

Teacher Resource Bank

GCE Chemistry

PSA13: A2 Physical Chemistry

• Carry out a kinetic study to determine the order of a reaction



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Technical Sheet

An iodine clock experiment: To investigate the reaction of iodate(V) ions with sulfate(IV) ions in acidic solution and to determine the order of the reaction with respect to hydrogen ions.

Whenever possible, students should work individually.

If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

- 400 cm³ beaker
- Two 100 cm³ measuring cylinder
- One 10 cm³ measuring cylinder
- Potassium iodate(V) solution (200 cm³ 3.50 g dm⁻³)
- Sodium sulfate(IV) solution (200 cm³ 5.00 g dm⁻³)
- 0.1 mol dm⁻³ sulfuric acid (500 cm³)
- Starch solution (freshly prepared)
- Stopwatch
- Glass stirring rod
- Graph paper

Centres are expected to carry out and be responsible for their own safety risk assessments.

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Student Sheet

An iodine clock experiment: The aim of this experiment is to investigate the reaction of iodate(V) ions with sulfate(IV) ions in acidic solution and determine the order of the reaction with respect to hydrogen ions.

Introduction

The iodate(V) ion is an oxidising agent and reacts with sulfate(IV) ions in acidic solution to produce iodine in solution, according to the following equations.

Stage 1 $IO_3^- + 3SO_3^{2-} \longrightarrow I^- + 3SO_4^{2-}$ Stage 2 $IO_3^- + 5I^- + 6H^+ \longrightarrow 3H_2O + 3I_2$ Overall $2IO_3^- + 5SO_3^{2-} + 2H^+ \longrightarrow I_2 + 5SO_4^{2-} + H_2O$

lodine is only liberated when acid is added. It is possible to determine the effect of acid on the initial rate of this reaction by timing how long it takes for iodine to be produced. This is indicated by the formation of a blue colour with starch solution under different conditions of acid concentration, whilst keeping all other concentrations constant.

It is the responsibility of the student to carry out and be responsible for their own safety risk assessment before carrying out this experiment. Wear safety glasses at all times. Assume that all of the reagents and liquids are toxic, corrosive and flammable.

Experiment

- a) Place 15 cm³ of the potassium iodate(V) solution into a 100 cm³ measuring cylinder and add 85 cm³ of deionised water to dilute it to 100 cm³.
- b) Transfer this solution to a 400 cm³ beaker and add 5 cm³ of starch solution using a 10 cm³ measuring cylinder.
- c) In a second 100 cm^3 measuring cylinder, take 15 cm^3 of sodium sulfate(IV) solution and add 85 cm^3 of 0.1 mol dm^{-3} sulfuric acid.
- Pour this solution into the 400 cm³ beaker containing the potassium iodate(V) solution and start the stop-clock simultaneously. Stir the contents of the beaker with the glass rod.

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- e) Record in a Table the time taken (*t* in seconds) for the blue colour to appear.
- f) Repeat the experiment using the same volumes of potassium iodate(V) solution, starch solution and sodium sulfate(IV) solution, but vary the concentration of sulfuric acid by changing the volume of sulfuric acid and making the total volume of the acidified sodium sulfate(IV) solution up to 100 cm³ by the addition of deionised water. The necessary volumes are shown in the Table below with the initial experiment recorded on the right hand side of the Table.

Experiment	1	2	3	4	5	Initial
Acid volume (cm ³)	25	35	45	55	70	85
Water volume (cm ³)	60	50	40	30	15	0
Na ₂ SO ₃ volume (cm ³)	15	15	15	15	15	15

g) Record a complete set of results in a form suitable for analysis.

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Analysing the data

The ability to calculate rates from recorded times and to plot a graph is NOT part of the PSA but this is a task which should be completed. Your teacher can help you with this part of the work.

Because we have kept all of the concentrations constant except the concentration of acid, the rate equation for this reaction simplifies to:

where **z** is the order of the reaction with respect to hydrogen ion concentration. We could write

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log (rate) = z log [H<sup>+</sup>] + constant
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Because the event being measured is <u>fixed</u>, i.e. the first appearance of the blue-black colour, it is possible in this instance for the rate to be expressed as

The total volume of solution in each experiment is constant and therefore the $[H^+]$ can be represented by the volume of sulfuric acid.

Therefore the rate expression becomes

If we plot a graph of log (1/t) on the *y*-axis against log (volume of sulfuric acid) on the *x*-axis, we should get a straight line of gradient **z** and from this we can determine the order of the reaction with respect to hydrogen ion concentration. [n.b. the graph is of the type y = mx + c and therefore the gradient m will give a value for the order, **z**)

Analysing the data for each of the six experiments

- Calculate 1/t (to 3 significant figures) (the units are s⁻¹).
- Calculate log 1/t (to 3 significant figures).
- Calculate log (volume of sulfuric acid.)
- Plot a graph of log 1/t (y-axis) against log (volume of sulfuric acid).
- Determine the value of the gradient of the graph (to 3 significant figures).
- Round the gradient to the nearest whole number. This is the order of the reaction with respect to hydrogen ion concentration.



Teacher Notes and Marking Guidance

The specific marking guidance in the specification is as follows

2 marks: All areas of the task are carried out competently.The quantities of reagents are measured precisely.Times are measured accurately and recorded precisely.Sufficient values are on a good straight line and the order of reaction is in the expected range.

1 mark: One of the areas of the task is performed poorly.
The quantities of reagents are measured imprecisely **OR** Times are measured inaccurately or recorded imprecisely **OR** The values are scattered or the order is not in the expected range.

0 marks: At least two of the areas of the task are performed poorly. The quantities of reagents are measured imprecisely. Times are measured inaccurately or recorded imprecisely. The values are scattered or the order is not in the expected range.

Guidance for Teachers

Teachers are expected to exercise professional judgement in assessing the competence of their candidates in following the instructions.

Candidates should have been given guidance in the correct use of equipment and this guidance **can continue during the practical session** for which this PSA forms a part.

If, however, the guidance required is fundamental or frequent, then the student should **not** be awarded 2 marks.

Most judgements of 2 marks, 1 mark or 0 marks will depend on whether the candidate is able to measure the volumes of reagents with appropriate care and transfer these to the beaker for reaction. Candidates are not judged on their ability to process the data.

Notwithstanding this, it is appropriate to have the students follow through with the production of a graph since this will allow teachers to judge the quality of the results more readily. The aim of the experiment is to generate results which lead to points on a graph with a straight line of best fit and a gradient of approximately 1. Values for the gradient of 0.85 to 1.15 would be judged to be in the expected range.

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It is important to remember when marking these practical exercises that PSA is about student competence and that for a student to score full marks on this exercise **perfection is neither expected nor required**.