Concentration and the rate of reaction

Answers, marking points and revision notes | AQA Combined Science 8464 and AQA GCSE Chemistry 8462

GCSE science required practicals

This practical online

Answers

1 State the independent variable and the dependent variable in this investigation. (2 marks)

Independent: the concentration of sodium thiosulfate. Dependent: the time for the cross to disappear.

Marking points

- Independent: concentration of sodium thiosulfate
- Dependent: time for the cross to disappear

2 Explain why water is added so that the total volume in the flask is always 50 cm^3 (before the acid). (2 marks)

It keeps the depth of liquid above the cross the same each time. If the volume changed, the cross would be harder or easier to see, which would change the time even if the rate stayed the same.

Marking points

- Same depth of liquid / same amount of cloudiness needed to hide the cross
- So only the concentration affects the time (fair test)

3 This reaction gives off sulfur dioxide. Describe the risk and how to reduce it. (2 marks)

Sulfur dioxide irritates the lungs and can cause an asthma attack. Keep the room well ventilated, do not breathe over the flask and dispose of the mixture straight after timing.

Marking points

- Irritates lungs / triggers asthma
- Ventilation / do not sniff / dispose of the mixture promptly

4 Explain why the cross disappears during the reaction. (2 marks)

One of the products is sulfur, which is an insoluble solid. As more sulfur forms, the mixture becomes cloudy and eventually you cannot see the cross through it.

Marking points

- Solid sulfur / a precipitate forms
- Mixture becomes cloudy so the cross cannot be seen

5 Identify the anomalous result in the table and say what should be done with it. (2 marks)

Trial 2 at 24 g/dm^3 (68 s). It is much longer than the other two trials at that concentration (49 s and 51 s). It should be left out when calculating the mean.

Marking points

- 68 s at 24 g/dm^3
- Ignore it when calculating the mean (or repeat that trial)

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6 Calculate the mean time for 24 g/dm^3, leaving out the anomalous result. (2 marks)

50 s

Leave out 68 s

Mean = (49 + 51) / 2

Mean = 100 / 2 = 50 s

Marking points

- (49 + 51) / 2
- 50 s

7 Use your answer to question 6 to calculate the rate of reaction at 24 g/dm^3, using rate = 1 / time. Give the unit. (2 marks)

0.020 /s (s^{-1})

Rate = 1 / time

Rate = 1 / 50

Rate = 0.020 /s

Marking points

- 1 / 50 = 0.020
- Unit /s or s^{-1}

8 Calculate the mean time for 40 g/dm^3 and the rate at this concentration. Give the rate to 2 significant figures. Show your working. (3 marks)

Mean time 30 s; rate 0.033 /s

Mean = (31 + 29 + 30) / 3

Mean = 90 / 3 = 30 s

Rate = 1 / 30 = 0.0333...

Rate = 0.033 /s (2 significant figures)

Marking points

- Mean = (31 + 29 + 30) / 3 = 30 s
- Rate = 1 / 30
- 0.033 /s

9 Describe the effect of concentration on the rate of reaction and explain it using collision theory. (3 marks)

As the concentration increases, the time gets shorter, so the rate increases. At a higher concentration there are more thiosulfate particles in the same volume. This means collisions between the reacting particles happen more often, so there are more successful collisions per second.

Marking points

- Higher concentration, faster rate (shorter time)
- More particles in the same volume
- More frequent collisions / more successful collisions per second

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10 **Higher tier**

The mean times at 16 g/dm^3 and 32 g/dm^3 are 75.3 s and 37.0 s. What does this suggest about the relationship between concentration and rate? Use the numbers. (2 marks)

Doubling the concentration from 16 to 32 g/dm^3 roughly halves the time (75.3 / 37.0 = 2.0), so it doubles the rate. This suggests the rate is directly proportional to the concentration.

Marking points

- Doubling concentration halves the time / doubles the rate (ratio about 2)
- Rate is (directly) proportional to concentration

11 **Higher tier**

In a different experiment, Mei collected hydrogen from magnesium and acid and plotted volume of gas against time. She drew a tangent to the curve at 25 s. The tangent passes through (10 s, 12 cm^3) and (40 s, 51 cm^3). Calculate the rate of reaction at 25 s. Show your working. (3 marks)

1.3 cm^3/s

Rate = gradient of tangent = change in volume / change in time

Change in volume = 51 - 12 = 39 cm^3

Change in time = 40 - 10 = 30 s

Rate = 39 / 30

Rate = 1.3 cm^3/s

Marking points

- Change in volume = 51 - 12 = 39 cm^3
- Change in time = 40 - 10 = 30 s
- 1.3 cm^3/s

12 Callum and Mei got slightly different times when they each judged the same flask. Suggest one way to make the end point less dependent on the person watching, and explain why it helps. (2 marks)

Use a light sensor and data logger placed under the flask to record when the light level falls to a set value. This removes human judgement, so the end point is the same each time and the times are more repeatable.

Marking points

- Light sensor / colorimeter with data logger (or same person, same cross, same lighting)
- Removes subjective judgement so results are more repeatable

13 Explain the difference between results being repeatable and results being reproducible, using this investigation. (2 marks)

Repeatable means Callum and Mei get similar times when they repeat the same concentration themselves with the same method. Reproducible means another group, or someone using different equipment or a different method such as a light sensor, gets similar results.

Marking points

- Repeatable: same person / group, same method gets similar results
- Reproducible: a different person, group or method gets similar results

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14 Plan an investigation to find out how the concentration of hydrochloric acid affects the rate of its reaction with magnesium ribbon, by measuring the volume of gas produced. (6 marks)

Wear goggles. Set up a conical flask with a bung and delivery tube leading to an upturned measuring cylinder full of water in a trough, or to a gas syringe. Measure 50 cm^3 of 0.5 mol/dm^3 hydrochloric acid into the flask. Cut a 3 cm length of magnesium ribbon, drop it in, put the bung in quickly and start a stopwatch. Record the volume of hydrogen every 10 seconds until no more gas is made. Repeat with 1.0, 1.5 and 2.0 mol/dm^3 acid. Keep the volume of acid, the length of magnesium and the temperature the same each time. Repeat each concentration and plot volume of gas against time for each one. Work out the mean rate over the first 30 seconds, or compare the gradients at the start, to see how concentration affects rate. Keep flames away because hydrogen is flammable.

Marking points (any 6, with the method in a logical order)

- Conical flask, bung and delivery tube to gas syringe or upturned measuring cylinder
- Fixed volume of acid measured with a measuring cylinder
- Same length / mass of magnesium ribbon each time
- Start the stopwatch when magnesium is added and bung inserted
- Record gas volume at regular time intervals
- At least four concentrations of acid
- Control: volume of acid, mass of magnesium, temperature
- Plot volume against time / calculate rate as volume / time
- Repeat each concentration; safety such as goggles, no flames near hydrogen

How it is marked

- 5-6 marks: a clear, workable plan with gas collection apparatus, timed volume readings, a range of concentrations, control variables, repeats and a way of working out the rate.
- 3-4 marks: a mostly workable plan, but some detail missing, such as how gas is collected or what is kept the same.
- 1-2 marks: some relevant ideas, such as adding magnesium to acid and timing, but not a coherent method.

Revision notes: the method

Aim: To find out how the concentration of sodium thiosulfate solution affects the rate of its reaction with dilute hydrochloric acid, by timing how long a cross takes to disappear.

Equipment

- sodium thiosulfate solution (40 g/dm^3)
- dilute hydrochloric acid
- distilled water
- 50 cm^3 measuring cylinder and 10 cm^3 measuring cylinder
- conical flask (100 cm^3)
- piece of white paper with a bold black cross drawn on it
- stopwatch
- safety goggles

Method

1. Draw a bold black cross on a sheet of white paper and put the conical flask on top of it.
2. Measure 50 cm^3 of sodium thiosulfate solution into the flask.

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3. Measure 10 cm^3 of dilute hydrochloric acid in a separate small measuring cylinder.
4. Add the acid to the flask, swirl once and start the stopwatch at the same moment.
5. Look down through the flask from above. Stop the stopwatch when you can no longer see the cross.
6. Record the time, then pour the mixture away as directed by your teacher and rinse the flask.
7. Repeat with diluted thiosulfate: 40 cm^3 thiosulfate + 10 cm^3 water, then 30 + 20, 20 + 30 and 10 + 40, so the total volume is always 50 cm^3.
8. Do each concentration three times and find the mean time, then work out the rate as 1 / mean time.

Variables

- **Independent:** The concentration of the sodium thiosulfate solution (changed by diluting with water).
- **Dependent:** The time taken for the cross to disappear, measured with a stopwatch, used to calculate rate = 1 / time.
- **Control:** Total volume of thiosulfate solution plus water (50 cm^3); Volume and concentration of hydrochloric acid (10 cm^3); Temperature of the solutions; The same cross, flask and person judging when the cross disappears

Hazards

Hazard	What could happen	How to reduce the risk
Sulfur dioxide gas given off	Irritates the lungs; can trigger an asthma attack	Work in a well-ventilated room, do not sniff the flask, and pour the mixture into a fume cupboard sink or sodium carbonate bath as soon as timing ends
Dilute hydrochloric acid	Irritates the eyes	Wear safety goggles

Key points

- Rate = 1 / time: a shorter time means a faster rate.
- Keep the total volume the same, so the depth of liquid over the cross is always the same.
- Higher concentration means more particles in the same volume, so more frequent collisions.
- The cross disappears because the reaction makes solid sulfur, which turns the mixture cloudy.
- Judging when the cross vanishes is subjective: use the same person and the same cross each time.
- Rate from a tangent on a gas volume graph is Higher tier: gradient = change in y / change in x.

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