

# Rates of Reaction

## Question Paper

Level	GCSE
Subject	Chemistry
Exam Board	Edexcel IGCSE
Module	Double Award (Paper 1C)
Topic	Physical Chemistry
Sub-Topic	Rates of Reaction
Booklet	Question Paper

**Time Allowed:** 142 minutes

**Score:** /118

**Percentage:** /100

**Grade Boundaries:**

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

1 Some students investigated the rate of reaction between sodium thiosulfate solution and hydrochloric acid. The equation for the reaction is



The precipitate of sulfur makes the reaction mixture go cloudy.

The students used this method.

- Place a mixture of sodium thiosulfate solution and water in a conical flask
- Add some dilute hydrochloric acid, swirl the mixture and start a timer
- Place the flask over a black cross marked on a piece of paper
- Record the time taken for the cross to disappear when viewed from above

The students used 10 cm<sup>3</sup> of dilute hydrochloric acid in each experiment.

They carried out all the experiments at the same temperature.

They used different volumes of sodium thiosulfate solution and water in each experiment. They were told to keep the total volume of sodium thiosulfate solution and water constant.

The table shows their results.

Student	Volume of sodium thiosulfate solution in cm <sup>3</sup>	Volume of water in cm <sup>3</sup>	Time in s
1	50	0	26.6
2	40	10	
3	35	15	76.4
4	30	20	105.6
5	25	25	
6	20	30	223.5
7	15	40	321.4

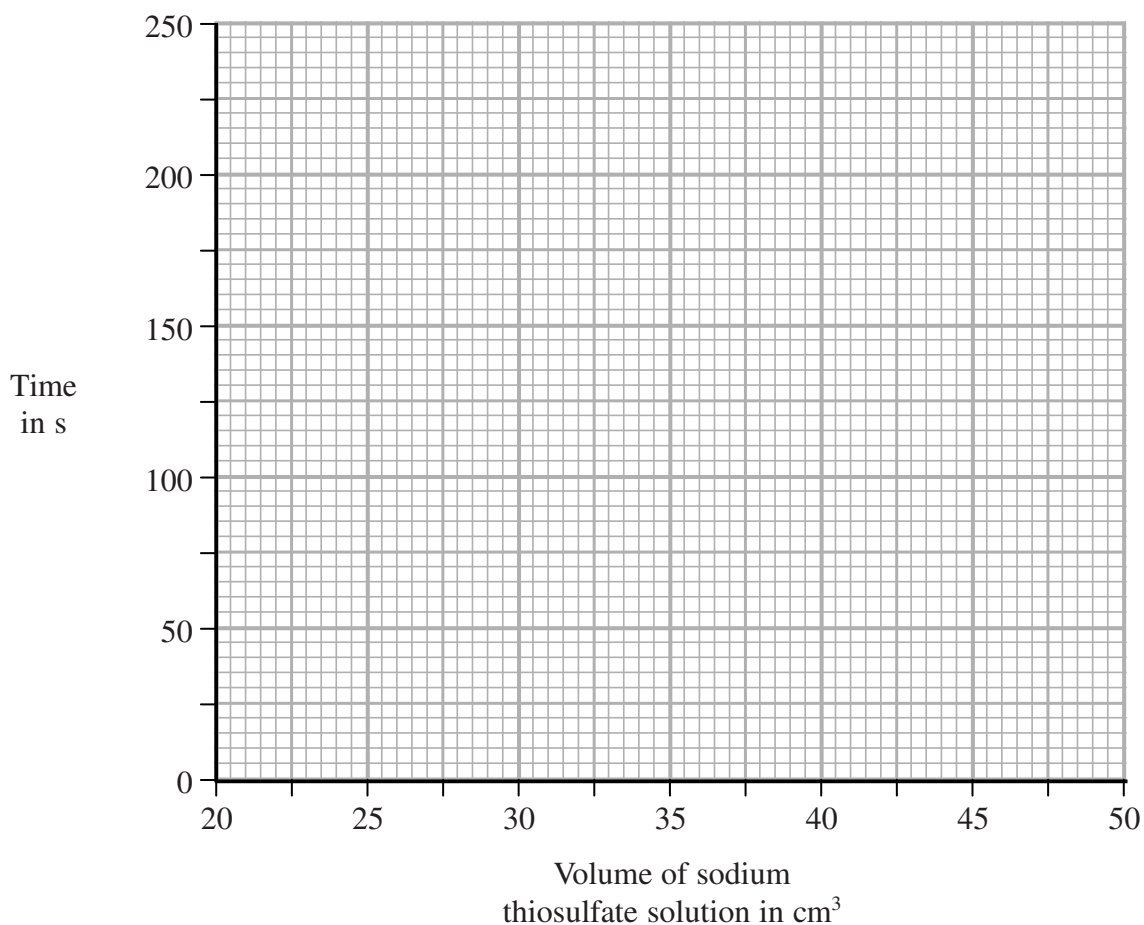
(a) Explain why the results of student 7 should not be used.

(1)

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(b) Plot the results of the six other students on the grid below. Draw a curve of best fit through the points.

(3)



(c) The students used this equation to calculate the rate of each reaction in their investigation.

$$\text{rate of reaction} = \frac{1000}{\text{time taken}}$$

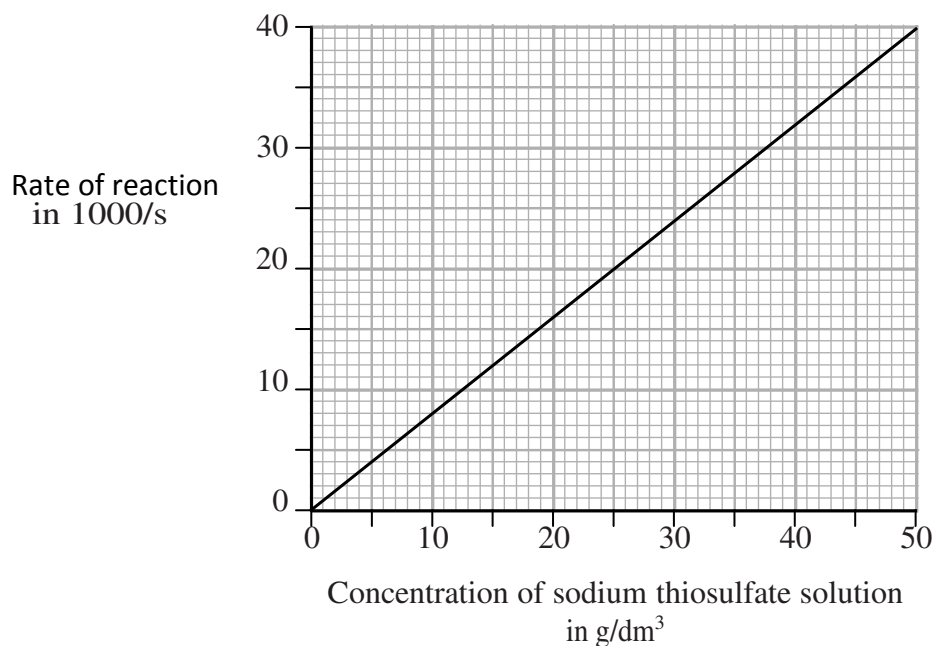
Calculate the rate of reaction for student 1's experiment.

Give your answer to **one** decimal place.

(2)

Rate .....

(d) Another group of students used the same method but with different solutions of sodium thiosulfate and hydrochloric acid. They calculated the rate of reaction for each experiment they did. Their results are shown on the following graph.



(i) Describe the relationship between rate and concentration as shown by the graph. (2)

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(ii) Explain why increasing the concentration has this effect on the rate. (3)

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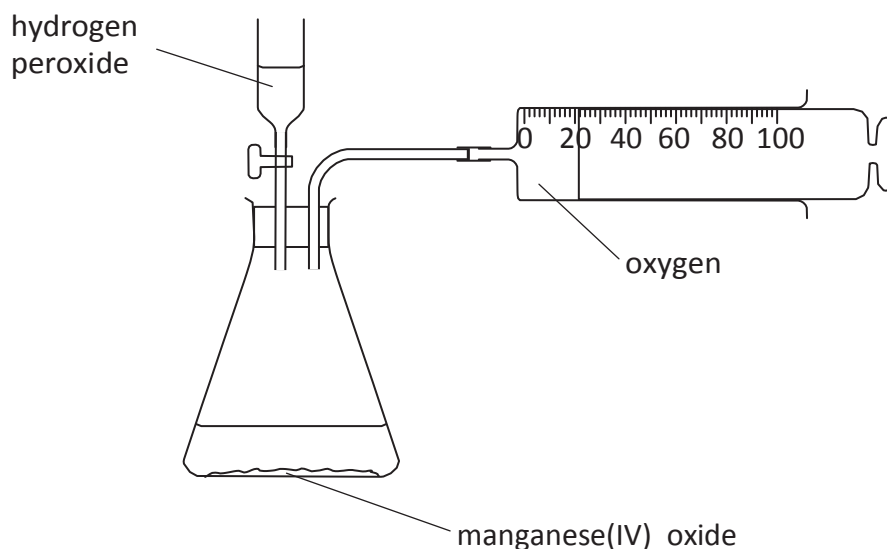
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(Total for Question 1 = 11 marks)

- 2 The apparatus in the diagram is used to collect the oxygen produced by the decomposition of hydrogen peroxide,  $\text{H}_2\text{O}_2$



- (a) Write a chemical equation for the decomposition of hydrogen peroxide.

(2)

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- (b) Describe a test to show that the gas collected in the syringe is oxygen.

(1)

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- (c) Manganese(IV) oxide is a catalyst for this reaction.

State and explain the effect of a catalyst on the rate of this reaction.

(3)

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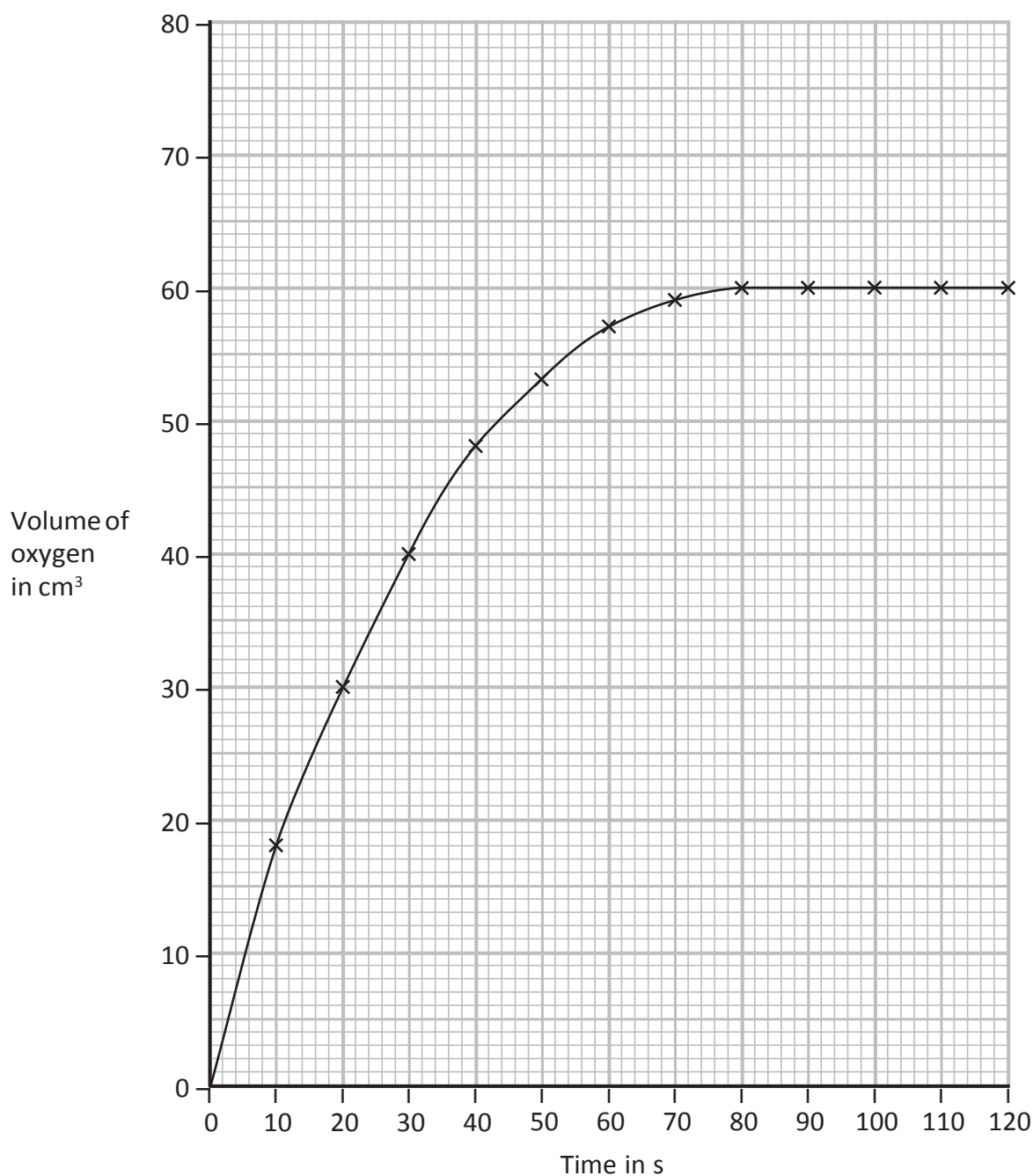
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(d) The graph shows the results from an experiment using a  $0.50 \text{ mol/dm}^3$  solution of hydrogen peroxide at  $25 \text{ }^\circ\text{C}$ .



(i) On the same axes, sketch the curve you would expect with the same volume of a  $0.25 \text{ mol/dm}^3$  solution of hydrogen peroxide at  $25 \text{ }^\circ\text{C}$ . Label this curve **A**.

(2)

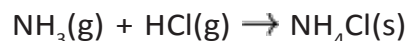
(ii) On the same axes, sketch the curve you would expect with the same volume of a  $0.50 \text{ mol/dm}^3$  solution of hydrogen peroxide at  $35 \text{ }^\circ\text{C}$ . Label this curve **B**.

(2)

(Total for Question 2 = 10 marks)

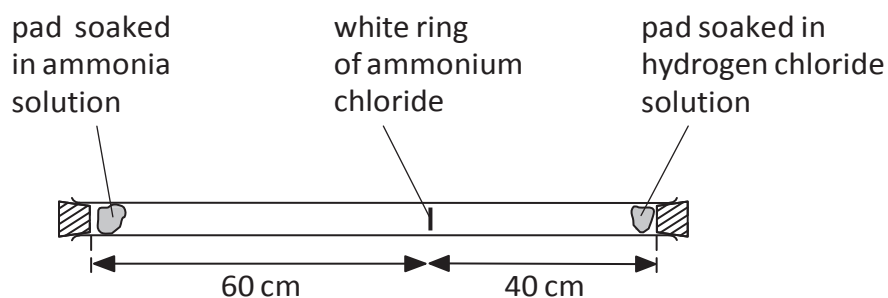
- 3 When ammonia gas and hydrogen chloride gas mix, they react together to form a white solid called ammonium chloride.

The equation for the reaction is:



A cotton wool pad was soaked in ammonia solution and another was soaked in hydrogen chloride solution. The two pads were then put into opposite ends of a dry glass tube at the same time.

After five minutes, a white ring of solid ammonium chloride formed.



- (a) (i) What name is given to the movement of the two gases?

(1)

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- (ii) Identify which gas is moving faster and give a reason for your choice.

(1)

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- (b) The experiment was repeated at a higher temperature.

State and explain how this change would affect the time taken for the white ring to form.

(3)

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(c) Gas particles move at a speed of several hundred metres per second at room temperature.

Suggest **one** reason why it took five minutes for the white ring to form.

(1)

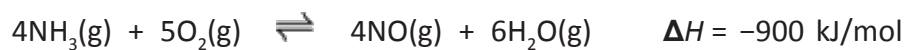
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**(Total for Question 3= 6 marks)**



4 The equation for a reaction that occurs in the manufacture of nitric acid is



(a) (i) State the meanings of the symbols  $\rightleftharpoons$  and  $\Delta H$ .

(2)

$\rightleftharpoons$

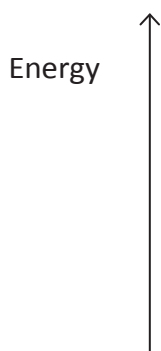
$\Delta H$

(ii) What does the negative sign of  $\Delta H$  indicate about the reaction?

(1)

(b) Complete the energy level diagram for this reaction.

(2)



(c) Typical conditions used for this reaction are a temperature of 900 °C and a pressure of 10 atmospheres.

Deduce the effects of changing the conditions as shown in the table. Choose from the words **increased**, **decreased** or **unchanged** to complete the table.

(4)

Change	Effect on rate of reaction	Effect on yield of products
increase in temperature		
addition of catalyst		

(d) A manufacturer considers using a pressure of 5 atm instead of 10 atm.

(i) Predict and explain the effect on the rate of reaction of changing the pressure to 5 atm.

(3)

Effect on rate of reaction .....

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Explanation .....

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(ii) Predict and explain the effect on the position of equilibrium of changing the pressure to 5 atm.

(2)

Effect on position of equilibrium .....

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Explanation .....

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(e) Balance the equation that represents the last stage in the manufacture of nitric acid.



(1)

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(Total for Question 4 = 15 marks)

5 A group of students investigated the reaction between marble chips (calcium carbonate) and dilute hydrochloric acid.

The equation for this reaction is

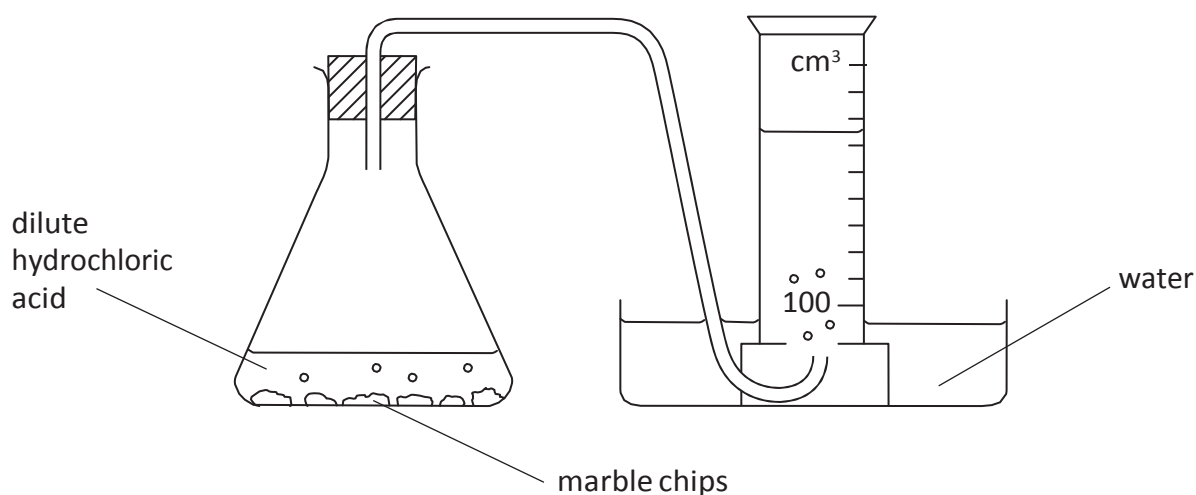


They wanted to find the effect of changing the concentration of hydrochloric acid on the rate of reaction. The teacher provided a solution that she had labelled 100% hydrochloric acid.

The teacher told them to do all their experiments

- using different concentrations of hydrochloric acid made by diluting the 100% hydrochloric acid
- by timing how long it took to collect carbon dioxide
- at room temperature

The students used this apparatus.



(a) The students tried to keep the amount of calcium carbonate constant by using the same number of marble chips in each experiment.

State two other properties of the marble chips that should be the same in each experiment.

(2)

1 .....

2 .....

(b) The table shows how some of the students wrote down their results.

Student	Results
1	I used 6 marble chips and 100% hydrochloric acid and collected 100 cm <sup>3</sup> of gas in 40 seconds.
2	In my experiment there were 6 marble chips and 80% hydrochloric acid and I collected 100 cm <sup>3</sup> of carbon dioxide by the end of the experiment.
3	The marble chips and 60% hydrochloric acid formed 100 cm <sup>3</sup> of gas in 70 seconds.
4	I used 40% hydrochloric acid and 6 marble chips. It took 105 seconds to collect the gas.
5	I collected 100 cm <sup>3</sup> of gas in 135 seconds when I used 6 marble chips.

The teacher said that she could only use the results from student 1 because the other students had not recorded enough information.

Identify the piece of information that each student failed to record.

(4)

Student 2.....

Student 3.....

Student 4.....

Student 5.....

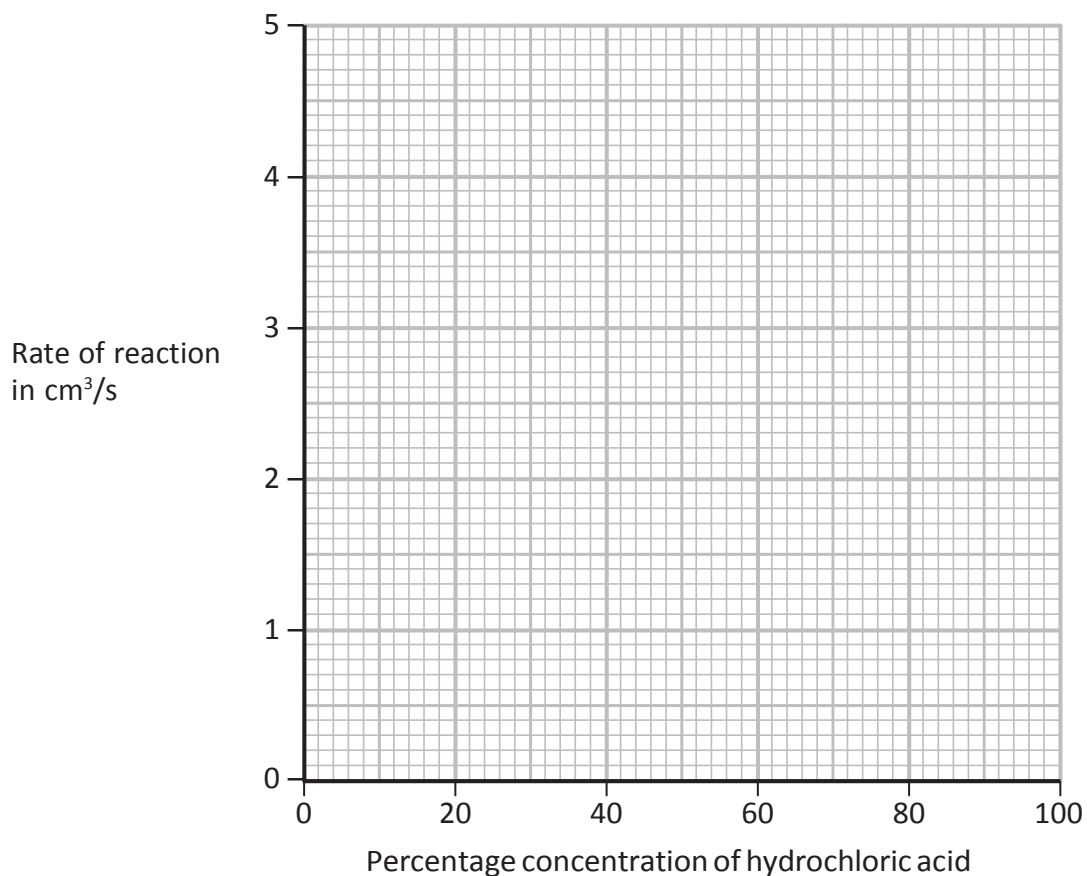
(c) The students repeated the experiment to make sure that it was a fair test. They used a different supply of hydrochloric acid. They all measured the time to collect 100 cm<sup>3</sup> of carbon dioxide and calculated the rate of each reaction.

Their results are shown in the table.

Percentage concentration of hydrochloric acid	Time to collect 100 cm <sup>3</sup> of gas in seconds	Rate of reaction in cm <sup>3</sup> /s
20	66.7	1.5
40	52.6	1.9
60	34.5	2.9
70	30.3	3.3
80	25.6	3.9
100	20.8	4.8

(i) Plot these results on the grid and draw a straight line of best fit.

(3)



(ii) One of the points is anomalous. Circle this point on the graph.

(1)

(iii) Suggest two errors in the experiment that could have caused this anomalous result.

(2)

1 .....

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2 .....

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(iv) Use your graph to estimate the rate of reaction using an acid concentration of 50%.

Show on your graph how you obtained your answer.

(2)

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**(Total for Question 5 = 14 marks)**

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6 Some students investigated the rate of the reaction between marble chips (calcium carbonate) and dilute hydrochloric acid.

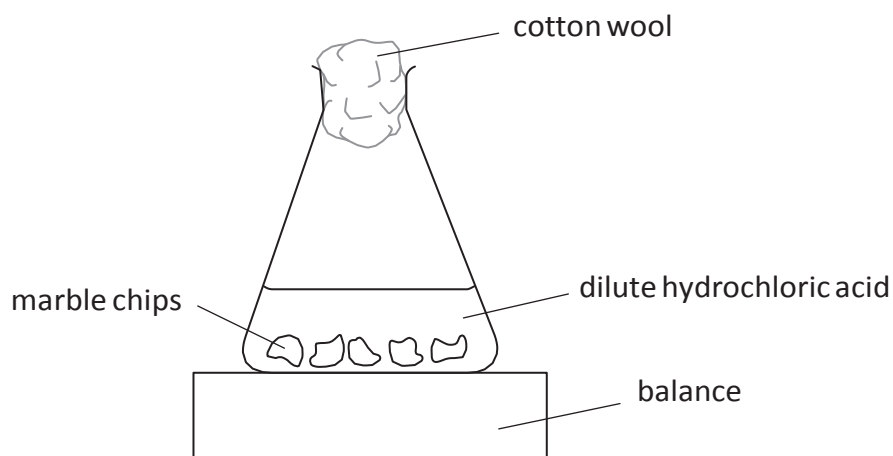
(a) The equation for the reaction is



Insert state symbols after each formula.

(2)

(b) One of the students used this apparatus.



(i) What is the purpose of the cotton wool?

(1)

(ii) He recorded the total mass of the conical flask and contents every 30 seconds for several minutes. He plotted the results as a graph of total mass (y-axis) against time.

Which of the graphs could represent his results?

Put a cross (☒) in a box to indicate your answer.

(1)

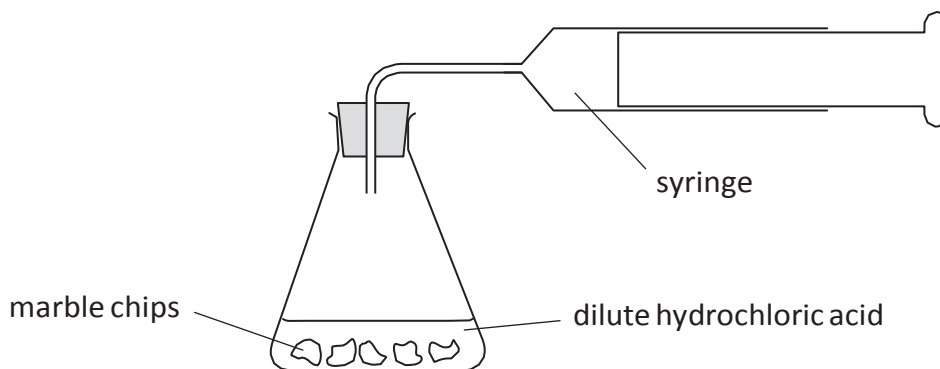
A <input type="checkbox"/>	B <input checked="" type="checkbox"/>	C <input type="checkbox"/>	D <input type="checkbox"/>

(c) Another student carried out three experiments to investigate the effect of changing the concentration and temperature of hydrochloric acid on the rate of reaction.

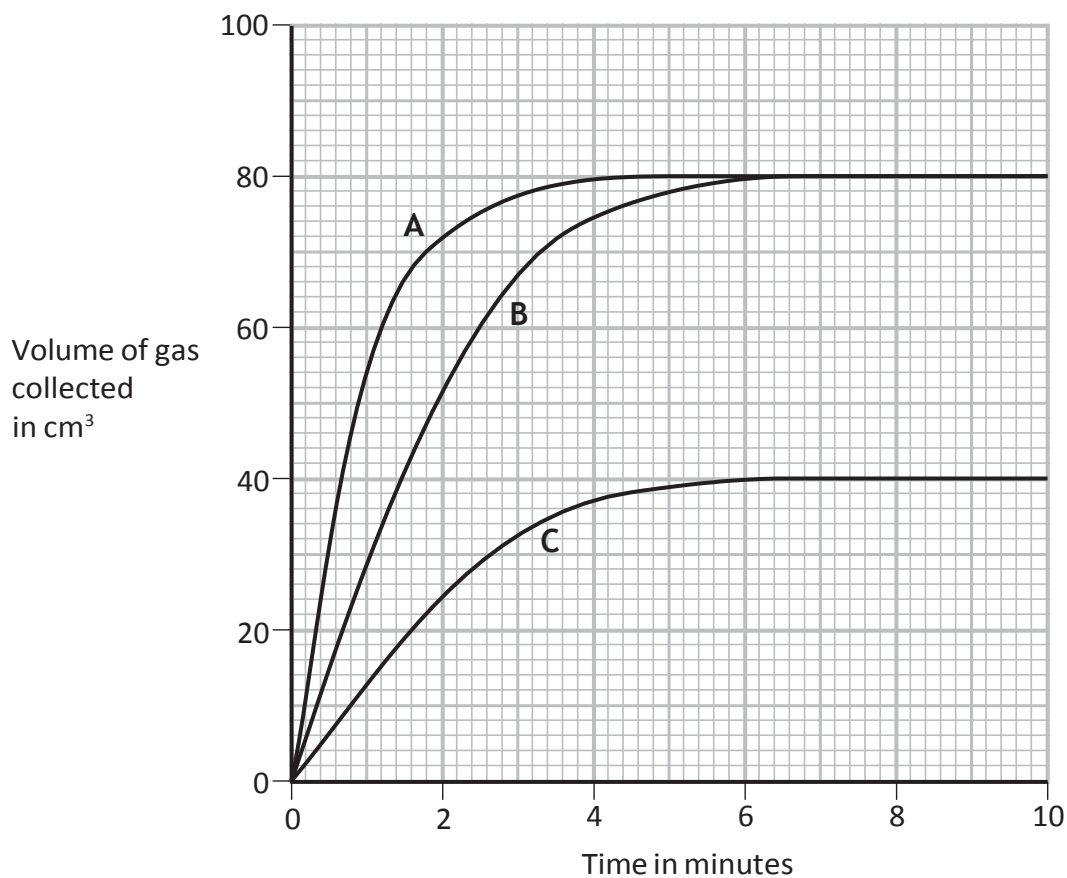
She kept the number and size of marble chips the same in each experiment.

The marble chips were in excess.

In each experiment she measured the volume of gas collected at different times, using this apparatus.



The graph shows the results of her experiments.





- (i) Experiments **A** and **B** represent experiments using the same concentration of hydrochloric acid but at different temperatures.

Which letter represents the experiment at the higher temperature?

Give a reason for your choice.

(2)

Letter .....

Reason .....

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- (ii) Experiments **B** and **C** represent experiments at the same temperatures and using the same volumes of hydrochloric acid.

The concentration of hydrochloric acid used in experiment **B** is  $0.20 \text{ mol/dm}^3$ .

What is the concentration of hydrochloric acid used in experiment **C**?

Explain how you worked out your answer.

(2)

Concentration .....

Explanation .....

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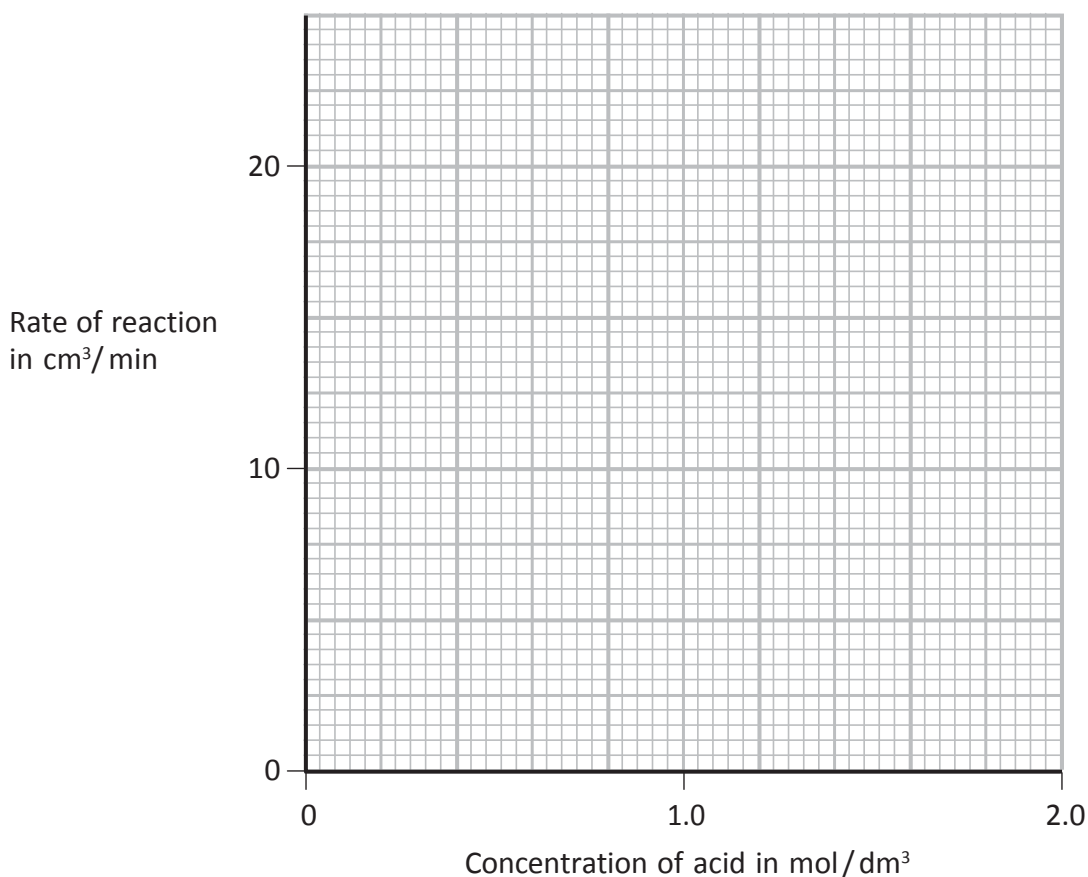
(d) (i) A third student calculated the rate of reaction in his experiments.

The table shows his results.

Rate of reaction in $\text{cm}^3/\text{min}$	4.0	9.0	13.5	18.5	23.0
Concentration of acid in $\text{mol}/\text{dm}^3$	0.4	0.8	1.2	1.6	2.0

Plot these results on the grid. Draw a straight line of best fit through the points.

(3)



(ii) Describe the relationship between rate of reaction and concentration of acid shown by the graph.

(2)

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(iii) Explain why increasing the concentration has this effect on the rate of reaction.

(3)

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**(Total for Question 6 = 16 marks)**

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7 A student investigates how temperature affects the rate of reaction between two colourless solutions containing ions.

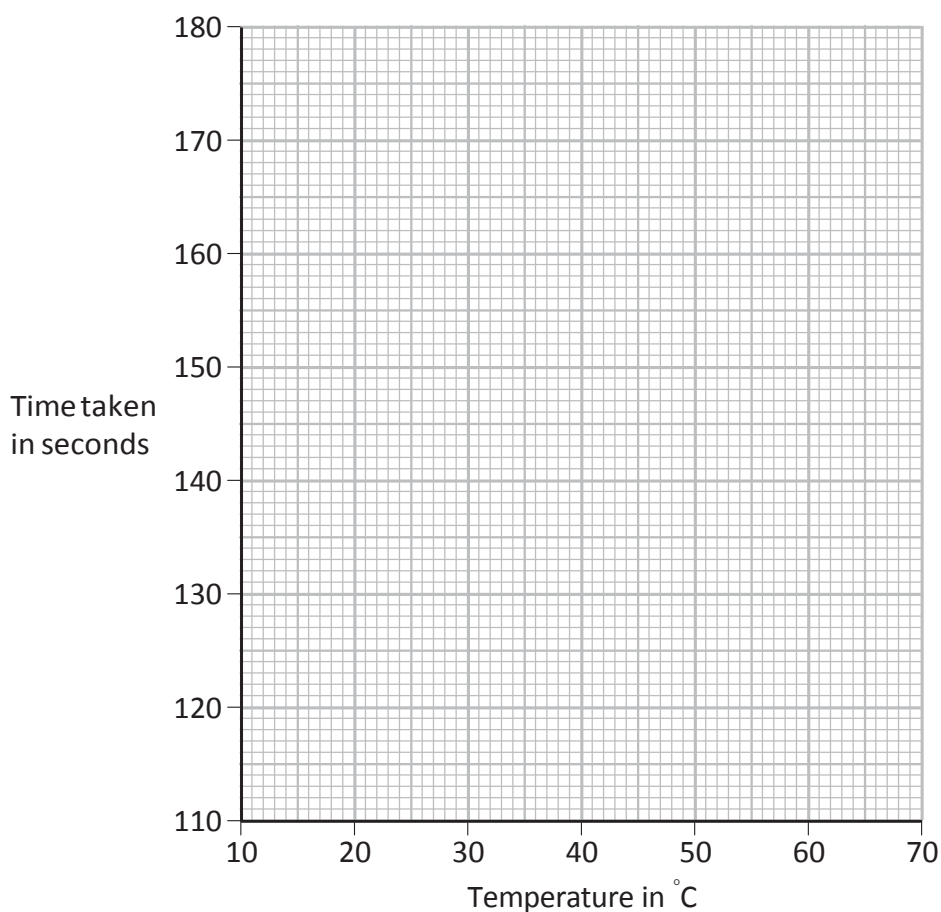
When he mixes the solutions, a reaction takes place between the ions and after a while the mixture suddenly turns blue. He performs the experiment at five different temperatures and on each occasion he measures the time taken for the mixture to turn blue.

The table shows his results.

Temperature in °C	15	19	26	38	60
Time taken in seconds	175	150	134	123	119

(a) (i) Plot the results on the grid and draw a curve of best fit.

(3)



(ii) Use your graph to estimate the time taken for the mixture to turn blue at 50 °C.

(1)

(iii) What does the graph show about the relationship between temperature and time taken?

(1)

(b) Explain, in terms of particles, why an increase in temperature increases the rate of this reaction.

(3)

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(c) State a variable that must be kept constant for the experiment to be valid (a fair test).

(1)

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**(Total for Question 7 = 9 marks)**

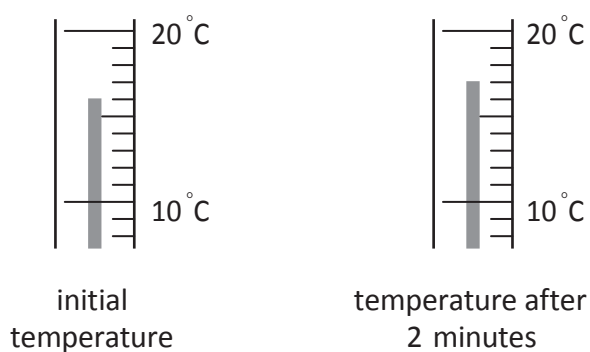
8 A student investigates the reaction between dilute hydrochloric acid and marble chips. She uses this method.

- put 50 cm<sup>3</sup> of dilute hydrochloric acid into a polystyrene cup
- measure the initial temperature of the acid
- add 5.0 g of marble chips to the acid and stir the mixture
- measure the temperature of the mixture after 2 minutes

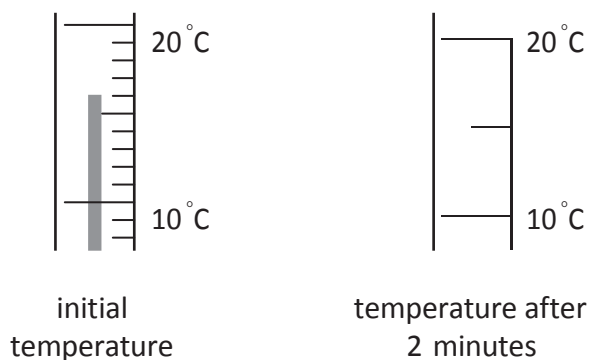
She carries out the experiment three times, using different sizes of marble chips each time.

The diagram shows the temperatures for each experiment.

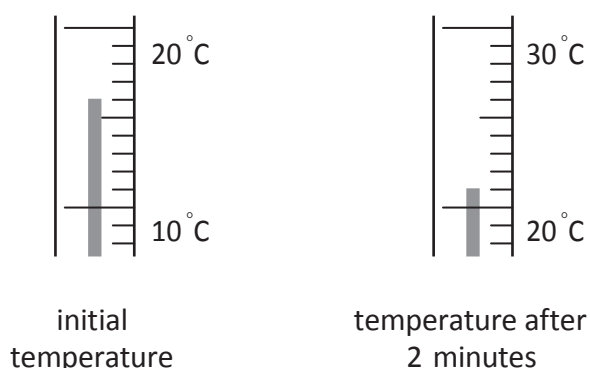
Experiment 1 – large marble chips



Experiment 2 – medium marble chips



Experiment 3 – small marble chips



(a) Record the temperature readings in the table and calculate the temperature changes. (3)

	Initial temperature in °C	Temperature in °C after 2 minutes	Temperature change in °C
experiment 1			
experiment 2			
experiment 3			

(b) Explain why the temperature change in experiment 2 is greater than the temperature change in experiment 1. (2)

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(c) Experiment 3 is repeated using 100 cm<sup>3</sup> of dilute hydrochloric acid in place of 50 cm<sup>3</sup>. The acid is in excess in both reactions.

State and explain how the temperature change would be different for 100 cm<sup>3</sup> of dilute hydrochloric acid.

(2)

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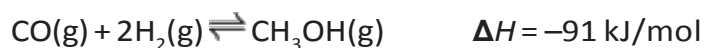
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**(Total for Question 8 = 7 marks)**

9 Carbon monoxide and hydrogen are used in the manufacture of methanol (CH<sub>3</sub>OH).

The reaction is reversible and can reach a position of dynamic equilibrium.



The reaction is carried out at a pressure of about 100 atmospheres and a temperature of 250 °C.

(a) State two features of a reaction that is in dynamic equilibrium.

(2)

1 .....

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2 .....

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(b) (i) How would a decrease in temperature at constant pressure affect the amount of methanol in the equilibrium mixture?

Explain your answer.

(2)

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(ii) How would an increase in pressure at constant temperature affect the amount of methanol in the equilibrium mixture?

Explain your answer.

(2)

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(c) Methanol (CH<sub>3</sub>OH) can be converted into methanal (H<sub>2</sub>CO).

A mixture of methanol and oxygen is passed over an iron oxide catalyst at 250°C.

Methanal and water are the only two products.

(i) Write a chemical equation for the conversion of methanol into methanal.

(2)

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(ii) What is meant by the term **catalyst**?

(2)

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(iii) Explain how a catalyst works.

(2)

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(d) Methanol can be used in racing cars as an alternative fuel to petrol.

Write the chemical equation for the complete combustion of methanol.

(2)

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**(Total for Question 9 = 14 marks)**

10 Hydrogen peroxide solution decomposes very slowly at room temperature.

The equation for this reaction is



Very few bubbles can be seen in the solution because of the slow decomposition.

The rate of this reaction is greatly increased by adding a catalyst.

(a) A student added a solid to some hydrogen peroxide solution to see if the solid acted as a catalyst.

He noticed that a lot of bubbles formed, and that the solid was still present at the end of the reaction.

Outline a method to show that the solid acted as a catalyst and not as a reactant.

(2)

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(b) The student investigated the effect that changing the concentration of the hydrogen peroxide solution has on the rate of the reaction.

He used solid manganese(IV) oxide as the catalyst in each experiment.

This is the method he used.

pour some hydrogen peroxide solution into a conical flask on a top-pan balance

add the catalyst and place some cotton wool loosely in the neck of the flask

record the balance reading and start a timer

record the balance reading every minute until the mass no longer changes

repeat the experiment several times using different concentrations of

hydrogen peroxide solution

(i) State one property of each substance that the student should keep the same in each experiment.

(2)

hydrogen peroxide solution.....

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manganese(IV) oxide .....

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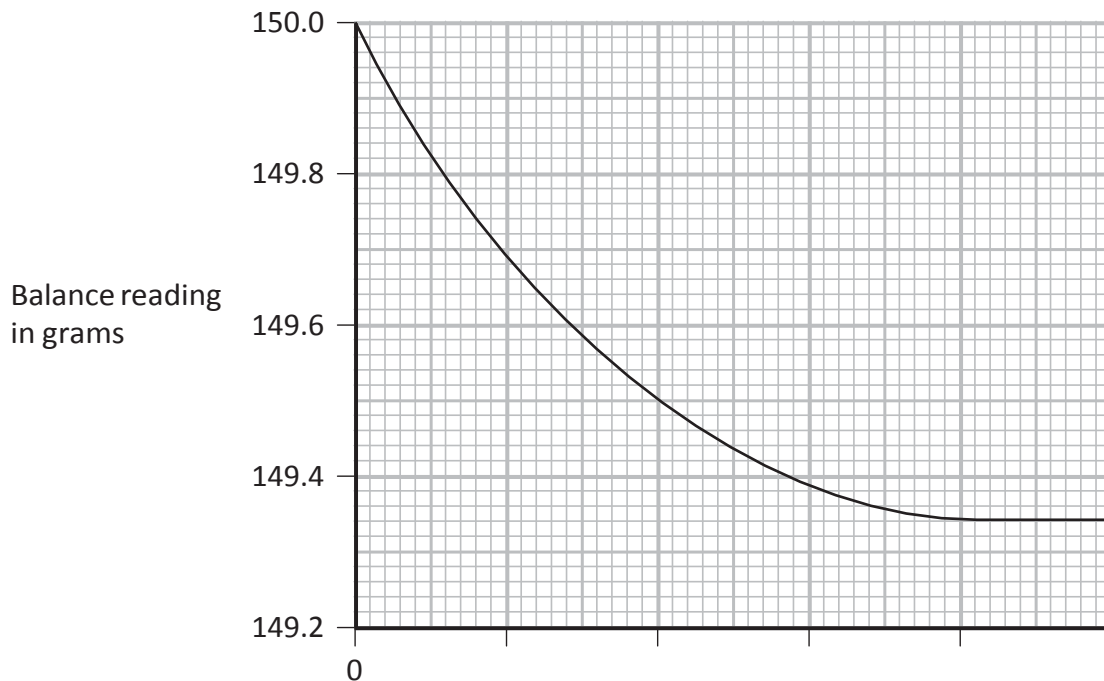
(ii) What is the purpose of the cotton wool?

(1)

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(c) The graph shows the results of one of the student's experiments.



(i) Why does the balance reading decrease during the experiment? (1)

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(ii) What does the slope of the curve indicate about the reaction? (1)

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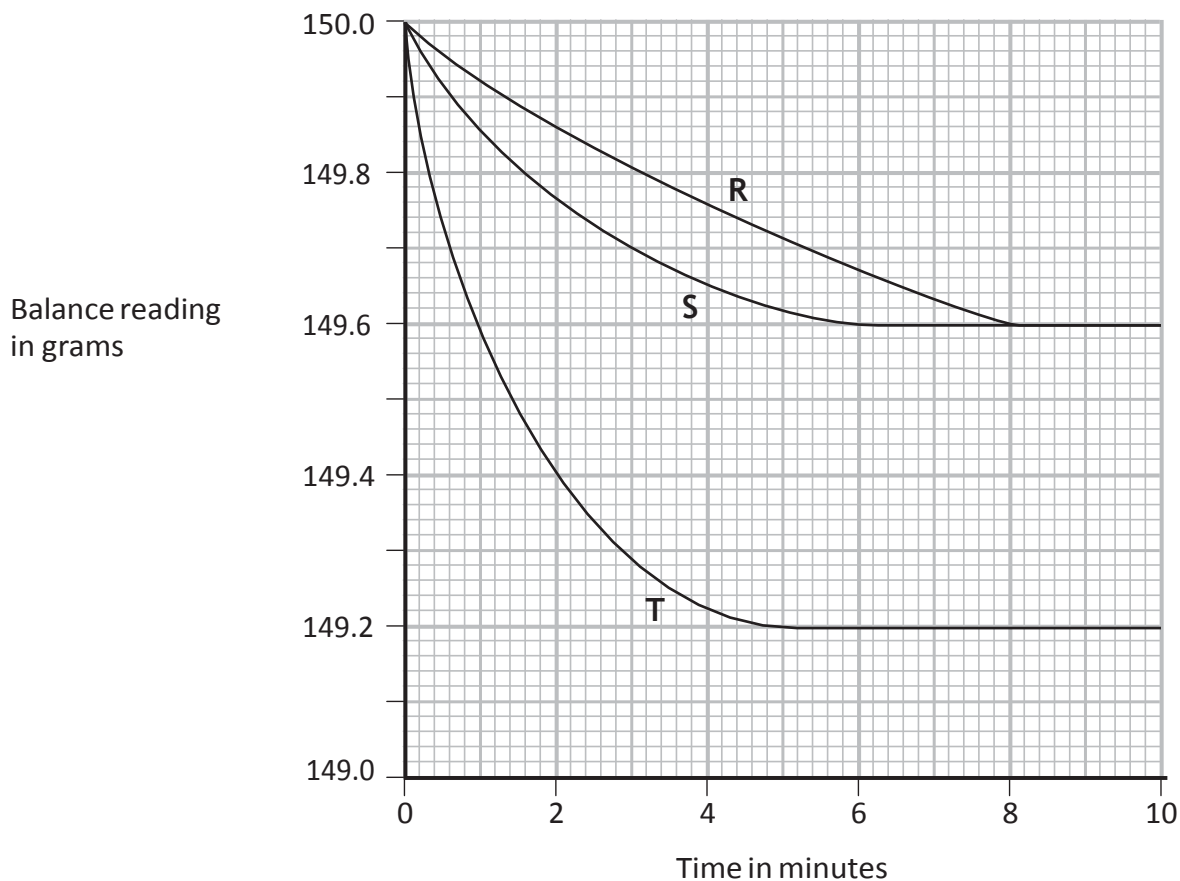
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(iii) How long does the reaction take to complete? (1)

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(d) The results of some of the student's other experiments are shown on this graph.



(i) Which one of the experiments, R, S or T, was the fastest?

(1)

(ii) The concentration of the hydrogen peroxide solution in experiment S was  $0.40 \text{ mol/dm}^3$ .

Use the graph to deduce the concentration of the hydrogen peroxide solution in experiment T.

State how you deduced your answer.

(2)

concentration = .....  $\text{mol/dm}^3$

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(e) Another student repeated the investigation.

She recorded the time for the total mass of the beaker and contents to decrease by 0.50 g in each experiment. She then converted the times to relative rates of reaction.

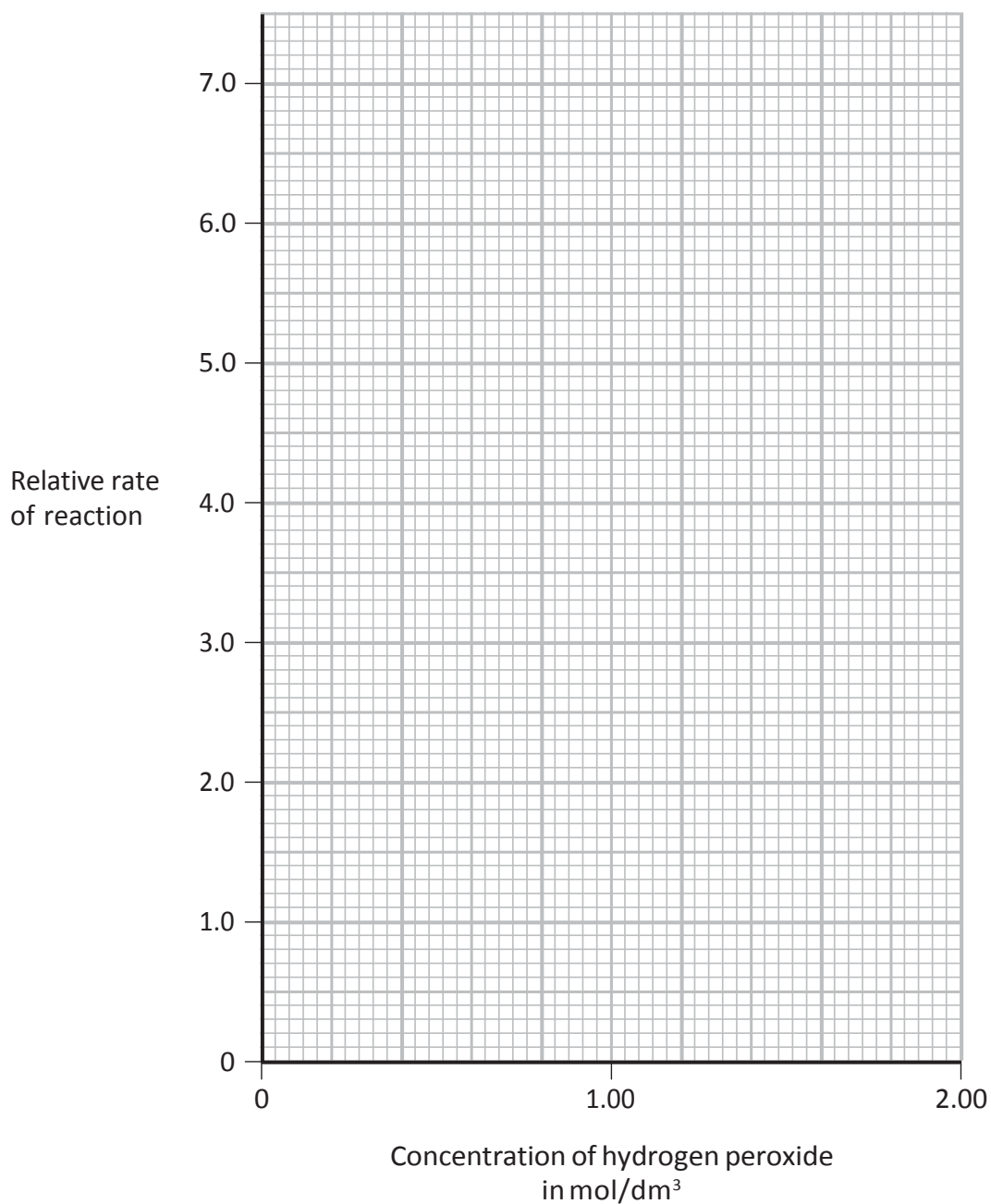
The table shows the concentrations she used and the relative rates of reaction she calculated.

<b>Relative rate of reaction</b>	1.5	2.2	3.0	4.4	5.1	6.0	7.4
<b>Concentration in mol/dm<sup>3</sup></b>	0.40	0.60	0.80	1.20	1.40	1.60	2.00

Plot a graph of these results on the grid.

Draw a straight line of best fit through the points.

(3)



(f) ) Explain, in terms of particles, why the rate of a reaction increases as the concentration of a reactant increases.

(2)

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**(Total for Question 10 = 16 marks)**