AQA GCSE Chemistry | 8462

SPECIFICATION POINT 4.6.1.1

Calculating rates of reactions

Past-paper questions

Tier	**Higher**
Question groups	**24**
Available paper years	**2008–2025**

Using this booklet

1. Answer the questions in order and show your working.
2. Original question numbers and marks are retained.
3. Print at actual size (100%) for measuring questions.
4. Use the companion answer booklet to check your work.

Name: _____ **Date:** _____

Whole questions are retained for context, so some parts assess other specification points. Current and legacy sources are labelled. Continue on extra paper if needed.

4.6.1.1 Calculating rates of reactions

Question 01

January 2008 | CHY2H | Original Q1 | Legacy

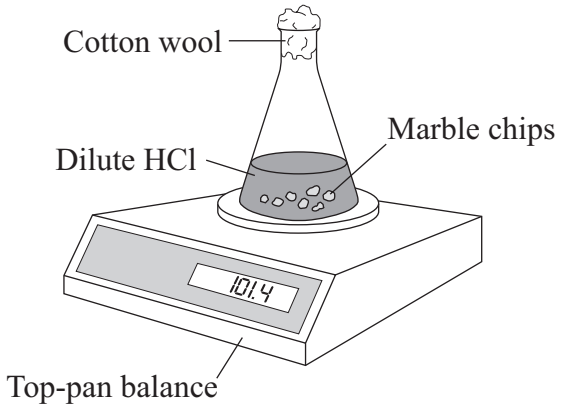
1 A student investigated the rate of reaction between marble and hydrochloric acid.

The student used an excess of marble.

The reaction can be represented by this equation.

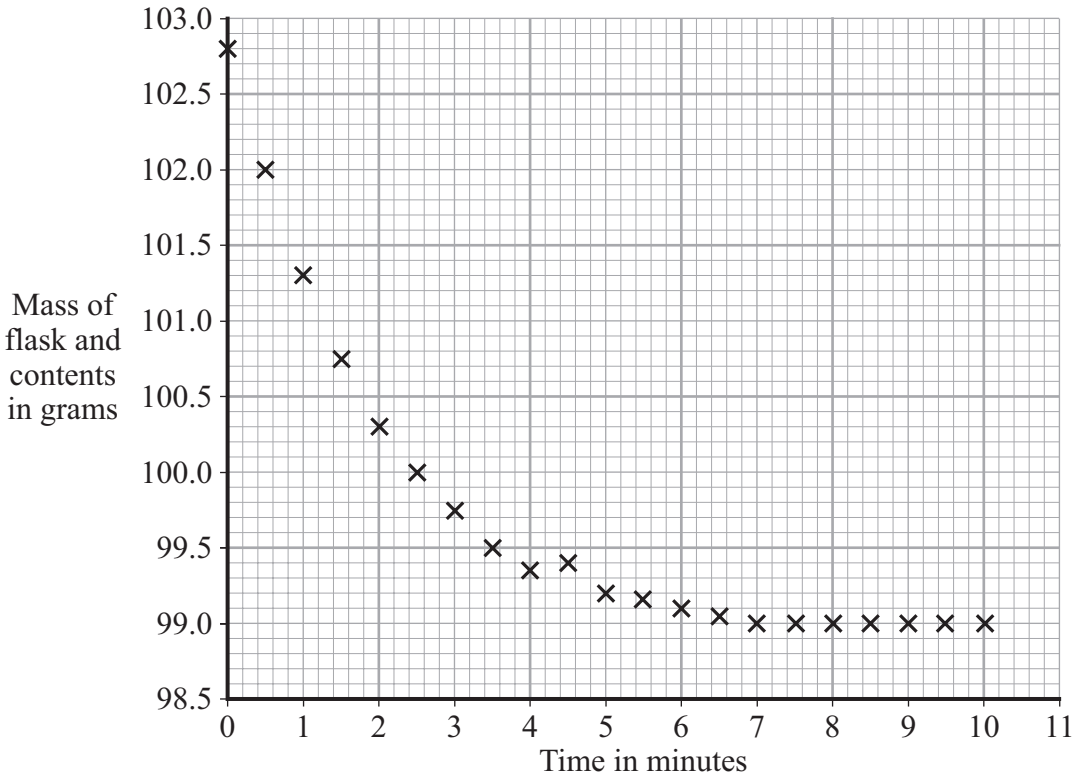
$CaCO_3$ (s) + 2HCl (aq) → $CaCl_2$ (aq) + H_2O (l) + CO_2 (g)

The student used the apparatus shown in the diagram.



The student measured the mass of the flask and contents every half minute for ten minutes.

The results are shown on the graph. Use the graph to answer the questions.



4.6.1.1 Calculating rates of reactions

Question 01 · continued

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(a) **Complete the graph** opposite by drawing a line of best fit.

(1 mark)

(b) Why did the mass of the flask and contents decrease with time?

.....

.....

(1 mark)

(c) After how many minutes had all the acid been used up?

..... minutes

(1 mark)

(d) The student repeated the experiment at a higher temperature. All other variables were kept the same as in the first experiment. The rate of reaction was much faster.

(i) Draw a line **on the graph** opposite to show what the results for this second experiment might look like.

(2 marks)

(ii) Why does an increase in temperature increase the rate of reaction?

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(3 marks)

8

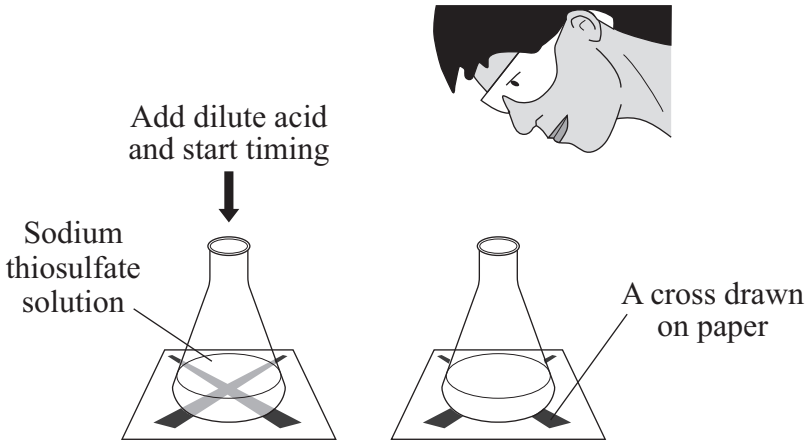
4.6.1.1 Calculating rates of reactions

Question 02

June 2009 | CHY2H | Original Q1 | Legacy

1 Sodium thiosulfate solution reacts with hydrochloric acid. As the reaction takes place the solution slowly turns cloudy.

The diagram shows a method of measuring the rate of this reaction.



A student used this method to investigate how changing the concentration of the sodium thiosulfate solution affects the rate of this reaction.

The student used different concentrations of sodium thiosulfate solution. All the other variables were kept the same.

The results are shown on the graph on the opposite page.

1 (a) (i) Draw a line of best fit on the graph. *(1 mark)*

1 (a) (ii) Suggest **two** reasons why all of the points do not lie on the line of best fit.

1 .....

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2 .....

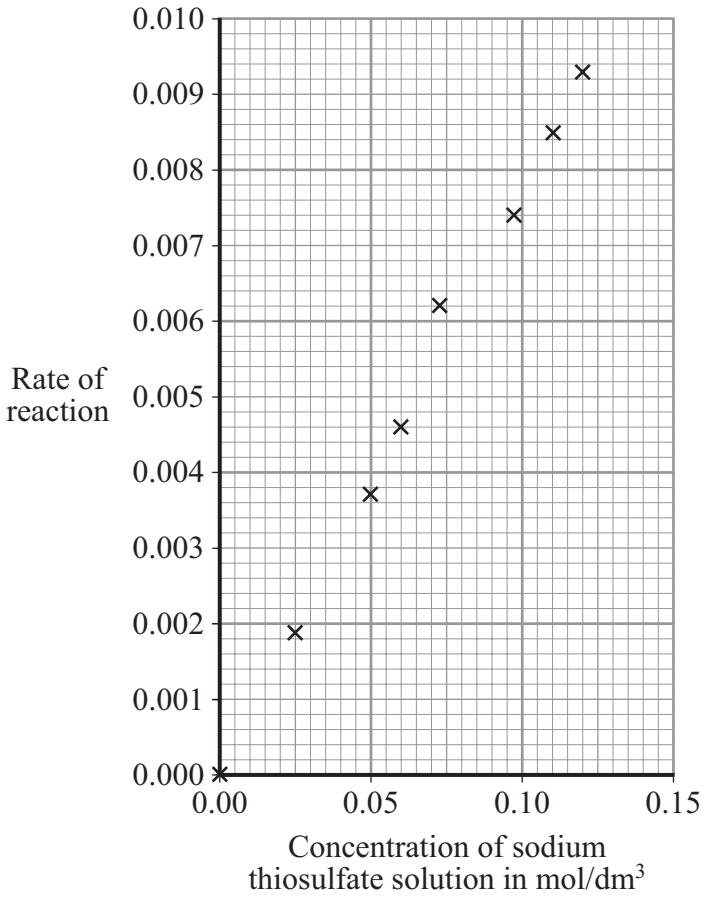
.....

(2 marks)

4.6.1.1 Calculating rates of reactions

Question 02 · continued

for mark



1 (b) (i) In a conclusion to the investigation the student stated that:

'The rate of this reaction is directly proportional to the concentration of the sodium thiosulfate solution.'

How does the graph support this conclusion?

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(1 mark)

1 (b) (ii) Explain, in terms of particles, why the rate of reaction increases when the concentration of sodium thiosulfate is increased.

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(2 marks)

6

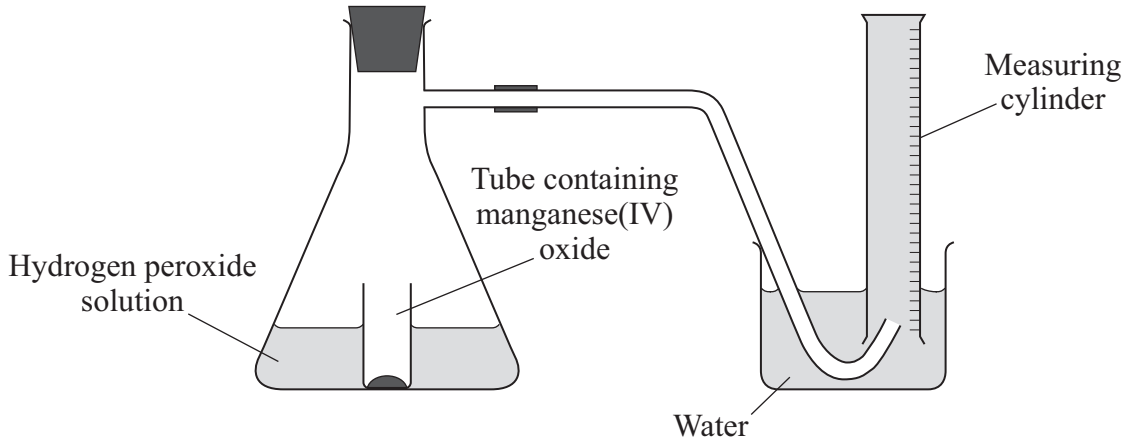
4.6.1.1 Calculating rates of reactions

Question 03

5 A student investigated the effect of temperature on the decomposition of hydrogen peroxide. Hydrogen peroxide decomposes to oxygen and water when a manganese(IV) oxide catalyst is added.

The student measured the time taken to collect 5 cm^3 of oxygen gas.

The apparatus shown below was used for the investigation. The reaction was started by shaking the flask so that the manganese(IV) oxide and hydrogen peroxide were mixed.



The student did the investigation at two different temperatures. All the other variables were kept constant.

The student's results are shown in the table.

Temperature of the hydrogen peroxide solution in °C	Volume of oxygen collected in cm^3	Time taken to collect the oxygen in seconds	Rate of reaction in cm^3 per second
20	5	40	0.125
25	5	25	

5 (a) (i) Calculate the rate of reaction at 25 °C.

.....

Rate of reaction = ... cm^3 per second
(2 marks)

5 (a) (ii) The teacher said that the student should repeat the investigation to get more results.

Suggest why.

.....

.....
(1 mark)

4.6.1.1 Calculating rates of reactions

Question 03 · continued

for mark

5 (b) The student concluded that:

'the rate of reaction increases when the temperature is increased'.

Explain, in terms of particles, why the rate of reaction increases.

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(2 marks)

5

Turn over for the next question

4.6.1.1 Calculating rates of reactions

Question 04

June 2010 | CHY2H | Original Q6 | Legacy

6 The equation for a reaction to produce hydrogen is:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

6 (a) Explain why changing the pressure does **not** affect the yield of hydrogen at equilibrium.

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(1 mark)

6 (b) Suggest why the best yield of hydrogen at equilibrium is obtained at **low** temperatures.

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(1 mark)

6 (c) The temperature used in industry needs to be high enough for the reaction to take place quickly. Explain, in terms of particles, why the rate of reaction increases when the temperature is increased.

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(3 marks)

6 (d) Scientists have developed catalysts which allow the reaction to take place quickly at lower temperatures. How could this be good for the manufacturer and for the environment?

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(2 marks)

7

4.6.1.1 Calculating rates of reactions

Question 05

January 2011 | CHY2H | Original Q6 | Legacy

6 The picture shows a wooden bowl.
The pieces of wood used for this bowl were dyed different colours.



The artist who made the bowl explained why he dissolved the coloured dyes in methanol.

> I use different coloured dyes dissolved in methanol.
> I use methanol because with dyes dissolved in water the wood needs to be soaked for a longer time.
> The bowl dries more quickly if I use methanol instead of water.

6 (a) (i) Why is using methanol an advantage to the artist?

.....

.....

(1 mark)

6 (a) (ii) The bonds within a methanol molecule are strong, covalent bonds.

Explain why methanol has a low boiling point.

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(2 marks)

4.6.1.1 Calculating rates of reactions

Question 05 · continued

6 (b) Methanol is made by reacting carbon monoxide with hydrogen.

The equation for this reaction is:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The forward reaction is exothermic.

The best equilibrium yield of methanol is obtained when the temperature is low and when the pressure is high.

Explain why the best equilibrium yield is obtained:

6 (b) (i) when the temperature is low

.....

.....

(1 mark)

6 (b) (ii) when the pressure is high.

.....

.....

(1 mark)

6 (b) (iii) In industry a high temperature is used for this reaction. This gives a fast rate of reaction. The increase in temperature gives the particles more energy.

Explain, in terms of particles, why this makes the reaction go faster.

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(2 marks)

Question 6 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 05 · continued

6 (c) (i) Calculate the maximum mass of methanol that could be made from 14 g of carbon monoxide.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

Relative formula masses (M_r): CO = 28; CH_3OH = 32.

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Maximum mass of methanol = ... g
(2 marks)

6 (c) (ii) In an experiment the actual mass of methanol made from 14 g of carbon monoxide was 12 g. Use this information and your answer from part (c)(i) to calculate the percentage yield of methanol in this experiment.

(If you did not get an answer to part (c)(i) then assume that the maximum yield is 18 g. This is **not** the correct answer to part (c)(i).)

.....

.....

Percentage yield of methanol = ...%
(2 marks)

6 (c) (iii) Suggest **one** reason why the yield obtained is less than the maximum yield.

.....

.....
(1 mark)

12

4.6.1.1 Calculating rates of reactions

Question 06

June 2011 | CHY2H | Original Q3 | Legacy

3 The picture shows lumps of phosphate rock.



Phosphoric acid is made by adding sulfuric acid to phosphate rock.

3 (a) The rate of reaction between sulfuric acid and phosphate rock can be increased if the mixture is heated to a higher temperature.

Explain, in terms of particles, why an increase in temperature increases the rate of reaction.

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(2 marks)

3 (b) State **one** other way in which the rate of reaction between sulfuric acid and phosphate rock can be increased.

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(1 mark)

3

4.6.1.1 Calculating rates of reactions

Question 07

January 2013 | CH2HP | Original Q1 | Legacy

1 A student investigated the rate of reaction between sodium thiosulfate and dilute hydrochloric acid.

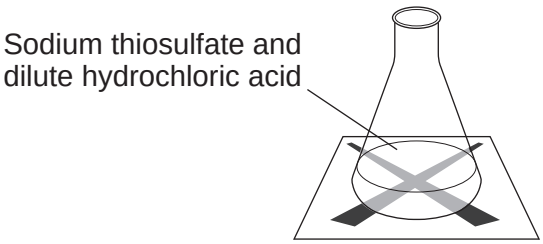
The student placed a conical flask over a cross on a piece of paper.

The student mixed the solutions in the flask.

The solution slowly went cloudy.

The student timed how long it took until the cross could not be seen.





The equation for the reaction is:

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

sodium thiosulfate + hydrochloric acid → sodium chloride + water + sulfur dioxide + sulfur

1 (a) Explain why the solution goes cloudy.

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.....

.....

(2 marks)

4.6.1.1 Calculating rates of reactions

Question 07 · continued

1 (b) The student repeated the experiment with different concentrations of sodium thiosulfate.

Concentration of sodium thiosulfate in moles per dm^3	Time taken until the cross could not be seen in seconds			
	Trial 1	Trial 2	Trial 3	Mean
0.040	71	67	69	69
0.060	42	45	45	44
0.080	31	41	33	

1 (b) (i) Calculate the mean time for 0.080 moles per dm^3 of sodium thiosulfate.

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Mean = ... seconds
(2 marks)

1 (b) (ii) Describe and explain, in terms of particles and collisions, the effect that increasing the concentration of sodium thiosulfate has on the rate of the reaction.

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(3 marks)

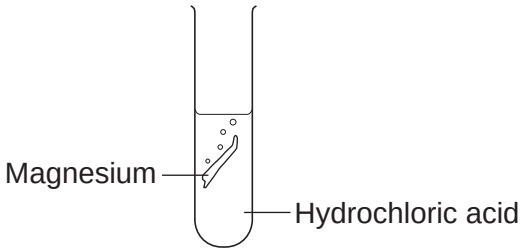
7

4.6.1.1 Calculating rates of reactions

Question 08

June 2013 | CH2HP | Original Q2 | Legacy

2 A student investigated the reaction between magnesium and hydrochloric acid.



The equation for the reaction is:

Mg(s)	+	2 HCl(aq)	⟶	$MgCl_2$(aq)	+	H_2(g)
magnesium		hydrochloric acid		magnesium chloride		hydrogen

2 (a) Give **two** observations the student could make during the reaction.

1 .....

.....

2 .....

.....

(2 marks)

2 (b) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

The student investigated how the rate of this reaction changed when the concentration of hydrochloric acid was changed.

Write a plan the student could use.

In your plan you should:

- describe how you would carry out the investigation and make it a fair test
- describe the measurements you would make.

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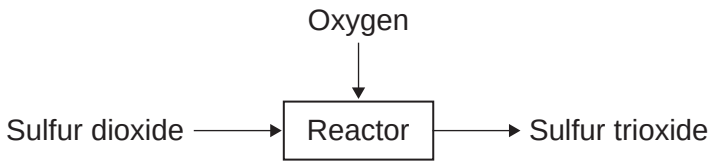
4.6.1.1 Calculating rates of reactions

Question 09

June 2014 | CH2HP | Original Q3 | Legacy

3 **Figure 2** represents a reaction in the production of sulfuric acid.

Figure 2



3 (a) Complete and balance the equation for the reaction.

[2 marks]

..... $SO_2(g)$ + ... (g) $\rightleftharpoons$ ..... $SO_3(g)$

3 (b) The conditions can affect the rate of the reaction.

3 (b) (i) The pressure of the reacting gases was increased.

State the effect of increasing the pressure on the rate of reaction.

Explain your answer in terms of particles.

[3 marks]

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4.6.1.1 Calculating rates of reactions

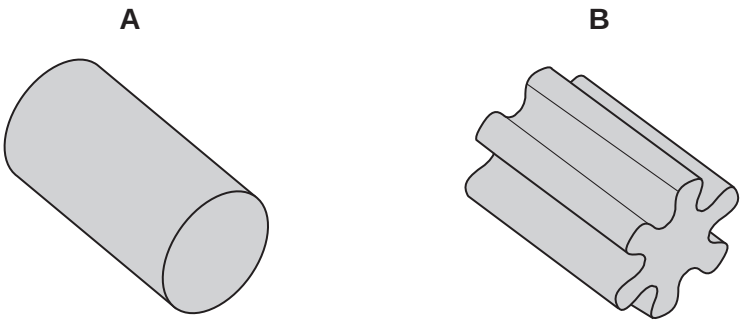
Question 09 · continued

3 (b) (ii) A catalyst is used for the reaction.

The gases pass through a layer containing pieces of the catalyst.

Figure 3 shows the shapes of pieces of catalyst.

Figure 3



Suggest and explain why shape **B** is more effective as a catalyst than shape **A**.

[2 marks]

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3 (c) The reaction is carried out at a high temperature to provide the reactants with the **activation energy**.

What is meant by the **activation energy**?

[1 mark]

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4.6.1.1 Calculating rates of reactions

Question 09 · continued

3 (d) Sulfuric acid reacts with metals to produce salts.

3 (d) (i) A student concluded that potassium would **not** be a suitable metal to react with sulfuric acid.

Explain why.

[2 marks]

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3 (d) (ii) A student reacted zinc metal with sulfuric acid to produce a salt and another product.

Complete the equation for this reaction.

[2 marks]

$Zn + H_2SO_4 \longrightarrow$ ..... + ...

3 (d) (iii) The student wanted to increase the rate of the reaction between the zinc and sulfuric acid.

State **one** way, other than using a catalyst, that the student could increase the rate of the reaction.

[1 mark]

.....

.....

13

4.6.1.1 Calculating rates of reactions

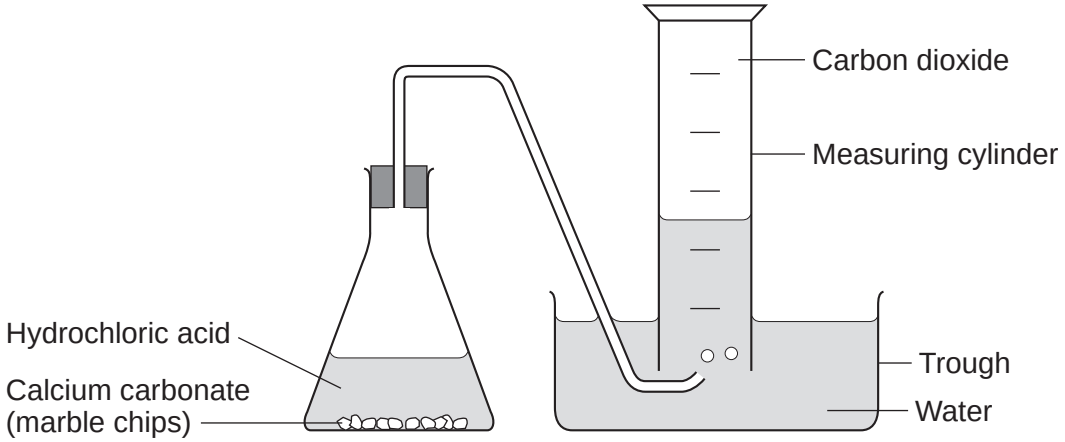
Question 10

June 2015 | CH2HP | Original Q1 | Legacy

1 A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

The student used the apparatus shown in **Figure 1**.

Figure 1



The student:

- recorded the volume of gas collected every 5 seconds
- repeated the experiment using hydrochloric acid at different temperatures.

The equation for the reaction is:

$$CaCO_3(s) + 2\,HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

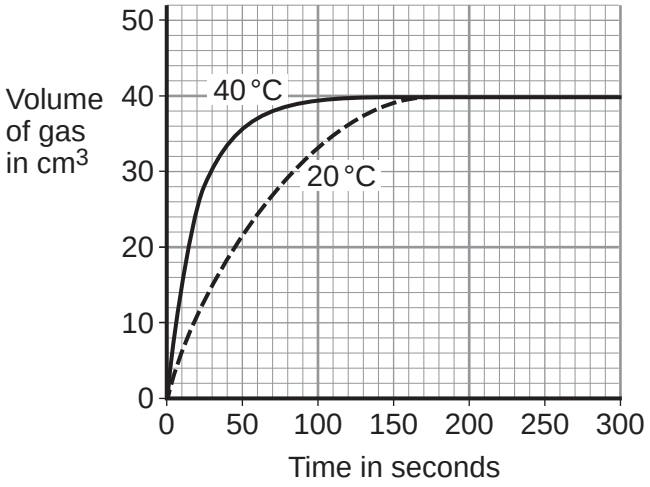
4.6.1.1 Calculating rates of reactions

Question 10 · continued

1 (a) The student plotted results for the hydrochloric acid at 20 °C and 40 °C on a graph.

Figure 2 shows the student's graph.

Figure 2



Use information from **Figure 2** to answer these questions.

1 (a) (i) State **one** conclusion the student could make about the effect of temperature on the rate of the reaction.

[1 mark]

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.....

1 (a) (ii) Give **one** reason why the student could make this conclusion.

[1 mark]

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1 (a) (iii) For the hydrochloric acid at 60 °C the student had collected 30 cm^3 after 15 seconds.

Calculate the average rate of reaction from 0 to 15 seconds.

[1 mark]

.....

.....

Rate of reaction = ... cm^3 per second

4.6.1.1 Calculating rates of reactions

Question 10 · continued

1 (b) The student then investigated how the surface area of marble chips affected the rate of reaction.

1 (b) (i) Which **two** variables should the student keep constant?

[2 marks]

Tick (✓) **two** boxes.

- Amount of water in the trough ☐
- Concentration of acid ☐
- Mass of marble chips ☐
- Size of marble chips ☐
- Volume of measuring cylinder ☐

1 (b) (ii) Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction.

[2 marks]

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1 (c) Calcium carbonate is a catalyst for the industrial production of biodiesel.

Give **one** reason why using a catalyst reduces costs.

[1 mark]

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.....

8

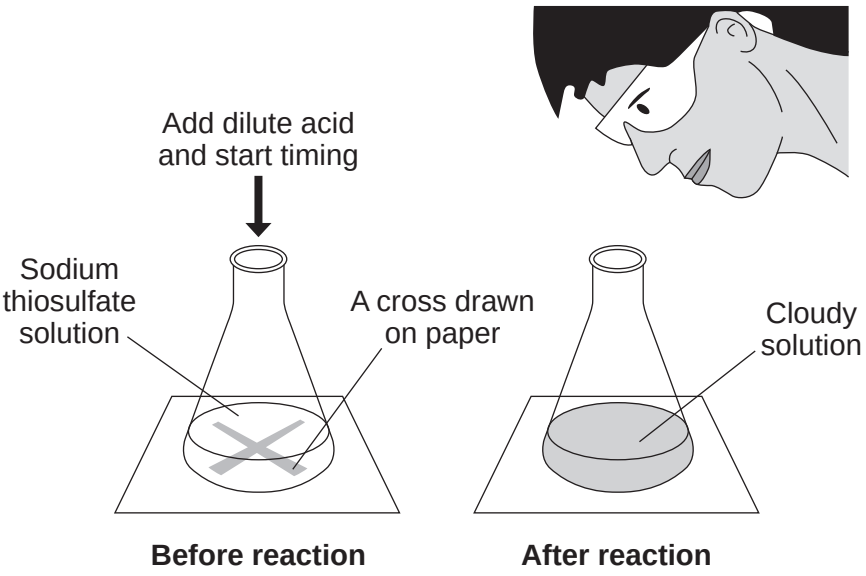
4.6.1.1 Calculating rates of reactions

Question 11

June 2016 | CH2HP | Original Q4 | Legacy

4 A student investigated the effect of temperature on the rate of a reaction.
Figure 4 shows an experiment.

Figure 4



The student:

- put sodium thiosulfate solution into a conical flask
- heated the sodium thiosulfate solution to the required temperature
- put the flask on a cross drawn on a piece of paper
- added dilute hydrochloric acid and started a stopclock
- stopped the stopclock when the cross could no longer be seen
- repeated the experiment at different temperatures.

The equation for the reaction is:

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

sodium thiosulfate	hydrochloric acid	sodium chloride	water	sulfur dioxide	sulfur

4.6.1.1 Calculating rates of reactions

Question 11 · continued

4 (a) Explain why the solution goes cloudy.

[2 marks]

4 (b) Give **two** variables the student must control to make the investigation a fair test.

[2 marks]

1 _____

2 _____

4 (c) State the effect that increasing the temperature of the sodium thiosulfate solution has on the rate of the reaction.
Explain this effect in terms of particles and collisions.

[4 marks]

4 (d) Suggest how the student should change the method to investigate the rate of reaction at 5 °C.

[1 mark]

9

4.6.1.1 Calculating rates of reactions

Question 12

June 2017 | CH2HP | Original Q1 | Legacy

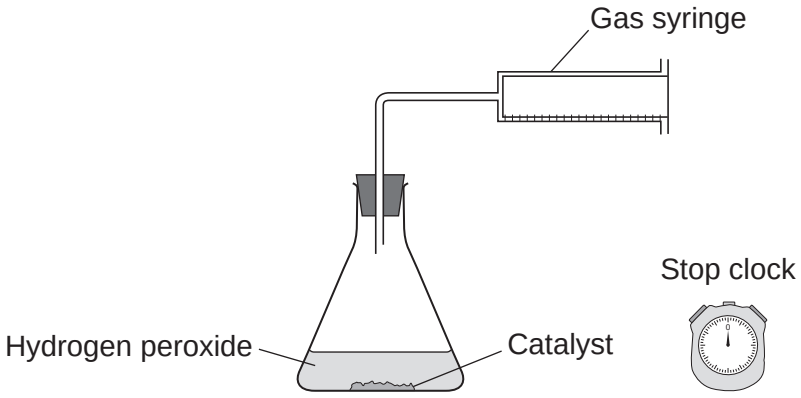
1 This question is about rates of reaction.

The equation for the decomposition of hydrogen peroxide is:

$$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$$

Figure 1 shows the apparatus a student used to investigate the rate of reaction for the decomposition of hydrogen peroxide.

Figure 1



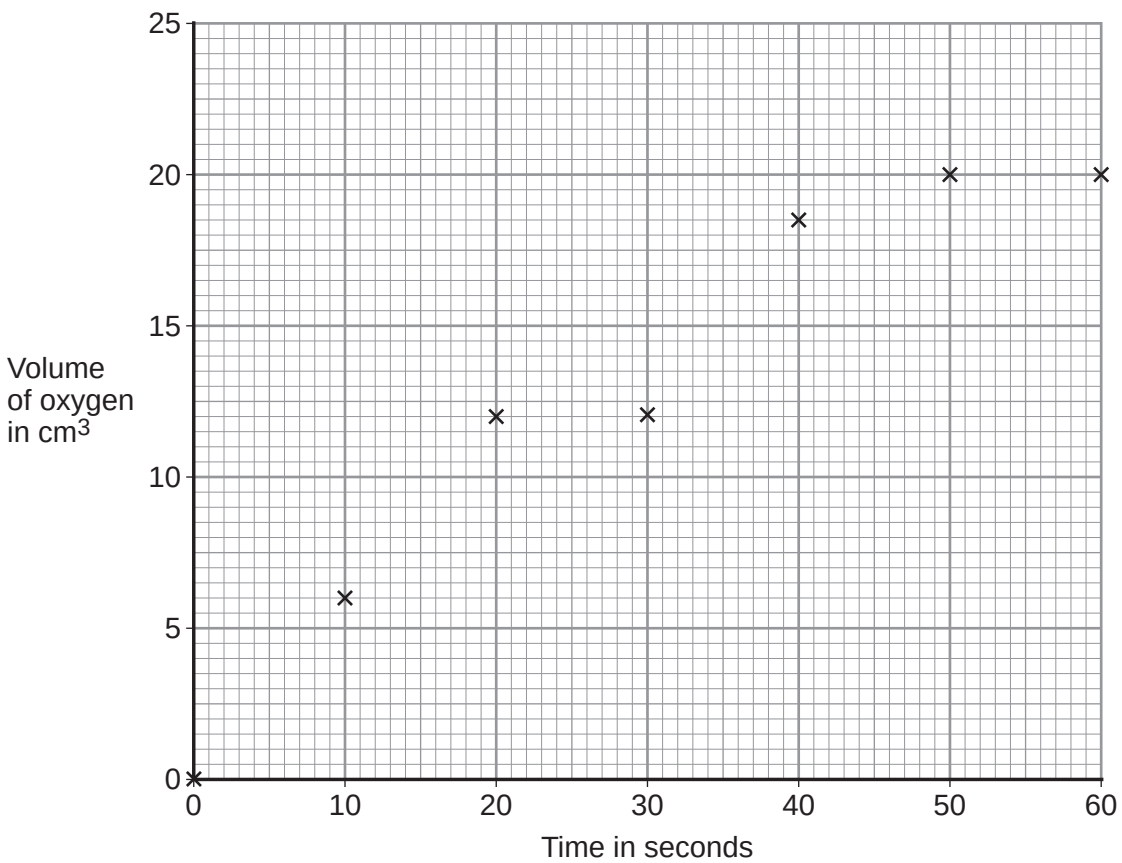
Question 1 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 12 · continued

The graph in **Figure 2** shows the results.

Figure 2



1 (a) (i) Draw a smooth curve of best fit on **Figure 2**.

[1 mark]

1 (a) (ii) Give the volume of oxygen produced at 25 seconds.

[1 mark]

Volume of oxygen = _____ cm^3

1 (a) (iii) After how many seconds does the reaction stop?

[1 mark]

Time = _____ seconds

4.6.1.1 Calculating rates of reactions

Question 12 · continued

1 (a) (iv) The student concluded that the rate of reaction decreases with time.

Explain how the results support this conclusion.

[2 marks]

1 (a) (v) Calculate the mean rate of reaction during the first 10 seconds.

[1 mark]

Mean rate of reaction = _____ cm^3 per second

1 (b) The student investigated the effect of concentration on the rate of the reaction.

The student repeated the experiment with greater concentrations of hydrogen peroxide.

1 (b) (i) The catalyst was kept the same. Give **two** other control variables.

[2 marks]

Question 1 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 12 · continued

1 (b) (ii) State and explain, in terms of particles and collisions, how a greater concentration affects the rate of the reaction.

[3 marks]

1 (c) Describe how increasing the amount of catalyst affects the results in **Figure 2**.

[2 marks]

13

4.6.1.1 Calculating rates of reactions

Question 13

June 2018 | 8462/2H | Original Q8

0 8 A student investigated how temperature affects the rate of reaction between magnesium carbonate and dilute hydrochloric acid.

This is the method used.

1. Heat hydrochloric acid to 30 ºC in a conical flask.
2. Add magnesium carbonate powder to the conical flask.
3. Measure the loss in mass of the flask and contents every 20 seconds for 140 seconds.
4. Repeat steps 1-3 with hydrochloric acid heated to 50 ºC

0 8 . 1 Explain why the contents of the conical flask lose mass.

[2 marks]

0 8 . 2 **Table 5** shows the student's results for hydrochloric acid at 30 ºC

Table 5

Time in seconds	Loss of mass in grams
0	0.00
20	0.26
40	0.48
60	0.67
80	0.82
100	0.91
120	0.96
140	0.99

4.6.1.1 Calculating rates of reactions

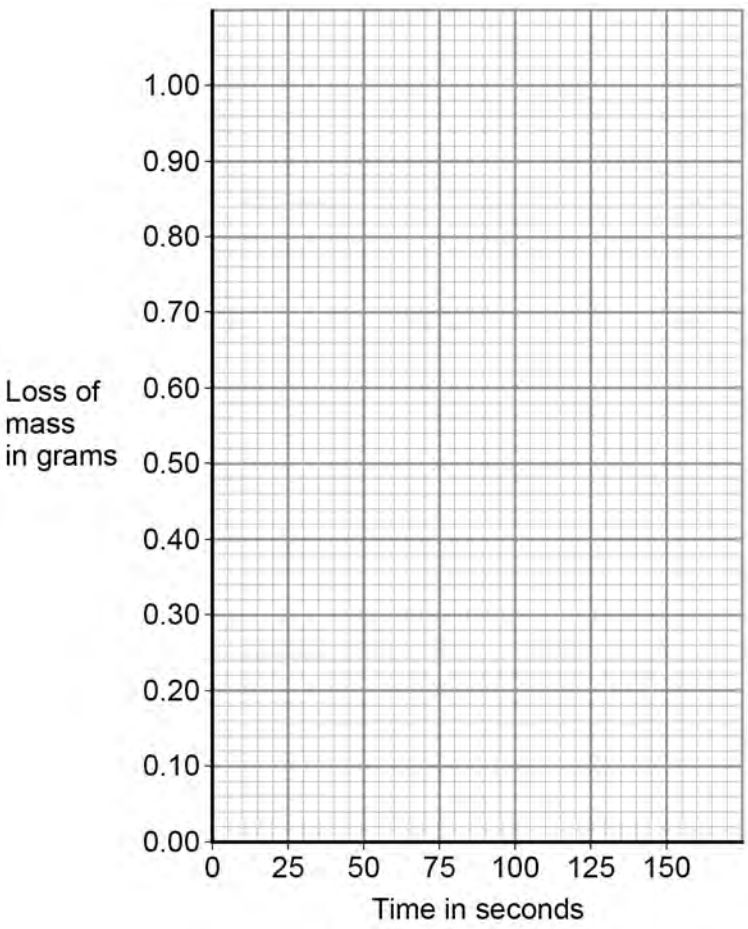
Question 13 · continued

Plot the data from **Table 5** on **Figure 6**.

Draw a line of best fit.

[3 marks]

Figure 6



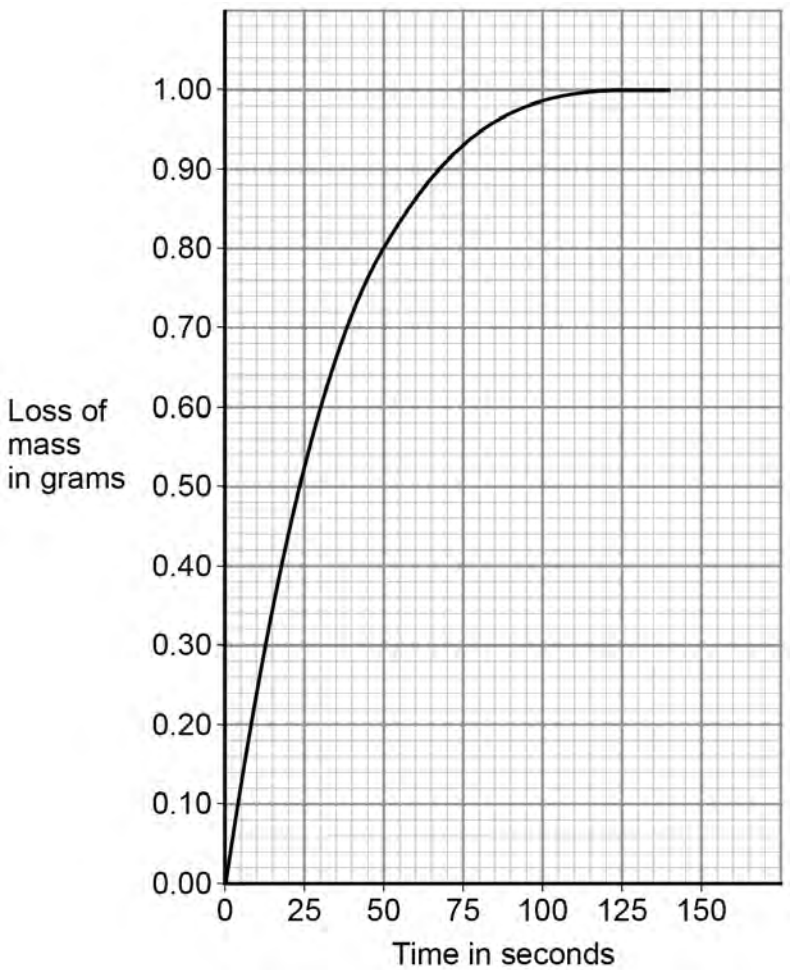
Question 8 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 13 · continued

Figure 7 shows the student's results for hydrochloric acid at 50 ºC

Figure 7



0 8 . 3 Determine the rate of reaction at 50 °C when the loss of mass is 0.95 g

Show your working on **Figure 7**.

Give your answer to 2 significant figures.

[4 marks]

Rate of reaction = _____ g/s

9

4.6.1.1 Calculating rates of reactions

Question 14

June 2018 | 8462/2H | Original Q9

0 9 This question is about methanol.

0 9 . 1 Methanol is broken down in the body during digestion.

What type of substance acts as a catalyst in this process?

[1 mark]

Tick **one** box.

- Amino acid ☐
- Enzyme ☐
- Ester ☐
- Nucleotide ☐

In industry, methanol is produced by reacting carbon monoxide with hydrogen.

The equation for the reaction is:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

0 9 . 2 How many moles of carbon monoxide react completely with 4.0×10^3 moles of hydrogen?

[1 mark]

Tick **one** box.

- 1.0×10^3 moles ☐
- 2.0×10^3 moles ☐
- 4.0×10^3 moles ☐
- 8.0×10^3 moles ☐

4.6.1.1 Calculating rates of reactions

Question 14 · continued

0 9 . 3 The reaction is carried out at a temperature of 250 ºC and a pressure of 100 atmospheres.

The forward reaction is exothermic.

Explain what happens to the yield of methanol if a temperature higher than 250 ºC is used.

[2 marks]

0 9 . 4 A pressure of 100 atmospheres is used instead of atmospheric pressure.

The higher pressure gives a greater yield of methanol **and** an increased rate of reaction.

Explain why.

[4 marks]

Question 9 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 14 · continued

A catalyst is used in the reaction to produce methanol from carbon monoxide and hydrogen.

0 9 . 5 Explain how a catalyst increases the rate of a reaction.

[2 marks]

0 9 . 6 Suggest why a catalyst is used in this industrial process.

Do **not** give answers in terms of increasing the rate of reaction.

[1 mark]

0 9 . 7 Suggest the effect of using the catalyst on the equilibrium yield of methanol.

[1 mark]

12

4.6.1.1 Calculating rates of reactions

Question 15

June 2019 | 8462/2H | Original Q3

0 3 This question is about rate of reaction.

A student investigated the rate of the reaction between magnesium and dilute hydrochloric acid.

The equation for the reaction is:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

0 3 . 1 Which state symbol in the equation for the reaction does **not** represent one of the three states of matter?

[1 mark]

The student determined the rate of production of hydrogen gas.

0 3 . 2 What **two** pieces of measuring apparatus could the student use to find the rate of production of hydrogen gas?

[2 marks]

1 _____

2 _____

Question 3 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 15 · continued

Table 2 shows the results of the investigation.

Table 2

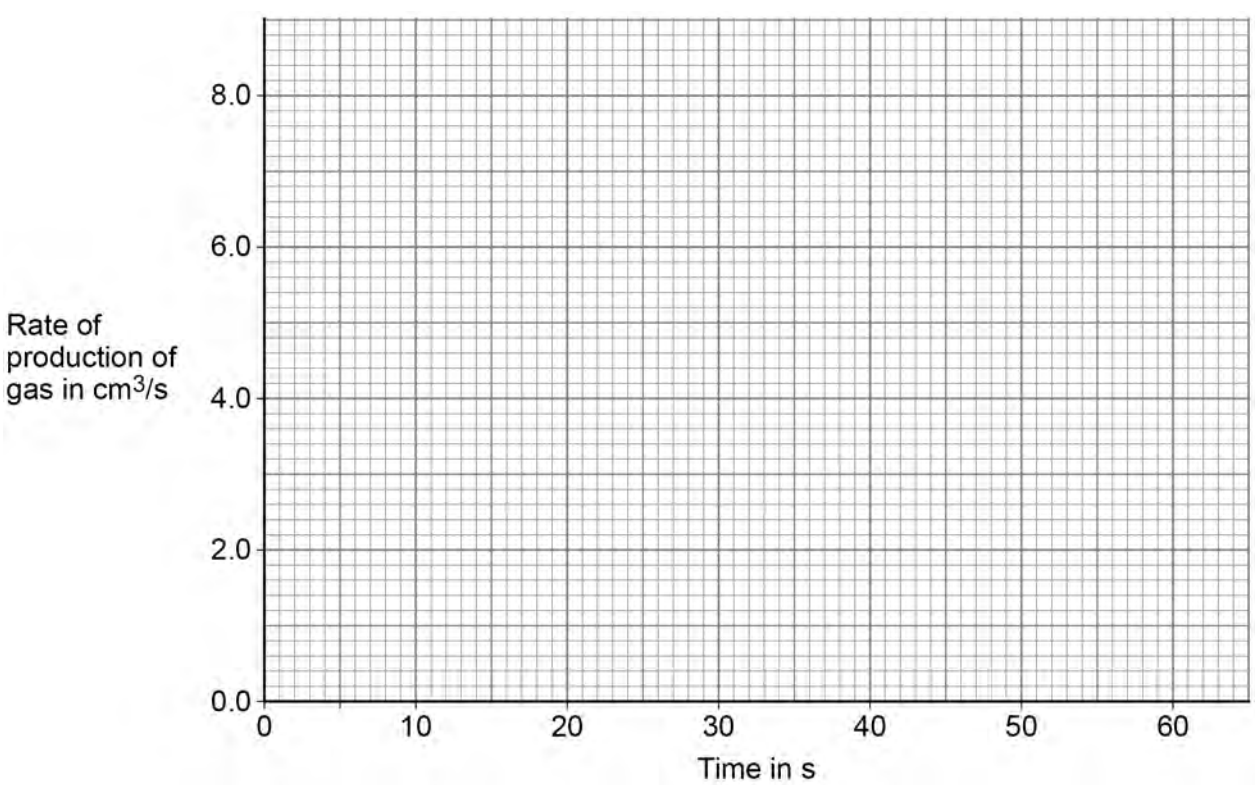
Time in s	Rate of production of gas in cm^3/s
10	6.9
20	3.9
30	2.0
40	0.9
50	0.3
60	0.0

0 3 . 3 Plot the data from **Table 2** on **Figure 3**.

You should draw a line of best fit.

[3 marks]

Figure 3



4.6.1.1 Calculating rates of reactions

Question 15 · continued

0 3 . 4 Give **three** conclusions that can be drawn about the rate of reaction between magnesium and dilute hydrochloric acid in this investigation.

Use data from **Figure 3** and **Table 2**.

[3 marks]

1 _____

_____

2 _____

_____

3 _____

_____

0 3 . 5 The student repeated the investigation using dilute hydrochloric acid at a higher temperature.

All the other variables were kept the same.

Which **two** statements are correct?

[2 marks]

Tick (✓) **two** boxes.

More bubbles were produced in the first 10 seconds. ☐

The activation energy for the reaction was higher. ☐

The magnesium was used up more quickly. ☐

The reaction finished at the same time. ☐

The total volume of gas collected was greater. ☐

11

4.6.1.1 Calculating rates of reactions

Question 16

June 2019 | 8462/2H | Original Q9

0 9 Some students investigated the rate of decomposition of hydrogen peroxide, H_2O_2

The equation for the reaction is:

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

The catalyst for the reaction is manganese dioxide.

0 9 . 1 Describe a test to identify the gas produced in the reaction.

Give the result of the test.

[2 marks]

Test _____

_____

Result _____

_____

4.6.1.1 Calculating rates of reactions

Question 16 · continued

Student **A** investigated the effect of the particle size of manganese dioxide on the rate of the reaction.

This is the method used.

1. Measure 25 cm^3 of 0.3 mol/dm^3 hydrogen peroxide solution into a conical flask.

2. Add a spatula of fine manganese dioxide powder to the conical flask.

3. Measure the volume of gas produced every minute for 10 minutes.

4. Repeat steps 1 to 3 with some coarse manganese dioxide lumps.

0 9 . 2 The method student **A** used did **not** give valid results.

What **two** improvements could student **A** make to the method to give valid results?

[2 marks]

Tick (✓) **two** boxes.

- Measure the increase in mass of the conical flask and contents. ☐
- Measure the volume of gas produced every 2 minutes. ☐
- Place the conical flask in a water bath at constant temperature. ☐
- Use 0.05 mol/dm^3 hydrogen peroxide solution. ☐
- Use a mass of 1 g manganese dioxide each time. ☐

Question 9 continues on the next page

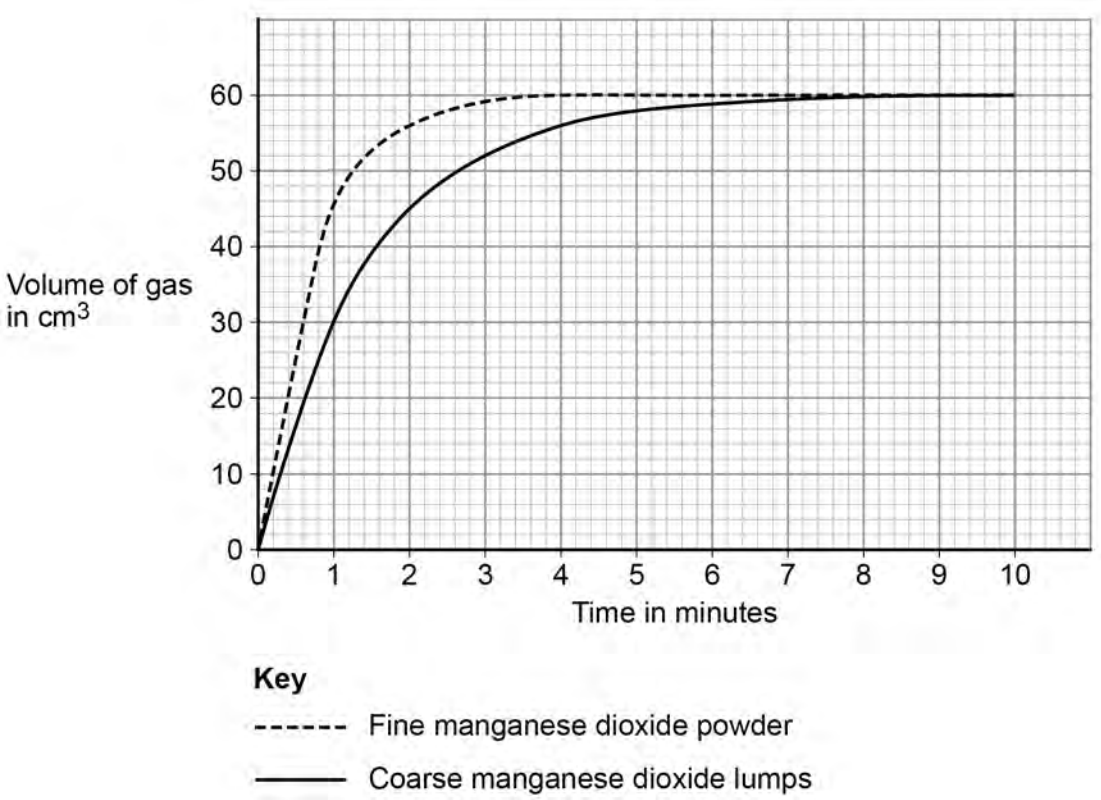
4.6.1.1 Calculating rates of reactions

Question 16 · continued

Student **B** used a method which gave valid results.

Figure 9 shows student **B**'s results.

Figure 9



0 9 . 3 Determine the mean rate of reaction in cm^3/s between 2 and 4 minutes for coarse manganese dioxide lumps.

Give your answer to 2 significant figures.

Use data from **Figure 9**.

[3 marks]

Mean rate of reaction = _____ cm^3/s

4.6.1.1 Calculating rates of reactions

Question 16 · continued

Hydrogen peroxide molecules must collide with manganese dioxide particles for catalysis to take place.

0 9 . 4 Student **B** repeated the experiment with coarse lumps of manganese dioxide.

Student **B** used the same volume of 0.2 mol/dm^3 hydrogen peroxide instead of 0.3 mol/dm^3 hydrogen peroxide.

Sketch on **Figure 9** the curve you would expect to see.

Assume that the reaction is complete after 9 minutes.

[2 marks]

0 9 . 5 The rate of reaction is different when manganese dioxide is used as a fine powder rather than coarse lumps.

Explain why.

You should answer in terms of collision theory.

[2 marks]

11

4.6.1.1 Calculating rates of reactions

Question 17

November 2020 | 8462/2H | Original Q8

0 8 This question is about the rate of the reaction between hydrochloric acid and calcium carbonate.

A student investigated the effect of changing the size of calcium carbonate lumps on the rate of this reaction.

This is the method used.

1. Pour 40 cm^3 of hydrochloric acid into a conical flask.

2. Add 10.0 g of small calcium carbonate lumps to the conical flask.

3. Attach a gas syringe to the conical flask.

4. Measure the volume of gas produced every 30 seconds for 180 seconds.

5. Repeat steps 1 to 4 using 10.0 g of large calcium carbonate lumps.

The student calculated the number of moles of gas from each volume of gas measured.

Table 4 shows the student's results for large calcium carbonate lumps.

Table 4

Time in seconds	Number of moles of gas
0	0.0000
30	0.0011
60	0.0020
90	0.0028
120	0.0034
150	0.0038
180	0.0040

The student plotted the results for small calcium carbonate lumps on **Figure 4**.

0 8 . 1 Complete **Figure 4**.

You should:

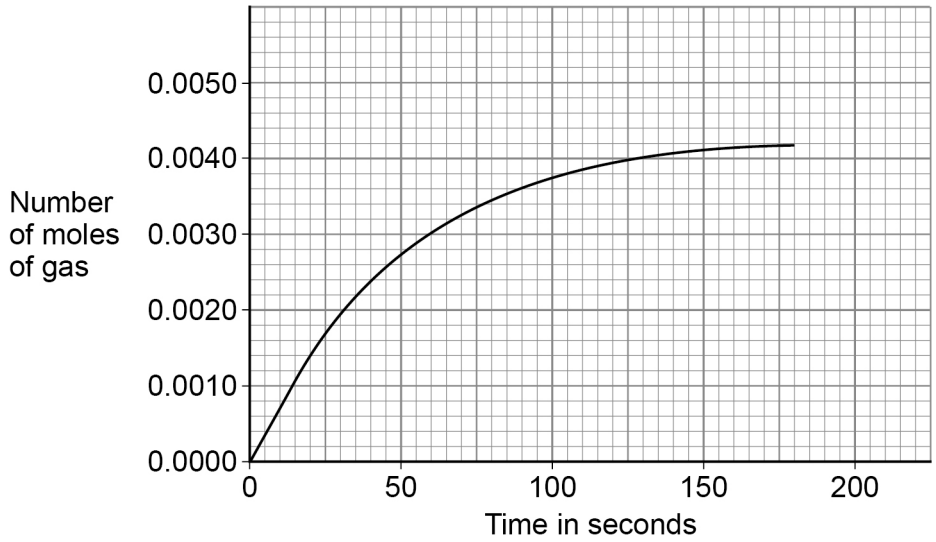
- plot the data for large calcium carbonate lumps from **Table 4**
- draw a line of best fit.

[3 marks]

4.6.1.1 Calculating rates of reactions

Question 17 · continued

Figure 4



0 8 . 2 Determine the mean rate of reaction for **small** calcium carbonate lumps between 20 seconds and 105 seconds.

Give the unit.

Use **Figure 4**.

[4 marks]

Mean rate of reaction = _____ Unit _____

0 8 . 3 The student concluded that the large calcium carbonate lumps reacted more slowly than the small calcium carbonate lumps.

How do the student's results show that this conclusion is correct?

[1 mark]

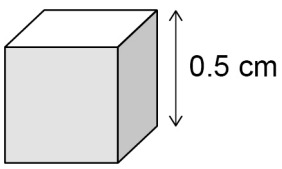
4.6.1.1 Calculating rates of reactions

Question 17 · continued

The difference in the rates of reaction of large lumps and of small lumps of calcium carbonate depends on the surface area to volume ratios of the lumps.

Figure 5 shows a cube of calcium carbonate.

Figure 5



0 8 . 4 Calculate the surface area to volume ratio of the cube in **Figure 5**.

Give your answer as the simplest whole number ratio.

[3 marks]

Surface area : volume = _____ : _____

0 8 . 5 A larger cube of calcium carbonate has sides of 5 cm

Describe how the surface area to volume ratio of this larger cube differs from that of the cube shown in **Figure 5**.

[1 mark]

12

4.6.1.1 Calculating rates of reactions

Question 18

November 2021 | 8462/2H | Original Q9

0 9 A student investigated how a change in concentration affects the rate of the reaction between zinc powder and sulfuric acid.

The equation for the reaction is:

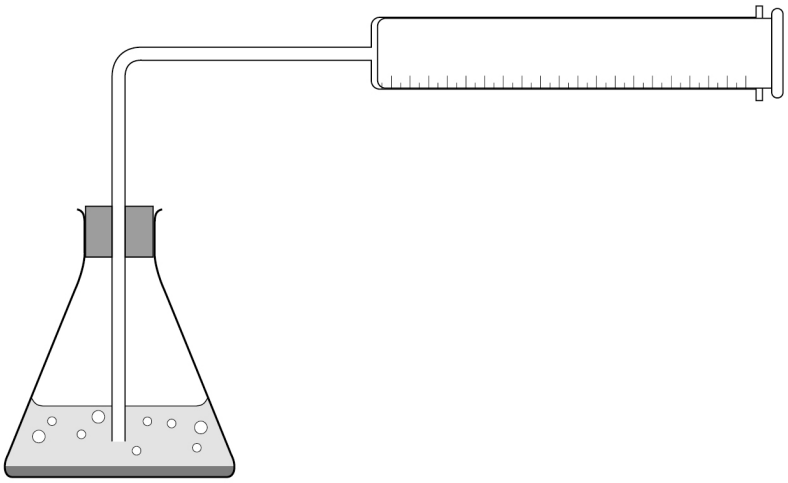
$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

This is the method used.

1. Pour 50 cm^3 of sulfuric acid of concentration 0.05 mol/dm^3 into a conical flask.
2. Add 0.2 g of zinc powder to the conical flask.
3. Put the stopper in the conical flask.
4. Measure the volume of gas collected every 30 seconds for 5 minutes.
5. Repeat steps 1 to 4 with sulfuric acid of concentration 0.10 mol/dm^3

Figure 8 shows the apparatus used.

Figure 8



0 9 . 1 The student made an error in setting up the apparatus in **Figure 8**.

What error did the student make?

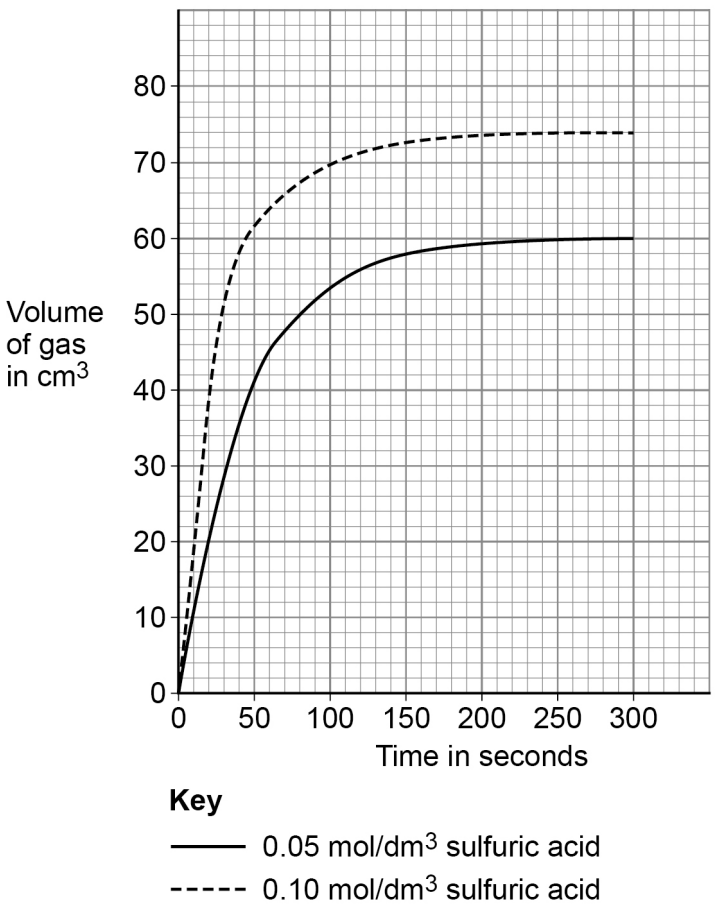
[1 mark]

Question 18 · continued

The student corrected the error.

Figure 9 shows the student's results.

Figure 9



0 9 . 2 Explain why the lines of best fit on **Figure 9** become horizontal.

[2 marks]

0 9 . 3 How does **Figure 9** show that zinc powder reacts more slowly with 0.05 mol/dm^3 sulfuric acid than with 0.10 mol/dm^3 sulfuric acid?

[1 mark]

4.6.1.1 Calculating rates of reactions

Question 18 · continued

0 9 . 4 Determine the rate of the reaction for 0.05 mol/dm^3 sulfuric acid at 80 seconds.

Show your working on **Figure 9**.

Give your answer to 2 significant figures.

[5 marks]

Rate of reaction (2 significant figures) = _____ cm^3/s

0 9 . 5 The activation energy for the reaction between zinc and sulfuric acid is lowered if a solution containing metal ions is added.

What is the most likely formula of the metal ions added?

[1 mark]

Tick (✓) **one** box.

Al^{3+} ☐

Ca^{2+} ☐

Cu^{2+} ☐

Na^{+} ☐

10

4.6.1.1 Calculating rates of reactions

Question 19

June 2022 | 8462/2H | Original Q7

0 7 Ammonia is produced in the Haber process.

The raw materials for the Haber process are nitrogen and hydrogen.

The equation for the reaction is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

0 7 . 1 Give the sources of the nitrogen and of the hydrogen used in the Haber process.

[2 marks]

Nitrogen _____

Hydrogen _____

0 7 . 2 How does the equation for the reaction show that the atom economy of the forward reaction is 100%?

[1 mark]

_____

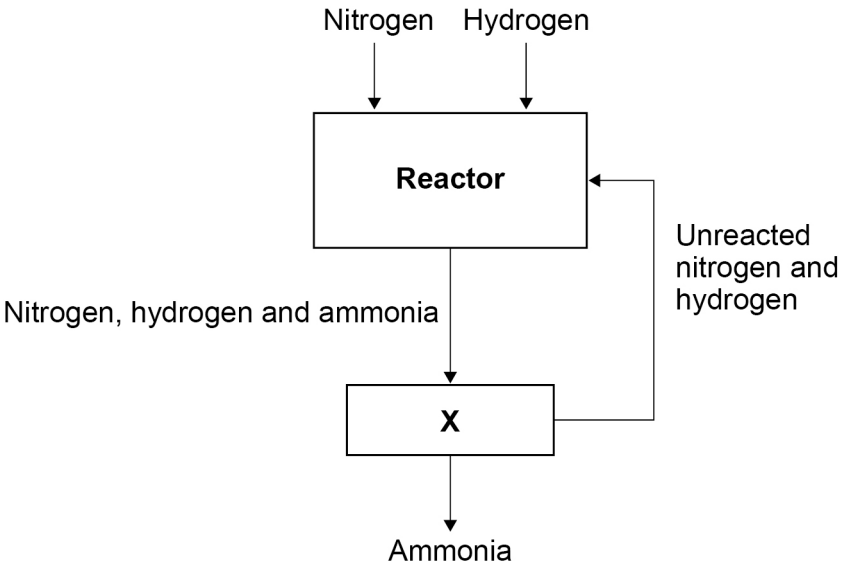
_____

4.6.1.1 Calculating rates of reactions

Question 19 · continued

0 7 . 3 **Figure 4** represents the Haber process.

Figure 4



Explain how the ammonia produced is separated from the unreacted nitrogen and hydrogen in **X**.

[2 marks]

Question 7 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 19 · continued

The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

Table 6 shows the percentage yield of ammonia produced at 450 °C using different pressures.

Table 6

Pressure in atmospheres	Percentage (%) yield of ammonia
60	9
120	18
180	25
240	31
300	36
360	40
420	43

Question 19 · continued

0 7 . 4 Complete **Figure 5**.

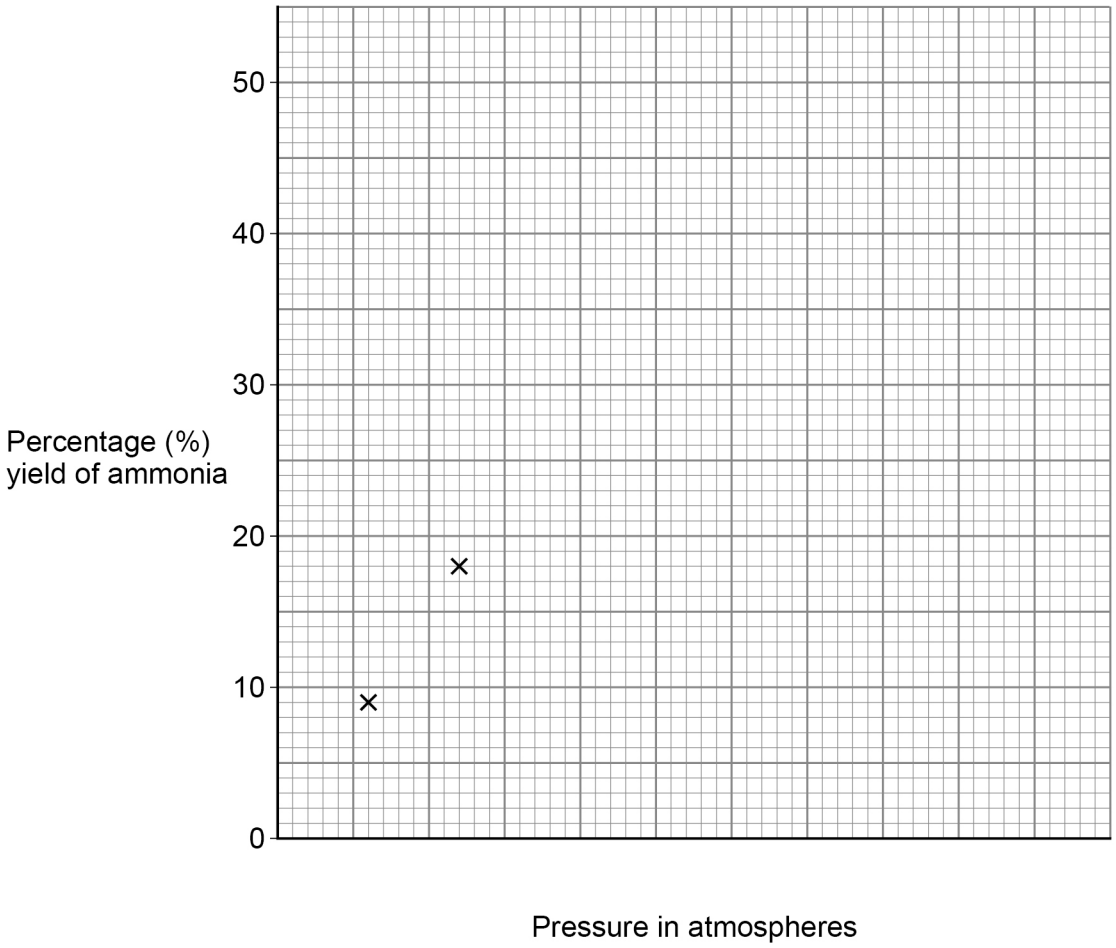
The first two points have been plotted.

You should:

- use a suitable scale for the *x*-axis
- plot the remaining data from **Table 6**
- draw a line of best fit.

[4 marks]

Figure 5



0 7 . 5 Determine the percentage yield of ammonia at 450 °C and 500 atmospheres.

Show your working on **Figure 5**.

[2 marks]

Percentage yield = _____ %

4.6.1.1 Calculating rates of reactions

Question 19 · continued

0 7 . 6 The equation for the production of ammonia in the Haber process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The forward reaction is exothermic.

The conditions used are:

- a temperature of 450 °C
- a pressure of 200 atmospheres
- the presence of an iron catalyst.

Explain why these conditions are chosen for economical production of ammonia in the Haber process.

You should include references to the rate of reaction and the position of equilibrium.

[6 marks]

17

4.6.1.1 Calculating rates of reactions

Question 20

June 2022 | 8462/2H | Original Q8

0 8 This question is about the reaction between sodium thiosulfate solution and hydrochloric acid.

When hydrochloric acid is added to sodium thiosulfate solution, the mixture gradually becomes cloudy.

The equation for the reaction is:

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

0 8 . 1 Sulfur is produced in the reaction.

Why does the mixture become cloudy?

[1 mark]

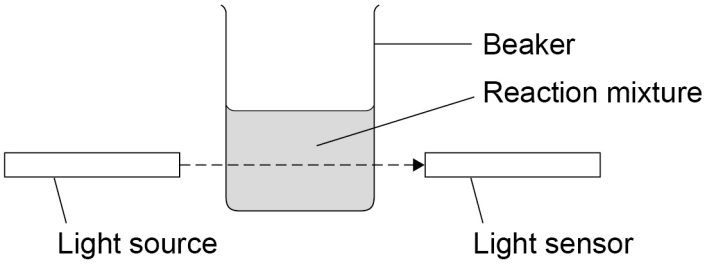
4.6.1.1 Calculating rates of reactions

Question 20 · continued

A student investigated the effect of changing the concentration of sodium thiosulfate solution on the rate of the reaction.

Figure 6 shows the apparatus used.

Figure 6



A smaller percentage of light from the light source reaches the light sensor as the mixture becomes more cloudy.

This is the method used.

1. Measure 50 cm^3 of 0.10 mol/dm^3 sodium thiosulfate solution into the beaker.
2. Add 10 cm^3 of hydrochloric acid to the sodium thiosulfate solution.
3. Immediately start a timer.
4. Record the percentage of light from the light source that reaches the light sensor every 20 seconds for 120 seconds.
5. Repeat steps 1 to 4 using 0.20 mol/dm^3 sodium thiosulfate solution.

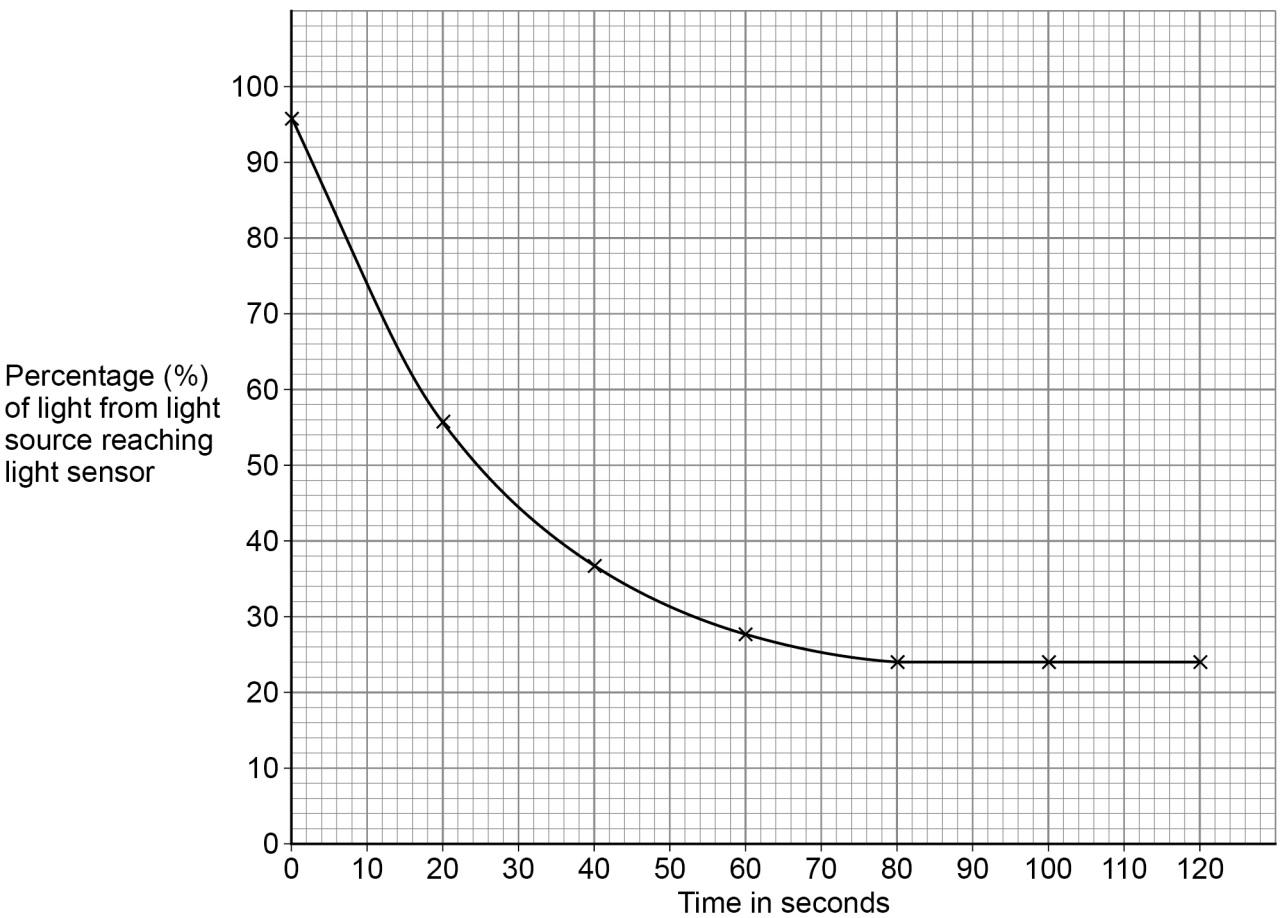
Question 8 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 20 · continued

Figure 7 shows the results for 0.10 mol/dm^3 sodium thiosulfate solution.

Figure 7



4.6.1.1 Calculating rates of reactions

Question 20 · continued

0 8 . 2 The percentage of light reaching the light sensor decreases by 1% when 7.1×10^{-5} moles of sulfur is produced.

Determine the rate of reaction in mol/s for the production of sulfur at 30 seconds.

You should draw a tangent on **Figure 7**.

[5 marks]

Rate = _____ mol/s

0 8 . 3 Explain why the rate of reaction changes between 0 and 60 seconds.

Answer in terms of concentration.

Use **Figure 7**.

[2 marks]

4.6.1.1 Calculating rates of reactions

Question 20 · continued

Figure 8 is a repeat of **Figure 7**.

Figure 8

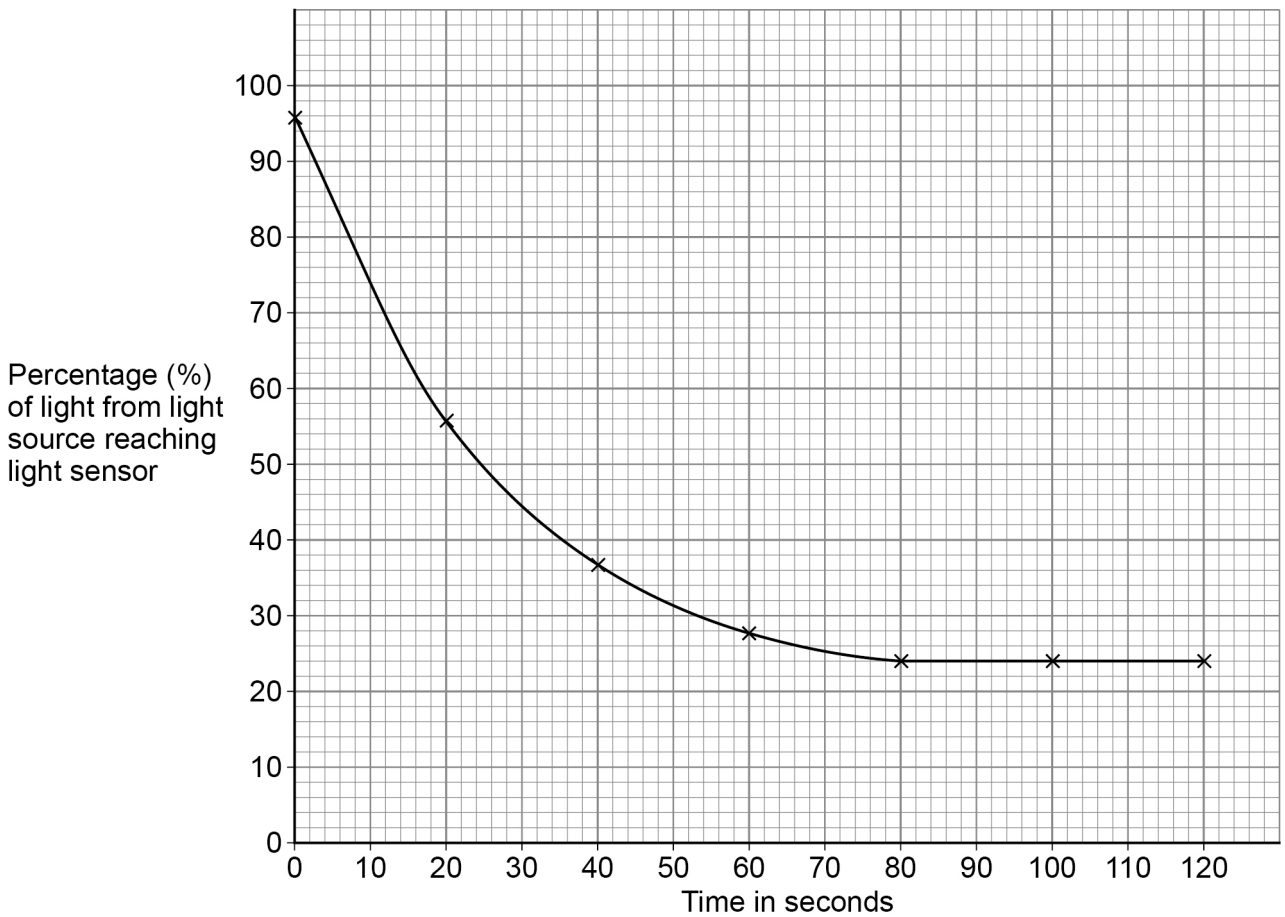


Figure 8 shows the results for 0.10 mol/dm^3 sodium thiosulfate solution.

Sodium thiosulfate solution was in excess in the investigation.

0 8 . 4 The line of best fit on **Figure 8** is horizontal between 80 and 120 seconds because the reaction stopped.

Why did the reaction stop?

[1 mark]

0 8 . 5 Sketch a line on **Figure 8** to show the results you would predict for 0.20 mol/dm^3 sodium thiosulfate solution.

[2 marks]

4.6.1.1 Calculating rates of reactions

Question 20 · continued June 2022 | 8462/2H | Original Q8

The same student did the investigation again the next day.

The student found that the same method produced different results for the percentage of light reaching the light sensor.

0 8 . 6 How could the student improve the method so that the same percentages of light reached the light sensor?

[1 mark]

Tick (✓) **one** box.

- Record the percentage of light every 10 seconds. ☐
- Stop light from other sources reaching the light sensor. ☐
- Use a larger volume of sodium thiosulfate solution. ☐
- Use a more sensitive light sensor. ☐

0 8 . 7 The student improved the method so that similar results were obtained on different days.

What name is given to similar results obtained on different days under the same conditions by the same student?

[1 mark]

Tick (✓) **one** box.

- Anomalous ☐
- Precise ☐
- Repeatable ☐
- Reproducible ☐

4.6.1.1 Calculating rates of reactions

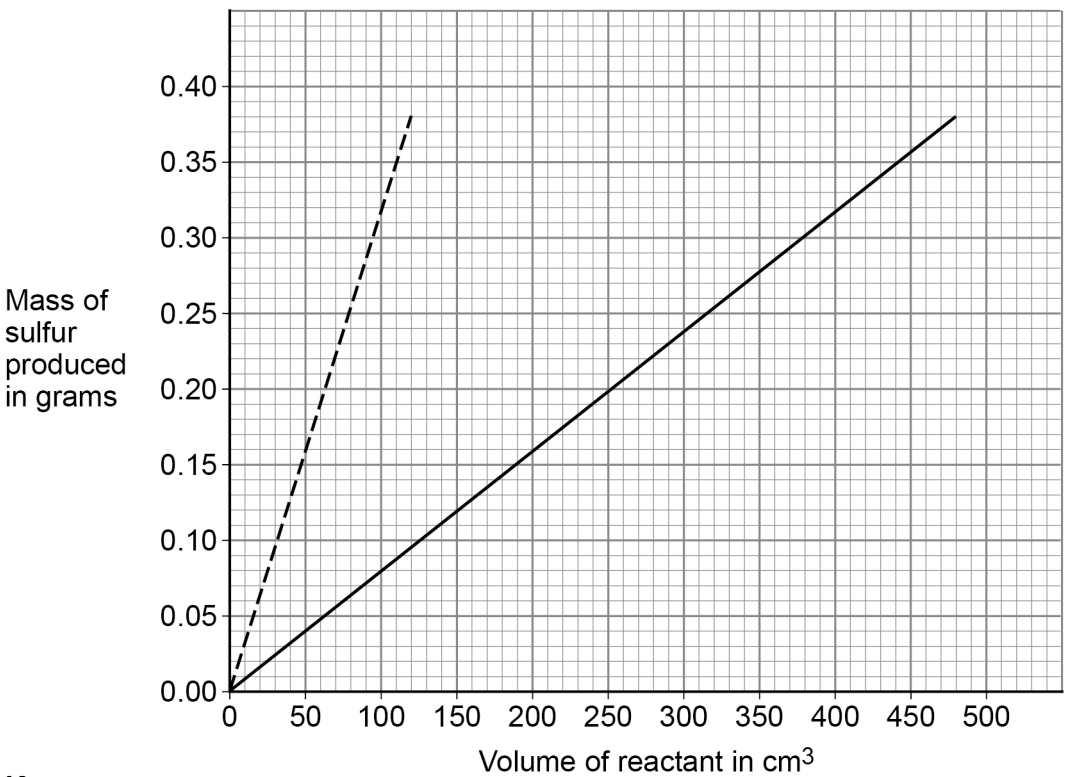
Question 20 · continued

Figure 9 shows the volumes of:

- sodium thiosulfate solution of concentration 0.10 mol/dm^3
- hydrochloric acid of concentration 0.05 mol/dm^3

which completely react to produce different masses of sulfur.

Figure 9



Key

– – – 0.10 mol/dm^3 sodium thiosulfate solution

—— 0.05 mol/dm^3 hydrochloric acid

4.6.1.1 Calculating rates of reactions

Question 20 · continued

0 8 . 8 Which expression represents the relationship between the volume (V) of sodium thiosulfate solution used and the mass (m) of sulfur produced?

Use **Figure 9**.

[1 mark]

Tick (✓) **one** box.

- V ∝ m ☐
- V ~ m ☐
- V << m ☐
- V = m ☐

0 8 . 9 Determine the simplest whole number ratio of the volumes of

sodium thiosulfate solution : hydrochloric acid

which completely react with each other.

Use **Figure 9**.

[3 marks]

Simplest whole number ratio = _____ : _____

17

4.6.1.1 Calculating rates of reactions

Question 21

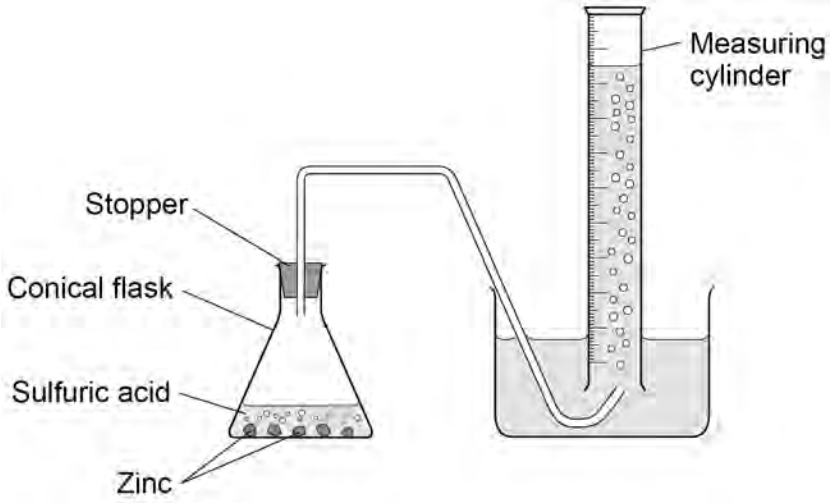
June 2023 | 8462/2H | Original Q1

0 1 A student investigated the rate of the reaction between zinc and sulfuric acid.

Hydrogen gas is produced during this reaction.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Add 50 cm^3 of sulfuric acid to a conical flask.

2. Add 2.0 g of zinc to the conical flask.

3. Quickly put a stopper in the conical flask and start a timer.

4. Measure the time taken to collect 20 cm^3 of gas.

5. Repeat steps 1 to 4 three more times.

0 1 . 1 Suggest why the stopper must be put in the conical flask as quickly as possible in **step 3**.

[1 mark]

4.6.1.1 Calculating rates of reactions

Question 21 · continued

0 1 . 2 The student calculated the rate of the reaction for each trial.

Table 1 shows the results of the calculations.

Table 1

	Trial 1	Trial 2	Trial 3	Trial 4
Rate of reaction in cm^3/s	0.78	0.81	0.68	0.81

Determine the mean time taken to collect 20 cm^3 of gas.

Do **not** include any anomalous results.

Use the equation:

$$\text{mean rate of reaction} = \frac{\text{volume of gas collected}}{\text{mean time taken}}$$

[5 marks]

Mean time taken = _____ s

Question 1 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 21 · continued

0 1 . 3 The student changed the investigation so that the mean time taken to collect 20 cm^3 of gas was greater.

Which **two** changes would increase the mean time taken to collect 20 cm^3 of gas?

[2 marks]

Tick (✓) **two** boxes.

- Use a catalyst ☐
- Use a larger conical flask ☐
- Use a lower temperature ☐
- Use smaller pieces of zinc ☐
- Use sulfuric acid of a lower concentration ☐

0 1 . 4 Hydrogen gas is produced during this reaction.

Describe the test for hydrogen gas.

Give the result of the test.

[2 marks]

Test _____

_____

Result _____

_____

10

4.6.1.1 Calculating rates of reactions

Question 22

June 2023 | 8462/2H | Original Q7

0 7 Manganese dioxide catalyses the decomposition of hydrogen peroxide solution.

Oxygen and water are produced.

0 7 . 1 Explain how a manganese dioxide catalyst increases the rate of decomposition of hydrogen peroxide.

[2 marks]

A student investigated the rate of this reaction.

This is the method used.

1. Add 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution to a conical flask.

2. Add 1.0 g of manganese dioxide to the conical flask.

3. Place the conical flask on a balance and start a timer.

4. Record the total mass lost from the conical flask every 20 seconds for 180 seconds.

0 7 . 2 Explain why the mass of the conical flask and contents decreased.

[2 marks]

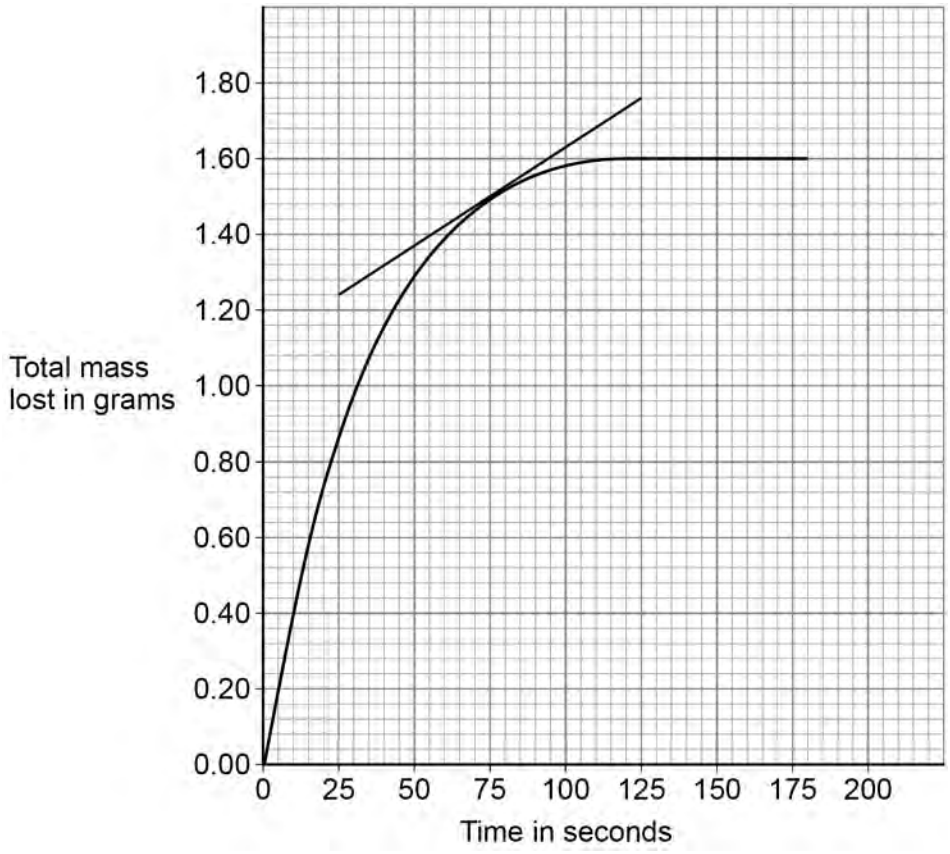
4.6.1.1 Calculating rates of reactions

Question 22 · continued

0 7 . 3 **Figure 4** shows the results for 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide.

A tangent to the line has been drawn at 75 seconds.

Figure 4



Determine the rate of reaction when the time was 75 seconds.

Give your answer to 2 significant figures.

[4 marks]

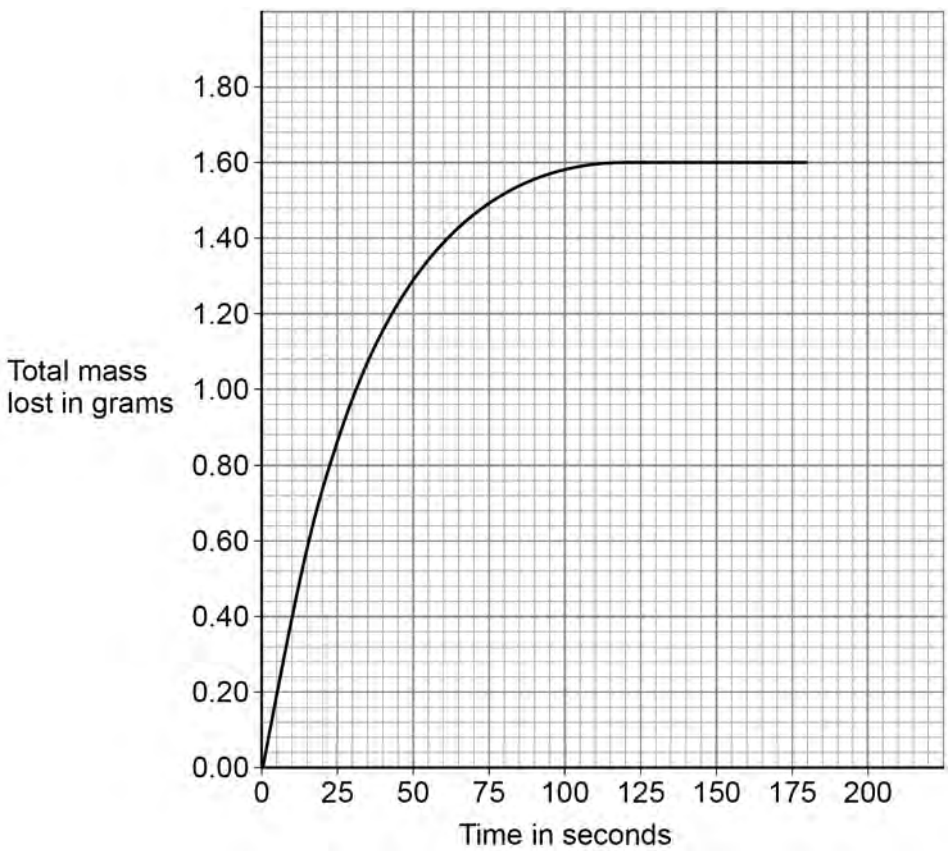
Rate (2 significant figures) = _____ g/s

4.6.1.1 Calculating rates of reactions

Question 22 · continued

0 7 . 4 The results for 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide are shown again on **Figure 5**.

Figure 5



The student repeated the investigation using 50 cm^3 of 1.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide.

Sketch the expected results for 1.0 mol/dm^3 hydrogen peroxide solution on **Figure 5**.

[2 marks]

10

4.6.1.1 Calculating rates of reactions

Question 23

June 2024 | 8462/2H | Original Q9

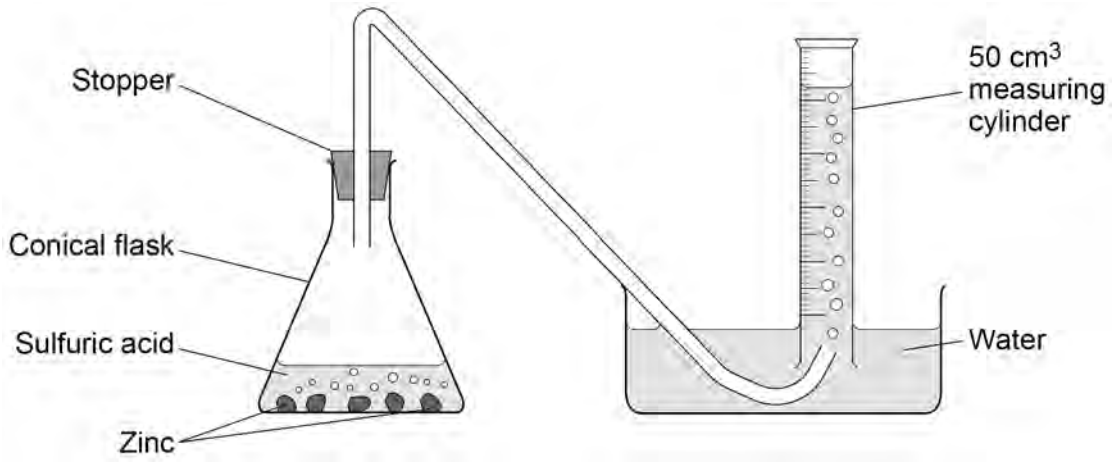
0 9 A student investigated the rate of the reaction between zinc and sulfuric acid.

The equation for the reaction is

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Figure 10 shows the apparatus.

Figure 10



This is the method used.

1. Pour 50 cm^3 of sulfuric acid into the conical flask.
2. Add excess zinc to the conical flask.
3. Insert the stopper and start a timer.
4. Measure the volume of hydrogen collected in the 50 cm^3 measuring cylinder every 20 seconds for 180 seconds.

0 9 . 1 Explain why the volume of hydrogen collected in the 50 cm^3 measuring cylinder is less than the volume of hydrogen produced.

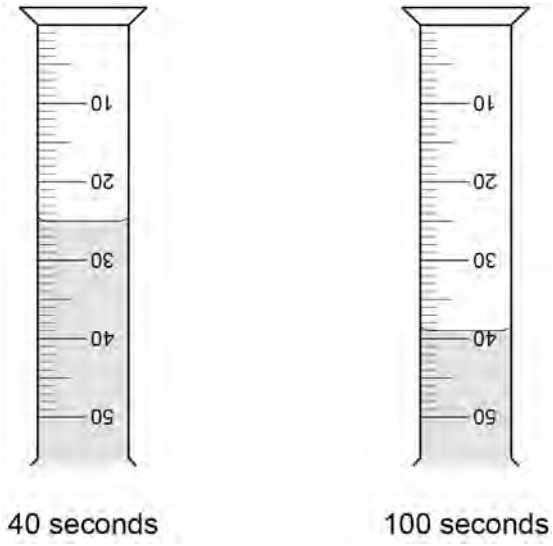
[2 marks]

4.6.1.1 Calculating rates of reactions

Question 23 · continued

Figure 11 shows the volumes of hydrogen collected in the 50 cm^3 measuring cylinder after 40 seconds and after 100 seconds.

Figure 11



0 9 . 2 Determine the number of moles of hydrogen collected between 40 seconds and 100 seconds.

The volume of one mole of any gas at room temperature and pressure is 24 dm^3.

[4 marks]

Moles of hydrogen = _____

Question 9 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 23 · continued

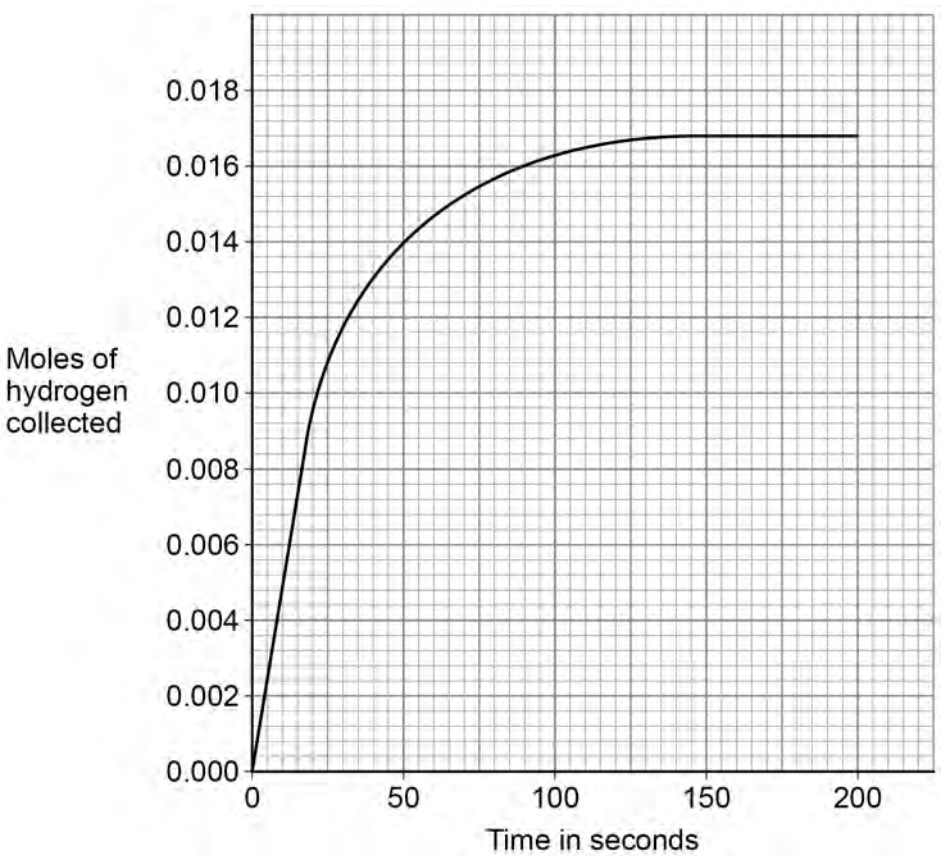
A different student investigated how the concentration of sulfuric acid affected the rate of the reaction.

0 9 . 3 The student did a different experiment using sulfuric acid of concentration 0.40 mol/dm^3.

The student calculated the number of moles of hydrogen collected after every 20 seconds.

Figure 12 shows the results.

Figure 12



4.6.1.1 Calculating rates of reactions

Question 23 · continued

Determine the rate of reaction at 45 seconds.

You should draw a tangent on **Figure 12**.

Give your answer in standard form.

[5 marks]

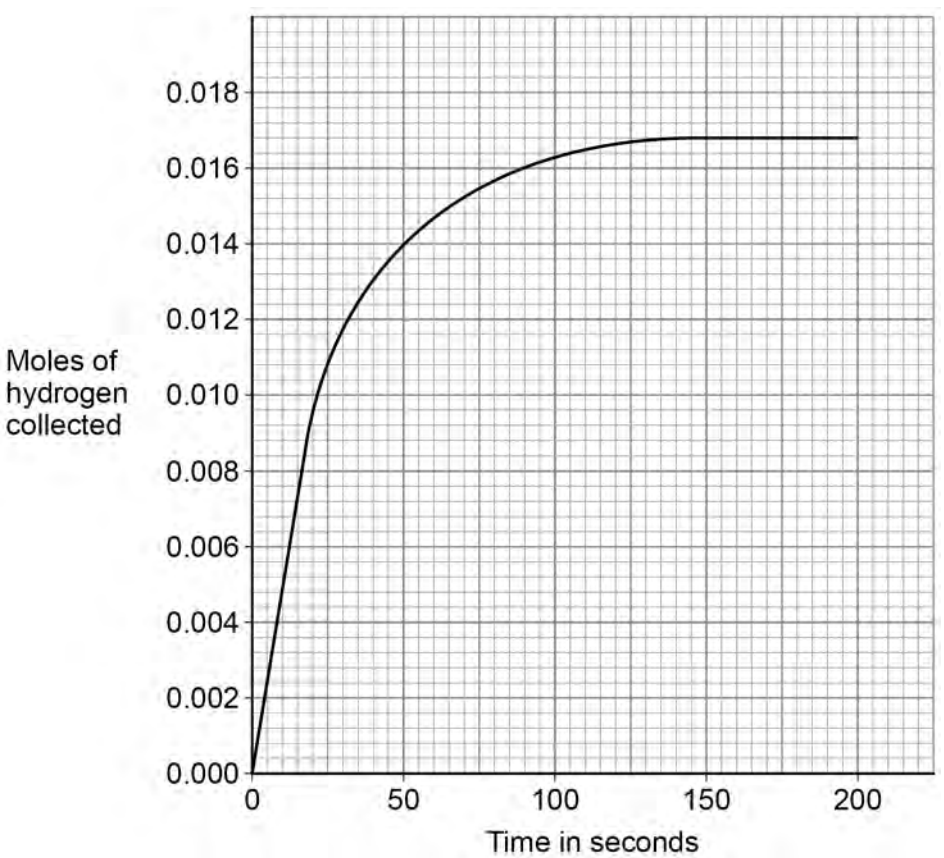
Rate of reaction (in standard form) = _____ mol/s

Question 9 continues on the next page

Question 23 · continued

0 9 . 4 **Figure 13** shows the results for 0.40 mol/dm^3 sulfuric acid.

Figure 13



The student repeated the experiment using 0.20 mol/dm^3 sulfuric acid instead of 0.40 mol/dm^3 sulfuric acid.

Excess zinc was used in each experiment.

Sketch a line on **Figure 13** to show the results you would expect.

[2 marks]

4.6.1.1 Calculating rates of reactions

Question 23 · continued

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0 9 . 5 Explain how increasing the temperature would affect the rate of reaction between zinc and sulfuric acid.

[3 marks]

16

4.6.1.1 Calculating rates of reactions

Question 24

0 8 Hydrogen peroxide decomposes into water and oxygen.

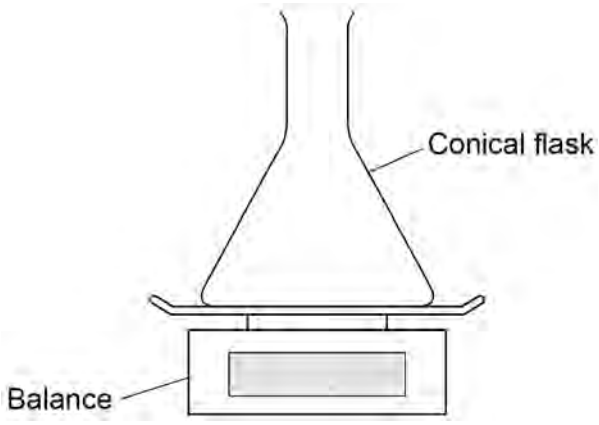
The equation for the reaction is:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

A student investigated the effect of catalyst **A** and of catalyst **B** on the rate of this reaction.

Figure 6 shows the apparatus.

Figure 6



This is the method used.

1. Put the conical flask on the balance.
2. Add 50 cm^3 of 1.5 mol/dm^3 hydrogen peroxide solution to the conical flask.
3. Add 1.00 g of catalyst **A** to the conical flask.
4. Start a timer.
5. Record the loss in mass of the conical flask and contents every 30 seconds for 3 minutes.
6. Repeat steps 1 to 5 using catalyst **B**.

0 8 . 1 Explain why the conical flask and contents lost mass.

[2 marks]

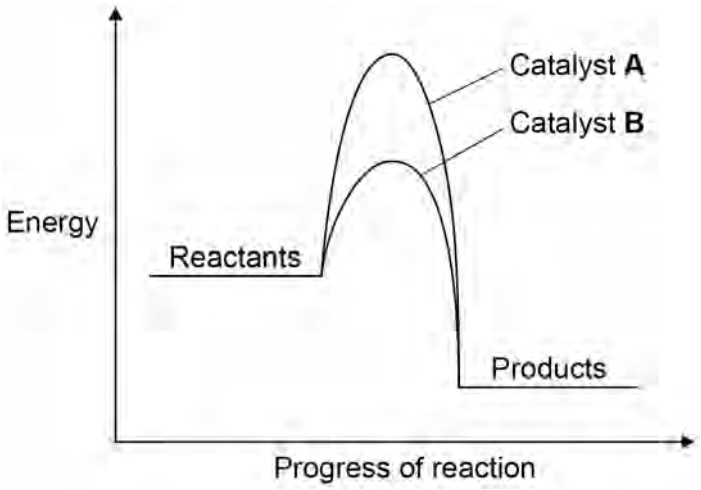
4.6.1.1 Calculating rates of reactions

Question 24 · continued

0 8 . 2 **Figure 7** shows the reaction profile for the decomposition of hydrogen peroxide using:

- catalyst **A**
- catalyst **B**.

Figure 7



Explain why catalyst **A** and catalyst **B** give different rates of reaction for the decomposition of hydrogen peroxide.

[3 marks]

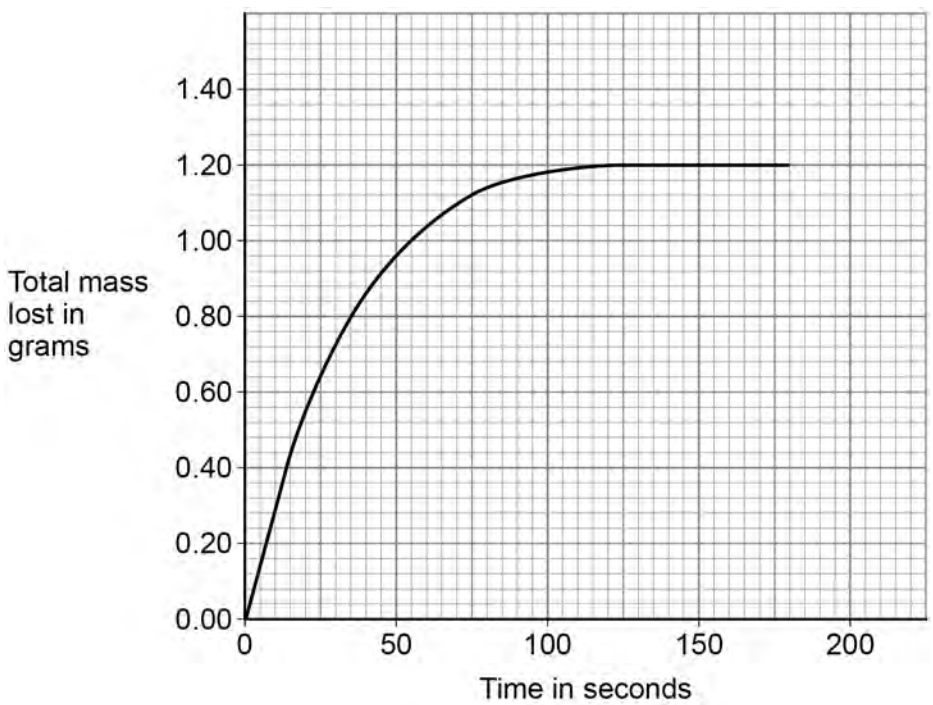
Question 8 continues on the next page

4.6.1.1 Calculating rates of reactions

Question 24 · continued

0 8 . 3 **Figure 8** shows the results for catalyst **A**.

Figure 8



Determine the rate of the reaction when the time was 60 seconds.

Give your answer in standard form.

[5 marks]

Rate (standard form) = _____ g/s

4.6.1.1 Calculating rates of reactions

Question 24 · continued

0 8 . 4 Explain how the rate of decomposition of hydrogen peroxide depends on the temperature of the solution.

[3 marks]

13

Turn over for the next question