Activity 1 - Investigate the effect of concentration of an acid on the rate of reaction by measuring the volume of gas produced.

Learning Objectives -

- React magnesium ribbon with different concentrations of hydrochloric acid
- Measure the volume of gas produced for each concentration.
- Use your results to work out how the rate of reaction is affected by the concentration of the acid.

Equipment & Apparatus

Independent variable - Concentration of hydrochloric acid (mol/dm³)

Dependent variable - Volume of gas produced (cm³)

Control variables - Mass of magnesium used, volume of water in through/cylinder, time before the first reading is taken

Method:

1) Measure 50cm³ of 1.0 mol/dm³ hydrochloric acid using one of the measuring cylinders.

2) Pour the acid into the 100cm³ conical flask.

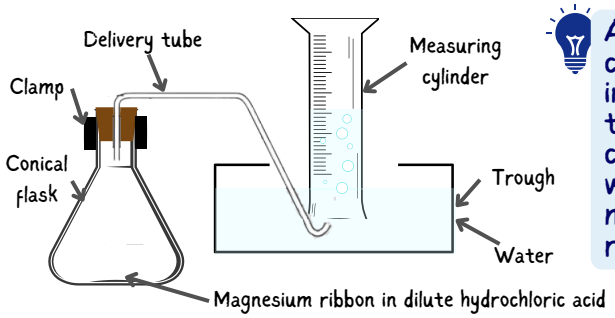
3) Fit the bung and delivery tube to the top of the flask.

4) Half fill the trough or bowl with water.

5) Fill in the other measuring cylinder with water.

6) Invert the cylinder into the water trough.

Your set up will look like this:



A gas syringe could be used instead of a trough and cylinder - this would produce more reliable results

Make sure it stays filled with water when you invert it into the water trough and that the delivery tube is positioned correctly.

Before step 7, record the reading at the top of water in the cylinder to get your 'initial reading'.

7) Add one 3cm strip of magnesium ribbon to the flask, quickly put the bung back into the flask and start the stop clock.

Do this step as fast as possible to minimise gas release.

8) At regular intervals (e.g. 10 seconds), record the volume of gas given off. Record results in a table.

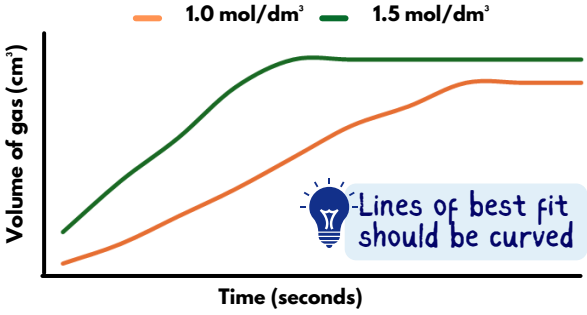
- Volume = initial reading - current reading

Layers of oxidation on the magnesium ring needs to be removed before the investigation, using sandpaper.

9) Stop the stop clock when the volume does not change for several intervals.

10) Repeat steps 1-10 using 1.5mol/dm³ hydochloric acid.

11) Plot results for both concentrations on the same graph.



12) For each concentration, calculate the mean rate of reaction until the reaction stops:

$$\text{Mean rate of reaction } (cm^3/s) = \frac{\text{total mass of gas produced } (cm^3)}{\text{reaction time (s)}}$$

Time in seconds (s)	Volume of gas produced (cm³)	
	1.0 mol/dm³	1.5 mol/dm³
10	4.0	12.0
20	9.0	25.0
...		
100	50.0	56.0

Mg oxidation number increases (reduction)

$$\overset{0}{Mg} + 2HCl \longrightarrow \overset{+2}{MgCl} + \overset{0}{H_2}$$

H oxidation number decreases (oxidation)

REQUIRED PRACTICAL 5 RATES OF REACTION - ACTIVITY 1

Kinetic Theory

- More Particles: Increasing the concentration of hydrochloric acid means more acid particles in the same volume of solution.
- More Collisions: With more particles, the frequency of collisions between acid and magnesium increases.
- Faster Reaction: More collisions lead to a faster rate of reaction as more magnesium reacts with the acid.

Comparing results

As the concentration of a solution increases, the volume of gas produced in a given time increases, showing that it increases the rate of the redox reaction between hydrochloric acid and magnesium.

Exam Style Questions - Rates of Reaction 1

1. What gas is produced when magnesium reacts with hydrochloric acid? (1 mark)

2. Complete the word equation for the reaction between magnesium and hydrochloric acid.

Magnesium + hydrochloric acid → _____ + _____ (2 marks)

3. What piece of equipment is used to collect the gas in this experiment? (1 mark)

4. Name the independent and dependent variables in this experiment. (2 marks)

5. Why is it important to record the gas volume at regular time intervals? (1 mark)

6. Suggest why the magnesium should be cleaned with sandpaper before the experiment. (1 mark)

7. Explain why the reaction happens faster with 1.5 mol/dm^3 acid than 1.0 mol/dm^3 acid. (3 marks)

8. A student collects the following gas volumes with 1.0 mol/dm^3 acid:

- **60 cm^3 of gas collected in 30 seconds.**
- **Calculate the mean rate of reaction. (2 marks)**

9. Describe how you could improve this experiment to reduce random errors. (2 marks)

10. A student plots a graph of volume of gas (y-axis) against time (x-axis).

a) What shape should the graph be?

b) Why does the graph level off? (2 marks)

Exam Style Questions - Rates of Reaction 1

1. What gas is produced when magnesium reacts with hydrochloric acid? (1 mark)

Mark One - Hydrogen

2. Complete the word equation for the reaction between magnesium and hydrochloric acid.

Magnesium + hydrochloric acid → Magnesium chloride (Mark 1) + Hydrogen (Mark 2) **(2 marks)**

3. What piece of equipment is used to collect the gas in this experiment? (1 mark)

Mark One - Inverted measuring cylinder / gas syringe (accept either)

4. Name the independent and dependent variables in this experiment. (2 marks)

Mark One - Independent variable: concentration of hydrochloric acid
Mark Two - Dependent variable: volume of gas produced

5. Why is it important to record the gas volume at regular time intervals? (1 mark)

Mark One - So you can track the rate of reaction over time

6. Suggest why the magnesium should be cleaned with sandpaper before the experiment. (1 mark)

Mark One - To remove the layer of oxidation on the surface

7. Explain why the reaction happens faster with 1.5 mol/dm^3 acid than 1.0 mol/dm^3 acid. (3 marks)

Mark One - Higher concentration means more acid particles
Mark Two - More frequent collisions with magnesium
Mark Three - Increases the rate of reaction

8. A student collects the following gas volumes with 1.0 mol/dm^3 acid:

- **60 cm^3 of gas collected in 30 seconds.**
- **Calculate the mean rate of reaction. (2 marks)**

Mark One - 60 ÷ 30 = 2
Mark Two - Mean rate = 2 cm^3/s

9. Describe how you could improve this experiment to reduce random errors. (2 marks)

Mark One - Repeat the experiment several times
Mark Two - Calculate a mean for each set of results

10. A student plots a graph of volume of gas (y-axis) against time (x-axis).
a) What shape should the graph be?
b) Why does the graph level off? (2 marks)

Mark One - A curve that flattens out
Mark Two - All the magnesium has reacted / reaction is complete

Activity 2 - Measure the rate of reaction using colour change or turgidity

Learning Objectives -

- React hydrochloric acid with with different concentrations of sodium thiosulfate.
- Use a stop clock to time how long it takes for the mixture to become cloudy for each concentration.
- Calculate the rate of reaction and determine how it changes as the concentration of sodium thiosulfate changes.

Equipment & Apparatus


Printed black paper cross

40g/dm³ sodium thiosulfate solution


Dilute hydrochloric acid



Stopclock


Conical flask (100cm³)


10cm³ and 100cm³ measuring cylinder


Safety goggles

Independent variable -
Concentration of sodium thiosulfate (g/dm³)

Dependent variable -
Time taken for the cross to disappear

Control variables -
- Volume of hydrochloric acid used
- Temperature of reacting mixture
- Volume of water added
- Equipment
- Method/speed of flask swirls

Method:

1) Measure 10cm³ of sodium thiosulfate solution and put into the conical flask.

2) Measure 40cm³ of water and add to the conical flask.

This dilutes sodium thiosulfate to 8g/dm³

3) Put the conical flask onto the black cross.

4) Measure 10cm³ of dilute hydrochloric acid.

5) Put the acid into the flask, whilst gently swirling. Start the stopwatch immediately.

7) Watch the reaction from the top of the flask. Stop the stop watch when you can no longer see the cross. Record this time on your table. Repeat 2 more times to obtain a mean.

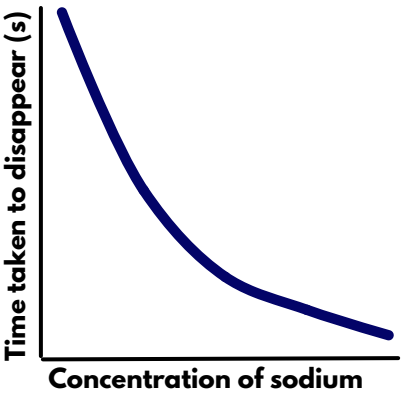
8) Repeat steps 1-7, but change the concentration of sodium thiosulfate each time:
- 20 cm³ sodium thiosulfate + 30 cm³ water (concentration 16 g/dm³)
- 30 cm³ sodium thiosulfate + 20 cm³ water (concentration 24 g/dm³)
- 40 cm³ sodium thiosulfate + 10 cm³ water (concentration 32 g/dm³)
- 50 cm³ sodium thiosulfate + no water (concentration 40 g/dm³).

Reaction:
$Na_2S_2O_3(aq)+2HCl(aq)\rightarrow 2NaCl(aq)+SO_2(g)+H_2O(l)+S(s)$

Sodium chloride is cloudy whereas sodium thiosulfate is colourless, allowing us to see when the reaction is completed.

$$\text{New concentration} = \frac{\text{Initial concentration} \times \text{Initial volume}}{\text{New volume}}$$

Concentration of sodium thiosulfate (g/dm³)	Time taken for the cross to disappear (seconds)			
	First trial	Second trial	Third trial	Mean
8	137	138	136	137
16	76	75	77	76.0
24	46	47	46	46.3
32	37	40	37	38.0
40	27	25	27	26.3



Analysing results

As the concentration of sodium thiosulfate increases, the time taken for the cross to disappear decreases.

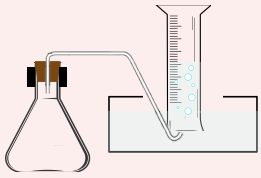
This means that the rate of reaction increases with increasing concentration.

The graph shows an inverse relationship, indicating that as the concentration goes up, the reaction occurs more quickly, causing the cross to disappear faster.

REQUIRED PRACTICAL 5 RATES OF REACTION - ACTIVITY 2

Comparing with classrooms: Reproducibility
- Checks for consistency in data
- Same results = reproducible investigation
- Variable in results caused by:
  - Experimental set up
  - Timing errors
  - Measurement errors
  - Interpretation of 'disappearance'

Evaluating Methods: Measuring Volume of Gas
- Simple and direct method
- Objective data
- Can be prone to timing errors or inaccuracies in measurements taken if not sealed properly.



- Gas syringe produces more precise results, but requires specialist equipment and is harder to set up.

Time taken for colour to change
- Simple and quick
- Subjective
- Not precise
- Colorimetry/Turbidity is more accurate and objective, but requires specialist equipment and is expensive.

Exam Style Questions - Rates of Reaction 2

1. What two reactants are used in this experiment? (2 marks)

2. What observation tells you the reaction is complete? (1 mark)

3. What is the independent variable in this experiment? (1 mark)

4. Why is water added to the sodium thiosulfate before the experiment begins? (1 mark)

5. Why should the acid be added and stopwatch started at the same time? (1 mark)

6. A student says their results are reproducible. What does this mean? (1 mark)

7. Suggest one reason why this method is less accurate than collecting gas. (1 mark)

8. 8. The student records the following result:
At a concentration of 40 g/dm^3, the cross disappeared in 23 seconds.
At 8 g/dm^3, it took 138 seconds.
Explain why the reaction is faster at higher concentrations. (3 marks)

9. The student plots a graph of concentration (x-axis) against time taken (y-axis).
a) What shape will the graph be?
b) Why does the graph curve downwards as concentration increases? (2 marks)

10. What are two sources of error in this experiment, and how could they be reduced? (4 marks)

Exam Style Questions - Rates of Reaction 2

1. What two reactants are used in this experiment? (2 marks)

Mark One - Sodium thiosulfate
Mark Two - Hydrochloric acid

2. What observation tells you the reaction is complete? (1 mark)

Mark One - When the cross is no longer visible through the solution

3. What is the independent variable in this experiment? (1 mark)

Mark One - Concentration of sodium thiosulfate

4. Why is water added to the sodium thiosulfate before the experiment begins? (1 mark)

Mark One - To reduce the concentration / to dilute the solution

5. Why should the acid be added and stopwatch started at the same time? (1 mark)

Mark One - To measure the reaction time accurately from the start

6. A student says their results are reproducible. What does this mean? (1 mark)

Mark One - That repeating the experiment gives similar results

7. Suggest one reason why this method is less accurate than collecting gas. (1 mark)

Mark One - Judging when the cross disappears is subjective

8. 8. The student records the following result:
At a concentration of 40 g/dm^3, the cross disappeared in 23 seconds.
At 8 g/dm^3, it took 138 seconds.
Explain why the reaction is faster at higher concentrations. (3 marks)

Mark One - There are more particles of sodium thiosulfate in a given volume
Mark Two - This leads to more frequent collisions
Mark Three - More collisions increase the rate of reaction

9. The student plots a graph of concentration (x-axis) against time taken (y-axis).
a) What shape will the graph be?
b) Why does the graph curve downwards as concentration increases? (2 marks)

Mark One - A curve that decreases (not a straight line)
Mark Two - Because higher concentrations cause the cross to disappear faster

10. What are two sources of error in this experiment, and how could they be reduced? (4 marks)

Mark One - Human error in judging when the cross disappears
Mark Two - Use a light sensor or colorimeter for more objective results
Mark Three - Inconsistent swirling of the flask
Mark Four - Use a mechanical stirrer to keep mixing constant