Core practical 13a: Follow the rate of the iodine–propanone reaction using a titrimetric method

Objectives

- To determine the rate of a reaction using a continuous monitoring method
- To determine the order of reaction with respect to a substance using a concentration–time graph

Safety	Specification links
• **WARNING!** The product from the reaction, iodopropanone, is a lachrymator (strongly irritant to the eyes). The reaction mixture should be poured down a fume cupboard sink with plenty of running water immediately once each measurement is complete. • Consult CLEAPSS Hazcards® 54B, 85A, 95C and 98A. Perform a risk assessment using up-to-date information before this practical is carried out. • Use eye protection. • Sodium thiosulfate releases sulfur dioxide when it reacts. Ensure that the room is well-ventilated. • Propanone is an irritant and is highly flammable. • Sulfuric acid solution is an irritant. • Do not run this practical for more than 12 minutes in total.	• Practical techniques 1, 4, 11, 12 • CPAC 1a, 2a, 2b, 3a, 4a, 4b

Procedure	Notes on procedure
1. Mix 25 cm^3 of 1 mol dm^{-3} aqueous propanone with 25 cm^3 of 1 mol dm^{-3} sulfuric acid in a beaker. 2. Start the stop clock the moment you add 50 cm^3 of 0.02 mol dm^{-3} iodine solution. Shake the beaker to mix well. 3. Using a pipette, withdraw a 10 cm^3 sample of the mixture and transfer it to a conical flask. 4. Stop the reaction by adding a spatula measure of sodium hydrogencarbonate. Note the exact time at which the sodium hydrogencarbonate is added. 5. Titrate the remaining iodine present in the sample with 0.01 mol dm^{-3} sodium thiosulfate(VI) solution, using starch indicator. Copy the table from the analysis section to record your results. 6. Continue to withdraw 10 cm^3 samples at suitable time intervals (approximately every 3 minutes) and treat them similarly. Always note the exact time at which the sodium hydrogencarbonate is added.	• This is a complicated procedure. Depending on the ability of the group, it may be necessary to demonstrate this practical first so that students are clear about what to do. • Warn students not to stop the clock when they quench the sample, but just to note the time and leave the clock running.

Answers to questions

1. The rate doubles.
2. The rate doubles.
3. The rate remains the same.
4. Rate = $k[H^+][CH_3COCH_3]$
5. The graph would be a curve. To prove that the reaction is first order, you can look at the half-life at various points; the half-life will be constant for a first order reaction. Alternatively, plot a graph of rate against concentration; for a first order reaction this will be a straight-line graph.

Sample data

Time hydrogencarbonate added/min	3:00	6:30	9:00	10:30	12:00
Initial reading/cm^3	39.55	29.50	43.90	28.95	46.65
Final reading/cm^3	23.15	14.20	29.50	14.75	28.95
Titre/cm^3	16.40	15.30	14.40	14.20	13.70

The graph produced (which is approximately linear) shows that the reaction is zero order with respect to iodine.

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- Sulfuric acid solution is an irritant.
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All the maths you need

- Calculate a rate of change from a graph showing a linear relationship.

Equipment

- 50 cm^3 of 1.0 mol dm^{-3} aqueous propanone solution
- 50 cm^3 of 1.0 mol dm^{-3} sulfuric acid
- 50 cm^3 of 0.02 mol dm^{-3} iodine solution (in 0.2 mol dm^{-3} potassium iodide solution)
- 0.01 mol dm^{-3} sodium thiosulfate(VI) solution
- 20 cm^3 of 1% starch solution/indicator
- sodium hydrogencarbonate
- 100 cm^3 beaker
- conical flasks
- 10 cm^3 graduated pipette
- pipette filler
- spatula
- stop clock

Procedure

1. Mix 25 cm^3 of 1 mol dm^{-3} aqueous propanone with 25 cm^3 of 1 mol dm^{-3} sulfuric acid in a beaker.
2. Start the stop clock the moment you add 50 cm^3 of 0.02 mol dm^{-3} iodine solution. Shake the beaker to mix well.
3. Using a pipette, withdraw a 10 cm^3 sample of the mixture and transfer it to a conical flask.
4. Stop the reaction by adding a spatula measure of sodium hydrogencarbonate. Note the exact time at which the sodium hydrogencarbonate is added.
5. Titrate the remaining iodine present in the sample with 0.01 mol dm^{-3} sodium thiosulfate(VI) solution, using starch indicator. Copy the table from the analysis section to record your results.
6. Continue to withdraw 10 cm^3 samples at suitable time intervals (approximately every 3 minutes) and treat them similarly. Always note the exact time at which the sodium hydrogencarbonate is added.

Analysis of results

Time hydrogencarbonate added/min					
Initial reading/cm^3					
Final reading/cm^3					
Titre/cm^3					

1. Plot a graph of titre against time. (The titre is proportional to the concentration of iodine.)
2. Deduce the order of reaction with respect to iodine from the graph.

Learning tips

- The reaction between propanone and iodine in aqueous solution can be catalysed by an acid:

  $I_2(aq) + CH_3COCH_3(aq) + H^+(aq) \rightarrow CH_3COCH_2I(aq) + 2H^+(aq) + I^-(aq)$

  The influence of the iodine on the reaction rate can be studied if the concentrations of propanone and hydrogen ions effectively remain constant during the reaction. This is achieved by using a large excess of both propanone and sulfuric acid in the starting reaction mixture.

Questions

Similar experiments show that the reaction is first order with respect to both propanone and to hydrogen ions. Use this information to answer the following questions.

1. What is the effect on the rate if the concentration of the hydrogen ions is doubled?
2. What is the effect on the rate if the concentration of the propanone is doubled?
3. What is the effect on the rate if the concentration of the iodine is doubled?
4. Write the overall rate expression for this reaction.
5. Two students monitored the concentration of propanone as the reaction proceeded and plotted a concentration–time graph from their results.

   What shape would you expect the graph to be? How would you use this graph to prove that the reaction is first order with respect to propanone?

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Equipment per student/group	Notes on equipment
50 cm^3 of 1.0 mol dm^{-3} aqueous propanone solution	Propanone is an irritant and highly flammable – prepare in a well-ventilated room.
50 cm^3 of 1.0 mol dm^{-3} sulfuric acid	Irritant If made from fresh using concentrated sulfuric acid, remember that concentrated sulfuric acid is corrosive and oxidising.
50 cm^3 of 0.02 mol dm^{-3} iodine solution (in 0.2 mol dm^{-3} potassium iodide solution)	Low hazard
0.01 mol dm^{-3} sodium thiosulfate(VI) solution	Low hazard
20 cm^3 of 1% starch solution/indicator	Prepare the solution in boiling water, on the day of the experiment.
sodium hydrogencarbonate	
100 cm^3 beaker	
conical flasks	
10 cm^3 graduated pipettes	
pipette filler	
spatula	
stop clock	