Cambridge Assessment
International Education

Practical Booklet 5

Reaction kinetics

Cambridge International AS & A Level Chemistry 9701

Version 2.0

Cambridge Pathway

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Introduction

Practical work is an essential part of science. Scientists use evidence gained from prior observations and experiments to build models and theories. Their predictions are tested with practical work to check that they are consistent with the behaviour of the real world. Learners who are well trained and experienced in practical skills will be more confident in their own abilities. The skills developed through practical work provide a good foundation for those wishing to pursue science further, as well as for those entering employment or a non-science career.

The science syllabuses address practical skills that contribute to the overall understanding of scientific methodology. Learners should be able to:

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data, and suggest improvements.

The practical skills established at AS Level are extended further in the full A Level. Learners will need to have practised basic skills from the AS Level experiments before using these skills to tackle the more demanding A Level exercises. Although A Level practical skills are assessed by a timetabled written paper, the best preparation for this paper is through extensive hands-on experience in the laboratory.

The example experiments suggested here can form the basis of a well-structured scheme of practical work for the teaching of AS and A Level science. The experiments have been carefully selected to reinforce theory and to develop learners' practical skills. The syllabus, scheme of work and past papers also provide a useful guide to the type of practical skills that learners might be expected to develop further. About 20% of teaching time should be allocated to practical work (not including the time spent observing teacher demonstrations), so this set of experiments provides only the starting point for a much more extensive scheme of practical work.

Guidance for teachers

Aim

To investigate the effect of change in concentration on the rate of the reaction between potassium iodate(V) and sodium sulfite in acidic solution.

Outcomes

Syllabus section 1.5 (a), 6.1 (a)(iii), 8.1 (b) as well as experimental skills 1, 2, 3 and 4.
Further work: AL syllabus section 8.2 (d), 8.1 (d)(ii) and (f), shown in *italics* below.

Skills included in the practical

AS level skills	How learners develop the skills
MMO collection	set up and use the apparatus to the level of precision indicated
MMO quality	obtain results that are close to those of an experienced chemist
MMO decisions	decide whether any experiment should be repeated *decide how many different concentrations/temperatures to use*
PDO recording	record the volumes and times with appropriate headings and units
PDO display	show working in the calculation and use significant figures appropriate to the precision of measurements
PDO layout	results clearly tabulated graph axes correctly labelled and majority of grid used points correctly plotted and the line of best fit drawn
ACE analysis	calculate relative rates identifying errors
ACE conclusions	calculate relative rates identifying errors
ACE improvements	suggest ways in which to extend the investigation
PLAN method	*plan which variables should be controlled* *plan how many experiments are needed and what range of values would be appropriate*

Method

- **Learners must wear eye protection for this investigation**.
- Many experiments to investigate rates of reaction involve redox reactions that produce iodine, which is detected by turning starch blue. The concentrations of chemicals used in these reactions have to be chosen such that the reaction takes a suitable length of time that is accurately measureable.
- Experiments of this kind give learners good practise at following what can be quite complex step-by-step instructions as to what to do. They require good levels of organisation by the learners and accurate use of measuring instruments.
- In kinetic experiments that investigate effect of concentration on the rate of reaction, it is important to keep the total volume of solutions used constant, so that there is only one variable. This is done by “topping up” with distilled water. The concentration of the reactant being investigated is varied, by altering the volume of it used. The concentrations (or volumes) of all other reactants must be kept constant.
- Stop watches should normally be read to the nearest second in examinations. Learners should become familiar with using the apparatus so they can perform such experiments to a high level of accuracy. They need to practice the skills necessary to mix the appropriate solutions and start the stop clock as soon as this is done.
- It is always advisable to dispose of reaction mixtures containing sulfites and acid as soon as possible after the end-point of the reaction, using plenty of water. However, the solutions used in this experiment are very dilute so the formation of sulfur dioxide is minimal.
- This method can be used for **further work** when studying orders of reaction at A Level.

Results

- Discussion can take place before the learners start the practical to decide what data should be tabulated, whether some can simply be recorded, and whether to include a column/row for relative rates. Headings should be unambiguous and units shown as specified in the syllabus. The time taken should be recorded to the nearest second. The unit for relative ‘rate’ will depend on the equation used for its calculation but is likely to be / s^{-1}.

Interpretation and evaluation

- You can discuss the plotting of the graph to use for the learners results, whether to include (0,0) and how to deal with anomalous results. (Learners should indicate anomalies on the graph paper or repeat the experiment to check results.)
- You can discuss any relationship shown by the shape of the best-fit line on the graph, whether concentration and rate are proportional (straight line) or directly proportional (straight line through the origin) or there is some other relationship.
- You can discuss why the use of the volume of iodate solution instead of concentration is valid.
- The equation for the reaction is,

  $$2IO_3^- + 5SO_3^{2-} + 2H^+ \rightarrow I_2 + 5SO_4^{2-} + H_2O$$

- Learners should discuss which of the timings you have made is the least accurate. (The quickest experiment will have the greatest percentage error in the timing. It is more difficult to judge when the blue colour appears in the slowest experiment.)

- The smallest volume measured will have the greatest percentage error (5.0%) using the burette whereas the greatest percentage error with the measuring cylinder is 1.25%.

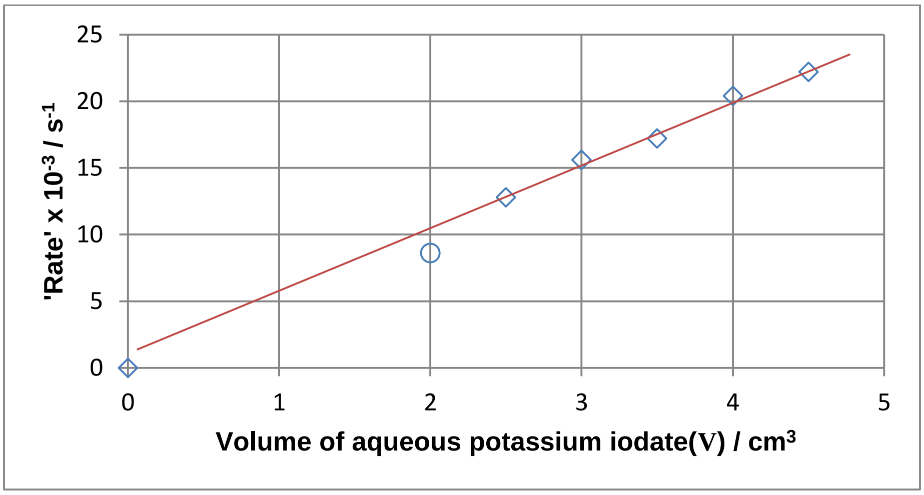
Extension

You can brainstorm ideas:

(i) how to find the temperature of each experiment (e.g. use of thermostatically controlled water baths; measuring the temperature when mixing the solutions and when the blue colour appears then calculate a mean);
(ii) deciding on a suitable range of temperatures to use (using ice as well as heating);
(iii) deciding on suitable volumes and concentrations of reactants so the rate is not too high.

Typical results

Volume IO_3^- / cm^3	Volume H_2O / cm^3	time / s	'rate' x 10^{-3} / s^{-1}
2.0	48.0	116	8.6
2.5	47.5	78	12.8
3.0	47.0	64	15.6
3.5	46.5	58	17.2
4.0	46.0	49	20.4
4.5	45.5	45	22.2



Further work

Learners can investigate the effect of changing the concentration of (i) sulfite ions, (ii) acid on the rate of reaction. **They can use the shapes of the graphs of their results to determine the order of reaction with respect to the concentrations of the ions and hence suggest a rate expression for the reaction.**

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Information for technicians

Each learner will require:

(a) Eye protection

(b) 250 cm^3 beaker

(c) 1 x foamed plastic (polystyrene) cup approximately 150 cm^3

(d) 1 x thermometer (–10 ºC to +110 ºC at 1 ºC)

(e) 1 x weighing boat or 100 cm^3 beaker

(f) 1 x 50 cm^3 measuring cylinder

(g) access to a balance reading to **at least** 1 dp

[MH] [N] (h) 50.0 cm^3 1.0 mol dm^{-3} copper(II) sulfate

[F] [N] (i) 2.0 ± 0.1 g zinc powder (supplied in a stoppered container)

Extension:

Apparatus and 1.0 mol dm^{-3} copper(II) sulfate as above

[F] (j) 0.8 ± 0.1 g magnesium turnings (supplied in a stoppered container)

Hazard symbols

 GHS02 (*flammable* **F**)	 GHS03 (*oxidising* **O**)	 GHS05 (*corrosive* **C**)
 GHS06 (*acutely toxic* **T**)	 GHS07 (*moderate hazard* MH)	 GHS08 (*health hazard* **HH**)
	 GHS09 (*hazardous to the aquatic environment* **N**)	

Worksheet

Aim

To investigate the effect of change in concentration on the rate of the reaction between potassium iodate(V) and sodium sulfite in acidic solution.

Method

Safety:

- Wear eye protection.

1. Set up 4 burettes labelled iodate, sulfite, acid and starch. Fill the burettes with the solution matching the label. Make sure that the region under each tap is full of solution.

First experiment

Beaker A (100 cm^3 capacity)

2. Run 2.00 cm^3 of aqueous potassium iodate(V) from the burette into the beaker. Use the 50 cm^3 measuring cylinder to add 48.0 cm^3 of water (use a dropping pipette to adjust the level of the meniscus).

Beaker B (250 cm^3 capacity)

3. Run 5.00 cm^3 of aqueous sodium sulfite from the burette and add 40.0 cm^3 of water from the measuring cylinder into the beaker. Add 2.50 cm^3 of dilute sulfuric acid and 2.50 cm^3 of starch indicator into the same beaker.

4. Stir the solution to mix the reactants and place beaker **B** on a white tile.

5. Tip all the solution from beaker **A** into beaker **B** as quickly as possible and simultaneously start the stop clock. Stir the contents of the beaker.

6. Stop the clock as soon as you see a blue colouration in the solution. Record the time taken for the blue coloration to appear.

7. Pour away the mixture and rinse both beakers with water. Shake them to get rid of excess water then wipe them dry with paper towel.

Second experiment

8. Run 2.50 cm^3 of aqueous potassium iodate(V) from the burette into beaker **A**. Add 47.5 cm^3 of water.

9. Use exactly the same combination of volumes in beaker **B** as in step 3.

10. Repeat steps 4 – 7.

Worksheet, continued

Third to fifth experiments

11. For these experiments, increase the volume of potassium iodate(V) by 0.50 cm^3 and reduce the volume of water by 0.5 cm^3 each time but keep the volumes of solutions and water in beaker **B** the same.

Results

Record **all** your observations.

When drawing a table for your results it is worth adding an extra line or column for the ‘rate’ of each reaction.

Before the start of the practical decide what data should be tabulated, whether some can simply be recorded, and whether to include a column/row for relative rates. Headings should be unambiguous and units shown as specified in the syllabus. The time taken should be recorded to the nearest second. The unit for relative ‘rate’ will depend on the equation used for its calculation but is likely to be / s^{-1}.

Interpretation and evaluation

Calculation

Use the following equation to calculate ‘rate’:

$$\text{‘rate’} = \frac{1000}{\text{time (s)}}$$

1. Calculate the ‘rate’ of each of the 5 experiments.

2. Plot a graph of ‘rate’ against volume of aqueous potassium iodate(V).

3. The volume of potassium iodate used is directly proportional to its concentration.
Use your graph to suggest a relationship between ‘rate’ and the concentration of potassium iodate.

4. The ions reacting in this experiment are IO_3^-, SO_3^{2-} and H^+. The overall reaction is to form I_2, SO_4^{2-} and H_2O.
(i) What is the change in oxidation number of the iodine?
(ii) What is the change in oxidation number of the sulfur?
(iii) Use your answers to (i) and (ii) to write a balanced ionic equation for the reaction that takes place.

5. Which of your five experiments do you consider to have the greatest error in the time recorded? Explain your answer.

6. Why is it not necessary to use a burette to measure the volume of water added?

Worksheet, continued

Extension

7. How could you adapt this method to investigate the effect of temperature on the rate of reaction? Give practical details of your procedure.

Points to consider

1. Why is the volume of potassium iodate(V) directly proportional to its concentration?

2. A burette is accurate to ± 0.05 cm^3. A 50 cm^3 measuring cylinder is accurate to ± 0.5 cm^3. Why was a measuring cylinder suitable for measuring the volumes of water to be added?

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