Experiment 3.2A – Candidate Instruction Sheet

A Group and/or Individual Study of the Kinetics of a Chemical reaction

Introduction

We may write equations for chemical reactions easily enough but how quickly do they actually occur, if at all? Our bodies, for example, should burn up in the oxygen of the air but fortunately do not. We can turn on the gas but nothing happens until we apply a spark.

Thus the rate at which reactions take place, or kinetics, is of great practical importance - in industry and the environment as well as in the laboratory. Also by studying kinetics we can find out the actual mechanism of the chemical change and thus make it more efficient such as by developing suitable catalysts.

For this exercise we choose the reliable and attractive experiment below which can be performed by an individual student or partly as a group exercise to widen its scope.

Aim

Your aims in this exercise are:

(a) to gather information and plan your work;
(b) to carry out the experiment;
(c) to calculate, analyse and evaluate your results, including combining your results with those of other members of your group if the exercise is run as a group experiment;
(d) to answer the questions in the pro forma relating to the experiment.

Kinetics of the oxidation of iodide ion by hydrogen peroxide in acid solution using a clock method

Background Information

Iodide ions are oxidised to iodine by hydrogen peroxide in acidic solutions at a measurable rate. Iodine gives a strongly coloured blue complex with starch solution but if a given amount of thiosulfate ion - with which iodine reacts very rapidly - is added, no blue colour will appear until enough iodine has been formed to react with all the thiosulfate. The time taken for this to occur thus acts as a "clock" to measure the rate of the H_2O_2/HI reaction. By varying the concentrations of the reactants, such as peroxide, one at a time and measuring the rate, as above, the dependence of rate on concentration (this is called the order of reaction) for any reactant may be found. The relevant equations are,

$$H_2O_2 + 2HI \xrightarrow{\text{slow}} 2H_2O + I_2$$

$$I_2 + 2S_2O_3^{2-} \xrightarrow{\text{fast}} 2I^- + S_4O_6^{2-}$$

Apparatus and chemicals

You will need safety goggles, a stopwatch or stopclock, pipettes and fillers, burettes and funnel, a conical flask or beaker, test tubes and a stirring rod. The solutions provided are 0.1 mol dm^{-3} hydrogen peroxide, 1 mol dm^{-3} sulfuric acid, 0.1 mol dm^{-3} potassium iodide, 0.005 mol dm^{-3} sodium thiosulfate and starch solution.

Safety Considerations

If you splash any of the sulfuric acid onto your skin, notify your supervisor and wash the affected area with copious water. Any spillage should be diluted with water before being mopped up.

At the concentrations involved the other chemicals (hydrogen peroxide, potassium iodide, sodium thiosulfate, starch and the iodine formed) present minimal hazards.

Note that hydrogen peroxide is not stable over long periods and should be prepared freshly. If a concentrated solution is used as the stock and diluted down as required, be aware that solutions more concentrated than 1.5 mol dm^{-3} ("20 volume") can act as irritants or even be corrosive.

At the end of the experiment, small quantities of the chemicals can be diluted with running water and run to waste.

Procedure

After absorbing all the information available to you, write a plan, which will enable you to study the kinetics of this reaction as accurately as possible. The plan must be checked by the teacher before proceeding with the experiment.

First perform a trial run to find out which ranges of concentrations will be suitable for your plan. All runs can be at room temperature but make sure that this is constant since rates vary rapidly with changes in temperature.

For the trial run mix 10.0 cm^3 of sulfuric acid, 10.0 cm^3 of thiosulfate, 15.0 cm^3 of KI, 1 cm^3 of starch solution and 9.0 cm^3 of deionised water, get ready with the stopwatch and rapidly add 5.0 cm^3 of peroxide which you have previously measured into a dry test tube, simultaneously starting the watch and mixing thoroughly. Once the solution is well-mixed there is no need to stir any more.
N.B. It may be easier to mix the water with the peroxide and add this mixture to the other reactants.
Observe carefully, stop the watch immediately the blue colour appears and record the time.

Now plan a set of five similar runs which each differ only in the peroxide concentration in the mixture, balancing the amount of water added so that the total volume is again 50 cm^3. Bearing in mind the time taken for the trial run, vary the amount of peroxide used by as much as practicable ensuring that runs are neither too short nor too long: each run is carried out in exactly the same way.

Since the acid, thiosulfate, KI and starch are constant in all the runs it is more efficient if a single batch containing these in the correct proportions is made up immediately before starting and 36.0 cm^3 of this used in each run with the required peroxide and balancing water.

Construct a table showing the volumes of reactants used in each run and record the time taken for the blue colour to appear.

Details for Group Component

If this is included each member of the group will carry out the procedure above using a different volume of iodide ion but keeping the total volume the same. Group members will then compare their rates at a given peroxide concentration, obtained from their graphs produced as below and thus find the effect of changing the iodide concentration on the rate.

Other possibilities are to find the effect of changing the acid concentration in the same way or to carry out the runs at different temperatures to find the effect on the rate.

Analysis

In each run the time taken for the blue colour to appear is inversely proportional to the rate of reaction (the slower the rate the longer it will take for the fixed amount of reaction to occur). In all your runs only the concentration of peroxide is different so that by comparing the times taken for the runs you will be able to see how the concentration of peroxide affects the rate of reaction.

Since the rate is inversely proportional to the time taken, this is best done by plotting a graph of (1/time) against peroxide concentration. Also since the total volume is constant in each case $[H_2O_2]$ is directly proportional to the volume of peroxide used in each run so that you can just plot (1/time) s^{-1} versus volume of peroxide.

If a straight line results this shows that the rate is directly proportional to $[H_2O_2]$.

Conclusion, Evaluation and Questions

From your plot decide how the peroxide concentration affects the rate.
Estimate how precise your results are and state the main source of error.
Answer the questions on the pro forma.

Allocation of marks

The 30 available marks for this experiment are allocated as follows:
Planning [5]; Implementing [15]; Analysing [5]; Evaluating [5].

Experiment 3.2A - Marking Scheme

All marks are AO3 except where indicated.

Planning [5]

An effective detailed plan is recorded (2)

Answers to questions:

1. The total volume affects the concentrations of reactants and must remain the same to make a fair comparison between runs. (1) AO1

2. The thiosulfate reacts with the same amount of iodine in each run, after which the starch/iodine colour appears. (1) AO1

   Thus, all runs are timed for the same extent of reaction. (1) AO1

Implementing [15]

As a result of the trial run - the range of concentration variables to be used is chosen and tabulated (1)
Constructs and completes clear table of results (1) with all relevant components present (1)
Records results to sensible levels of precision (1)
Has obtained sensible reaction times (2)
[i.e. in range 20-180 s (2), otherwise (1) unless < 5 s when 0 marks]
Has chosen a meaningful range of peroxide concentrations (5)
[i.e. ≥ threefold (5), twofold (3), < twofold (1)]
Converts raw data into required form, [i.e., t to 1/ t] (1)
Has obtained raw data in which reaction times vary smoothly with concentration changes (3) - one serious discontinuity (2) – two discontinuities (1) - random variation (0)

Analysis [5]

Quality of graph plotting (1)
Correct labelling of axes (1)
The line of best fit is chosen correctly (1)
Data points fall on this line within the known precision of the experiment (1)
States how changes in peroxide concentration affect the rate. (1)

Evaluation [5]

Estimate the precision of the experiment (1) and state the main source of error (1)
Answers to question:
Place peroxide solutions in a flask connected to a gas syringe. (1) AO2
Weighed amounts of catalase are rapidly mixed into the peroxide (1) AO2
The volume of oxygen produced is measured over time. (1) AO2

Maximum Mark [30]

Experiment 3.2A - Technical Advice Notes for Teachers and Technicians

Kinetics of the oxidation of iodide ion by hydrogen peroxide in acid solution using a clock method

The apparatus, chemicals and solutions required are listed below.

Universally available items may not be listed.

Each student will require:

safety goggles
stopwatch / stopclock
pipettes and fillers
burettes and funnels
conical flask / beaker
test tubes
stirring rod
0.1 mol dm^{-3} hydrogen peroxide
1 mol dm^{-3} sulfuric acid
0.1 mol dm^{-3} potassium iodide
0.005 mol dm^{-3} sodium thiosulfate
starch solution

Examiner only

PRO FORMA EXPT 3.2A SUMMER 200…..

Centre Name …………………………………………… Centre Number ……………………

Candidate's Name ……………………………………… Candidate's Number ………………

Kinetics of oxidation of iodide by hydrogen peroxide in acid solution

(Attach another sheet, in the appropriate position, if you need more space)

Plan

Before proceeding to carry out your plan you must have the plan checked by your teacher.

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[2]

Questions

1. State why it is essential that all your runs are with the same total volume of liquid. [1]

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2. Explain the roles of the thiosulfate and starch in the way that this rate is measured.[2] P_2

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…………………………………………………………………………………………………

P

Examiner only

Results

Trial run

Volumes used

I_1

Time to blue colour

I_2

I_3

Runs varying peroxide concentration
(table of volumes and times for numbered runs)

I_4

I_5

I_6

I

Examiner only

Analysing results
(show sample of working)

Calculation of 1/time for each run

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A1

Table of peroxide volumes and 1/time for graph

A2

A3

Result from attached graph

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A4

How does the rate depend on the concentration of peroxide?

A5

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………

[1]

A

Examiner only

Evaluation

Give an estimate of how precise your experiment was and state the largest source of error.

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…… E_1

[2]

Question

3. The formation of highly oxidising peroxides is dangerous to living cells and enzymes such as catalase have evolved to destroy them. Briefly summarise an experiment that you would design to study the kinetics of the decomposition of hydrogen peroxide solutions to oxygen and water by catalase powder. [3]

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…… E_2

Remember that your graph must be attached to your work

E

Allocation of marks

The 30 available marks for this experiment are allocated in the following manner:
Planning [5]; Implementing [15]; Analysing [5]; Evaluating [5].

		Examiner only
	Maximum Mark	Candidate Mark
Planning	5	
Implementing	15	
Analysing	5	
Evaluating	5	
Total Mark	**30**	