability and reproducibility, identify potential sources of random and systematic error, and discuss the decision to discard or retain an outlier

IaS2.10 evaluate an experimental strategy, suggest improvements and explain why they would increase the quality (accuracy, precision, repeatability and reproducibility) of the data collected, and suggest further investigations

IaS2.11 in a given context interpret observations and other data (presented in diagrammatic, graphical, symbolic or numerical form) to make inferences and to draw reasoned conclusions, using appropriate scientific vocabulary and terminology to communicate the scientific rationale for findings and conclusions

IaS3.4 use a variety of models (including representational, spatial, descriptive, computational and mathematical models) to: i) solve problems, ii) make predictions, iii) develop scientific explanations and understanding, iv) identify limitations of models

### Mathematical Skills covered

M1a: Recognise and use expressions in decimal form

M1c: Use ratios, fractions and percentages

M2a: Use an appropriate number of significant figures

M3a: Understand and use the symbols, =, <, ≪, ≫, >, α, ~

M3c: Substitute numerical values into algebraic equations using appropriate units for physical quantities

M4a: Translate information between graphical and numeric form

M4c: Plot two variables from experimental or other data

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| Technical RequirementsChemicals (per group)  | **Identity** | **Approximate quantity required or produced** | **Hazard information** | | **Risk information** | | --- | --- | --- | --- | --- | | 1.00 mol/dm3 aqueous hydrochloric acid, HC*l*(aq) | c. 10 cm3 | Currently not classified as hazardous at this concentration | |  | | 0.100 mol/dm3 aqueous sodium thiosulfate solution, Na2S2O3(aq) | c. 50 cm3 | Currently not classified as hazardous at this concentration | |  | | 1 mol/dm3 aqueous sodium carbonate solution, Na2CO3(aq) | c. 25 cm3 | HSE warning symbol | WARNING  Causes serious eye irritation | Wear eye protection | | universal indicator solution  < 1% w/v commercial formulation or follow CLEAPSS Recipe Book #47. | access to dropper bottle | Flammable | FLAMMABLE if made up in 50:50 ethanol:water | Keep the dropper bottles away from naked flames | | sulfur dioxide, SO2(g) | Small but significant in limited areas | Toxic gas which can affect asthmatic students | Once the reading is taken the reaction should be poured into the sodium carbonate solution which reacts with the sulfur dioxide and neutralises the acid, stopping the reaction. |  |  Equipment  * plastic reaction box (see note below) * glass vials × 2 (c. 12-14 cm3 capacity) * measuring cylinder × 2 (10 cm3) * beaker (250 cm3) * beaker × 2 (100 cm3) * plastic dropper pipette with volume readings * glass marker pen * deionised water * stop watch |

### Notes

Reaction box – plastic food containers (e.g. those used by food take-aways). The black cross should be made with permanent black ink. The holes in the lid can be made using very hot wide-diameter cork borers or hot 2p coins (heated in a Bunsen flame) – do this in a fume hood. The glass vials should contain about 12-14 cm3 of liquid (e.g. TIMSTAR VI16982, SciChem TVL060030).

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| food container  food container lid with holes  **Side view**  **Top view**  hole for acid stock vial  hole for reaction vessel vial  X marked in permanent pen on base of food container |

Figure 1 – Diagram of the reaction box

### Health and Safety

Eye protection should be worn at all times.

Ensure the laboratory is well ventilated. Take particular care if you have any asthmatic members of the group.

### Method

Once all the set-up is complete for this activity, and they understand the process involved, learners should be able to rapidly collect results in this rate of reaction practical. A demonstration of the method is recommended.

Learners should replace their ‘STOP BATH’ with fresh sodium carbonate/indicator solution if it turns yellow.

### Analysis of results – Trial results

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| --- | --- | --- | --- |
| **volume of 0.1 mol dm–3 sodium thiosulfate solution / cm3** | **volume of deionised water / cm3** | **time / s** | **Rate of reaction as 1/time / s–1** |
| 0.0 | 10 | 0 | 0.0 |
| 2.0 | 8.0 | 240 | 0.0042 |
| 4.0 | 6.0 | 125 | 0.0080 |
| 6.0 | 4.0 | 75 | 0.013 |
| 8.0 | 2.0 | 55 | 0.018 |
| 10.0 | 0.0 | 42 | 0.024 |

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| **1.** | Calculate the rate of each reaction by dividing 1 by the time taken for the black cross to disappear. **[2 marks]** |  |
|  | 1 mark for correct calculations ✓  1 mark for all answers to the appropriate and same number of significant figures ✓ |  |

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| **2.** | Plot a graph of volume of sodium thiosulfate against rate of reaction. **[4 marks]** |  |
|  | graph of volume of sodium thiosulfate against rate of reaction  1 mark for correctly labelled x-axis, including units ✓  1 mark for correctly labelled y-axis, including units ✓  1 mark for correct plotting (allow within one small square on 2 mm graph paper) ✓  1 mark for suitable line of best fit – must pass through the origin ✓ |  |

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| **3.** | Describe the mathematical relationship between concentration of sodium thiosulfate and the rate of reaction. **[2 marks]**  *As the volume and concentration of sodium thiosulfate are proportional, you can assume the graph you plotted in question 2 will have the same shape as the concentration against rate graph.* |  |
|  | The concentration of sodium thiosulfate and the rate of the reaction are directly ✓ proportional ✓. |  |

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| **4.** | Explain, using collision theory, the relationship found between the concentration of sodium thiosulfate and the rate of reaction. **[3 marks]** |  |
|  | As the concentration of the sodium thiosulfate increases the rate of reaction increases ✓ as there are more particles in the same volume of solution ✓, therefore the particles collide more frequently ✓. |  |

### Extension opportunities

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| **1.** | Describe how you would modify the experimental method to increase the accuracy of your results. **[2 marks]** |  |
|  | Carry out three repeats of each reaction ✓ and calculate a mean average time taken for each sodium thiosulfate concentration ✓. |  |

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| **2.** | Describe one potential source of random error and one of systematic error and how you would modify the experimental method to minimise these errors. **[4 marks]** |  |
|  | Allow any suitable source of error and related modification (1 mark each).  For example:  random error: viewing the cross from different angles meaning it is viewed through different depths of solution ✓; place a stand next to the apparatus that your head can rest against to ensure it is always in the same position ✓.  random error: two different people judging when the cross ‘disappears’ ✓; use the same person to make the judgement in each experiment ✓.  systematic error: adding the acid then starting the stopwatch afterwards ✓ add the acid and start the timing simultaneously ✓ |  |

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| **3.** | Explain, using collision theory, how increasing the temperature of the reaction would affect the rate of the reaction. **[4 marks]** |  |
|  | As the temperature of the solution increases the rate of reaction increases ✓ for two reasons. Firstly, at higher temperatures the particles are moving faster ✓ and therefore collide more frequently ✓.Secondly, more particle collisions have at least the activation energy (further increasing the rate of reaction) ✓. |  |

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| **4.** | Explain, using collision theory, how adding a catalyst would affect the rate of the reaction. **[3 marks]** |  |
|  | A catalyst provides a reaction with a lower activation energy ✓ so more collisions have at least the activation energy ✓ so the rate of reaction increases ✓. |  |

**Document updates**

v0.4 July 2016 Draft version released on OCR Community

v1 August 2016 Published on the qualification pages

v1.1 January 2017 Consolidated labelling and formatting of activities

v1.2 June 2021 Updated to meet digital accessibility standards



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# Chemistry PAG 8: Measuring rates of reaction

# Combined Science PAG C5: Measuring rates of reaction

# Suggested Activity 2: The disappearing cross

## Learner Activity

### Introduction

Measuring the rate of a chemical reaction is a key technique in chemistry, and gives insights into how the reaction is occurring. Rates of reaction can be measured in a variety of ways such as by measuring the volume of gaseous products, changes in reaction masses, changes in colour and changes in pH.

In this reduced-scale activity, the rate of reaction between hydrochloric acid and sodium thiosulfate is investigated. By varying the concentration of the sodium thiosulfate solution, the relationship between concentration and rate of reaction can be investigated. This activity will give you opportunities to refine your skills in handling experimental apparatus and in careful observation and measurement.

sodium thiosulfate + hydrochloric acid → sodium chloride + sulfur dioxide + sulfur

Na2S2O3(aq) + 2HC*l*(aq) → 2NaC*l*(aq) + SO2(g) + S(s)

### Aims

To investigate the effect of concentration on the rate of reaction between acid and sodium thiosulfate

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| Figure 1 The equipment set-up |

**Figure 1: The equipment set-up**

### Intended class time

20 – 25 minutes

### Equipment (per group)

* plastic reaction box
* glass vials × 2
* measuring cylinder × 2 (10 cm3)
* beaker (250 cm3)
* beaker × 2 (100 cm3)
* plastic dropper pipette with volume readings
* glass marker pen
* deionised water
* stop watch
* 1.00 mol/dm3 hydrochloric acid
* 0.100 mol/dm3 sodium thiosulfate solution
* 1 mol/dm3 sodium carbonate solution (WARNING: Causes serious eye irritation)
* universal indicator solution (WARNING: Flammable)

### Health and Safety

* Eye protection should be worn at all times.
* Small quantities of sulfur dioxide gas (DANGER: Toxic and corrosive gas) are made in each reaction – minimise your exposure by keeping your face at least 30 cm from the reaction and pouring the solution into the ‘STOP BATH’ as soon as possible after taking your readings.
* Let your teacher know if you are asthmatic.
* Ensure the laboratory is well ventilated.

### Method

***STAGE 1: Set up***

1. Collect about 50 cm3 of 0.100 mol/dm3 sodium thiosulfate solution in a labelled 100 cm3 beaker and 50 cm3 deionised water in a separate labelled beaker.
2. Measure out about 25 cm3 of 1 mol/dm3 sodium carbonate solution into a 250 cm3 beaker, and add a few drops of universal indicator solution – label this **'STOP BATH'**
3. Measure 10 cm3 1.00 mol/dm3 hydrochloric acid into the 'acid' vial, and place the vial into the correct hole in the plastic container (i.e. the one without the cross).

***STAGE 2: The reactions***

1. Using a 10 cm3 measuring cylinder, measure 5 cm3 of sodium thiosulfate into the reaction vial, then 5 cm3 of deionised water. Place the vial in the 'reaction' hole (i.e. the one with the cross).
2. Measure out 1.0 cm3 of hydrochloric acid into a dropping pipette.
3. Holding the dropping pipette in one hand, and the stop watch in the other, simultaneously add the acid to the reaction vial and start the stop watch.
4. Give the vial a quick swirl to ensure complete mixing.
5. Look down through the 'reaction' vial from above and record the time taken for the cross to disappear from view.
6. Pour the cloudy contents of 'reaction' vial into your 'STOP BATH', and rinse the vial several times with tap water and shake dry.
7. Repeat the procedure using different volumes of sodium thiosulfate and water, to a total volume of 10 cm3 (minimum sodium thiosulfate volume should be 3 cm3).

***STAGE 3: End notes***

1. If you have the time and reagents available, carry out repeat experiments to help you increase the accuracy of your results.
2. All solutions can be rinsed down the sink with plenty of water and glassware rinsed with tap-water.

### Analysis of results

You can draw your own table, or use the one below:

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| --- | --- | --- | --- |
| **volume of 0.1 mol dm–3 sodium thiosulfate solution / cm3** | **volume of deionised water / cm3** | **time / s** | **Rate of reaction as 1/time / s–1** |
| 5 | 5 |  |  |
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Your ability to analyse your observations may depend on how much of the GCSE Chemistry course you have studied. Your teacher will let you know which questions you should focus on:

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| --- | --- | --- |
| **1.** | Calculate the rate of each reaction by dividing 1 by the time taken for the black cross to disappear. **[2 marks]** |  |
| **2.** | Plot a graph of volume of sodium thiosulfate against rate of reaction. **[4 marks]** |  |
| **3.** | Describe the mathematical relationship between concentration of sodium thiosulfate and the rate of reaction. **[2 marks]**  *As the volume and concentration of sodium thiosulfate are proportional, you can assume the graph you plotted in question 2 will have the same shape as the concentration against rate graph.* |  |
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| --- | --- | --- |
| **4.** | Explain, using collision theory, the relationship found between the concentration of sodium thiosulfate and the rate of reaction. **[3 marks]** |  |
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### Extension opportunities

|  |  |  |
| --- | --- | --- |
| **1.** | Describe how you would modify the experimental method to increase the accuracy of your results. **[2 marks]** |  |
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| --- | --- | --- |
| **2.** | Describe one potential source of random error and one of systematic error and how you would modify the experimental method to minimise these errors. **[4 marks]** |  |
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| **3.** | Explain, using collision theory, how increasing the temperature of the reaction would affect the rate of the reaction. **[4 marks]** |  |
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| **4.** | Explain, using collision theory, how adding a catalyst would affect the rate of the reaction. **[3 marks]** |  |
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### DfE Apparatus and Techniques covered

If you are using the OCR Practical Activity Learner Record Sheet ([**Chemistry**](https://www.ocr.org.uk/Images/295630-gcse-chemistry-student-record-sheet.doc) / [*Combined Science*](http://www.ocr.org.uk/Images/304431-gcse-combined-science-learner-record-sheet.doc)) you may be able to tick off the following skills:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Chemistry** | | | |  | ***Combined Science*** | | | |
| 1-ii | 1-iv | 3-i | 5-iii |  | *1-iv* | *1-vi* | *8-i* | *10-iii* |
| 6-i | 6-ii |  |  |  | *11-i* | *11-ii* |  |  |