Experiment 3.2B – Candidate Instruction Sheet

A Study of the Kinetics of the Chemical reaction between Thiosulfate ions and Nitric Acid

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 experiment below which can be performed by an individual student or partly as a group exercise if desired..

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 reaction of thiosulfate ions with nitric acid

You are going to measure the rate of reaction of thiosulfate ions with acid in solution and find out how this rate depends on the concentration of both thiosulfate and acid. The reaction equation is:

$$S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow S(s) + H_2SO_3(aq).$$

The reaction is easy to follow since one sulfur atom is formed for each thiosulfate ion reacting and the sulfur makes the reacting solution more cloudy as its concentration increases. By placing the reaction vessel over a black cross - that will disappear from view when a fixed amount of reaction has produced a fixed amount of sulfur- the rates of reaction of solutions of differing concentrations can be compared and the effects of changing concentrations on the rate found.

This is because the time taken for this fixed amount of reaction in all the runs is inversely proportional to the rate of reaction, i.e., if the reaction is fast the cross will disappear quickly and vice versa.

Apparatus and chemicals

You will need safety goggles, three burettes (for the 1 mol dm^{-3} sodium thiosulfate, 0.1 mol dm^{-3} nitric acid and water respectively) a 100 cm^3 conical flask, a black cross on a white background, test tubes, a stirring rod and a stopwatch or stopclock. The solutions provided are 1 mol dm^{-3} thiosulfate and 0.1 mol dm^{-3} nitric acid.

Safety Considerations

If you splash any of the nitric 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 chemical involved (sodium thiosulfate) presents a minimal hazard.

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 6.0 cm^3 of thiosulfate, 4.0 cm^3 of water and 10.0 cm^3 of nitric acid, start the watch immediately and mix thoroughly. Once the solution is well-mixed there is no need to mix any more. On the basis of the time this takes plan three other runs in which you vary the thiosulfate volume at constant acid, and thus concentration and three in which you vary the acid at constant thiosulfate. Adjust the volume of water added so that the total volume is the same in each case. There will thus be seven runs in all. Separately vary the two concentrations by as much as practicable ensuring that the times are not too short (less than 20 s) or too long.

Observe carefully and stop the watch immediately the black cross disappears and record the time.

NB In each run the best procedure is to add the required volumes of thiosulfate and water to the reaction flask, measure the acid into a clean test tube and add it rapidly to the flask with stirring while starting the watch.

Construct a table for your results based on the following columns:

vol. thio	vol. acid	vol. water	time	concn thio	concn acid	1/time

with appropriate units.

Analysis and Calculation

Carry out the calculations needed to complete the table and plot the two graphs:

1. 1/time versus concentration of thiosulfate at constant acid concentration;

2. 1/time versus acid concentration at constant thiosulfate concentration.

Each graph will have four points, each including the trial run.

NB IMPORTANT - Remember when working out the concentration that each solution dilutes the other, e.g. 10 cm^3 of 1.0 mol dm^{-3} thiosulfate added to an equal volume of nitric acid will now have an initial concentration of 0.50 mol dm^{-3}.

Conclusion, Evaluation and Questions

From your plot decide how the thiosulfate ion and the nitric acid concentrations affect 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 3.2B - Marking Scheme

Planning [5]

An effective detailed plan is recorded (2)

1.	The total volume affects the concentrations of reactants and must remain the same to make a fair comparison between runs.	(1)	AO1
2.	Rates depend strongly on temp.	(1)	AO1
3.	To give a wide spread of results for a good graph.	(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)
Records results to sensible levels of precision (2)
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 thiosulfate and nitric acid concentrations (6)
[i.e. $\geq$ threefold (3), twofold (2), $<$ twofold (1) for each reactant]
Converts raw data into required form, [i.e., t to 1/ t] (3)

Analysis [5]

Quality of graph plotting (2)
The lines of best fit are chosen correctly (2)
Data points fall on this line within the known precision of the experiment (1)

Evaluation [5]

Estimate the precision of the experiment and state the main source of error (1)

4.	Correct structure.	(1)	AO2
5.	$S_2O_3^{2-}$ is S(II); S is S(0); SO_3^{2-} is S(IV)	(1)	AO2
6.	State how changes in each concentration affect the rate.	(2)	

NB The mark scheme will be modified according to the amount of group work used. Typically part of the Analysis and Evaluation marks will be allocated to group activity.

Maximum Mark [30]

Experiment 3.2B -Technical Advice Notes for Teachers and Technicians

Kinetics of the reaction of thiosulfate ions with nitric acid

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} nitric acid
1.0 mol dm^{-3} sodium thiosulfate
a black cross on a white background

Examiner only

PRO FORMA EXPT 3.2B SUMMER 200…..

Centre Name …… Centre Number ……

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

Kinetics of reaction of thiosulfate ions with nitric acid

(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] P_1

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. State why it is important that the temperature does not change during your series of runs. [1]

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3. State why the range of concentrations that you design should be as wide as practicable. [1] P_2

……

P

Examiner only

Results

Trial run

Volumes used

Time taken

I_1

I_2

Runs varying thiosulfate and nitric acid concentrations
(table of volumes and times for numbered runs)

I_3

I_4

I_5

I_6

I

Examiner only

Analysing results
(show sample of working)

Calculation of 1/time and concentrations for each run

……..……..……

……..

Table of results (as in Procedure)

Attach graphs A_1

A_2

How does the rate depend on the concentration of both thiosulfate and nitric acid?

A_3

……..……..……

……..

[2]

A

Examiner only

Evaluation

Give an estimate of how precise your experiment was and state the largest source of error. [1]

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…… E_1

Question

4. Draw the structure of the thiosulfate ion. [1]

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5. State the oxidation states of all the sulfur atoms in the equation above for the reaction you have studied. [1]

…… E_2

……

6. How does the rate depend on the concentration of both thiosulfate and nitric acid? [2]

……

…… E_3

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**	