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

The equation for this reaction is

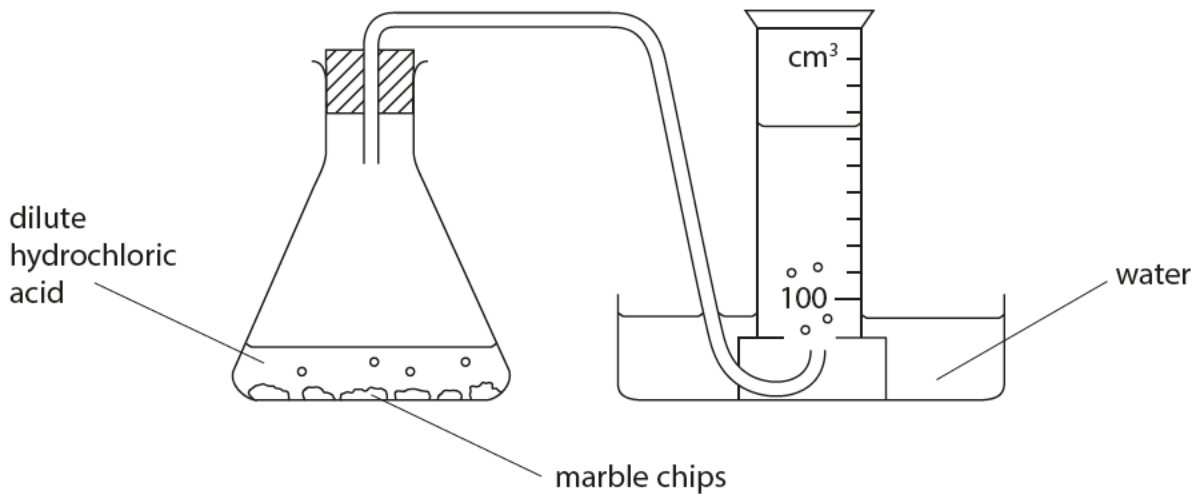
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

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^3 of gas in 40 seconds.
2	In my experiment there were 6 marble chips and 80% hydrochloric acid and I collected 100 cm^3 of carbon dioxide by the end of the experiment.
3	The marble chips and 60% hydrochloric acid formed 100 cm^3 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^3 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 .....

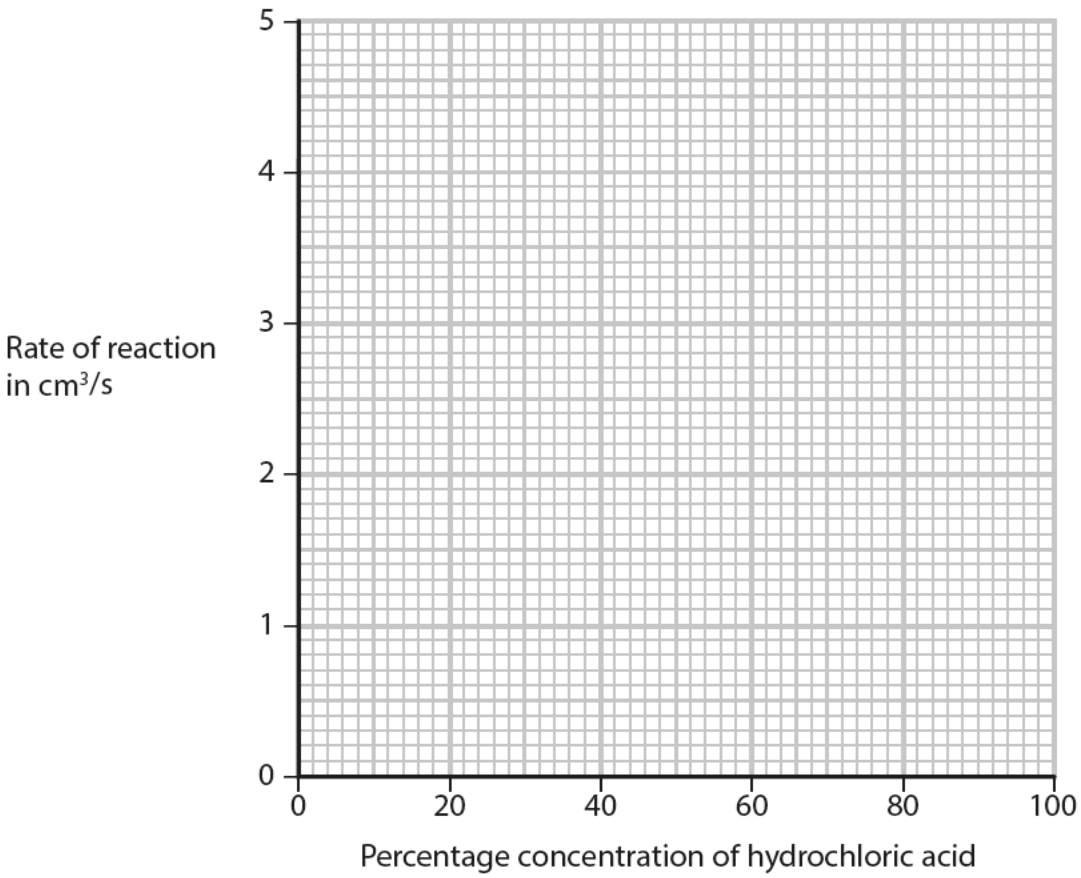
(c) The students repeated the experiment to make sure that it was a fair test. They used a different supply of hydrochloric acid. They all measured the time to collect 100 cm^3 of carbon dioxide and calculated the rate of each reaction.

Their results are shown in the table.

Percentage concentration of hydrochloric acid	Time to collect 100 cm^3 of gas in seconds	Rate of reaction in cm^3/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 1 = 14 marks)

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

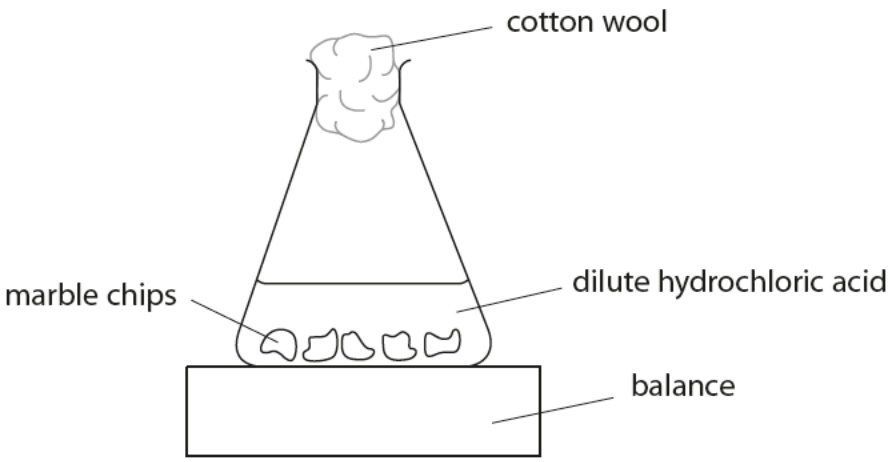
(a) The equation for the reaction is

$$CaCO_3\ (\ldots\ldots) + 2HCl\ (\ldots\ldots) \rightarrow CaCl_2\ (\ldots\ldots) + H_2O\ (\ldots\ldots) + CO_2\ (\ldots\ldots)$$

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)

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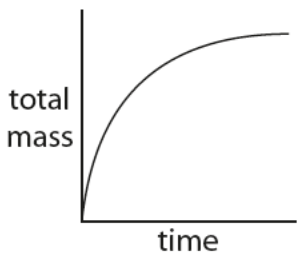
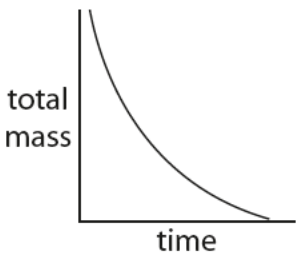
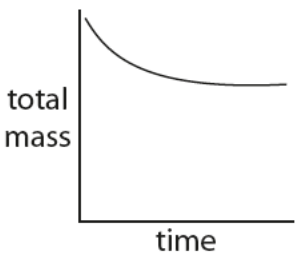
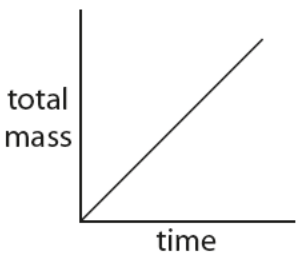
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(ii) He recorded the total mass of the conical flask and contents every 30 seconds for several minutes. He plotted the results as a graph of total mass (*y*-axis) against time.

Which of the graphs could represent his results?

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

(1)

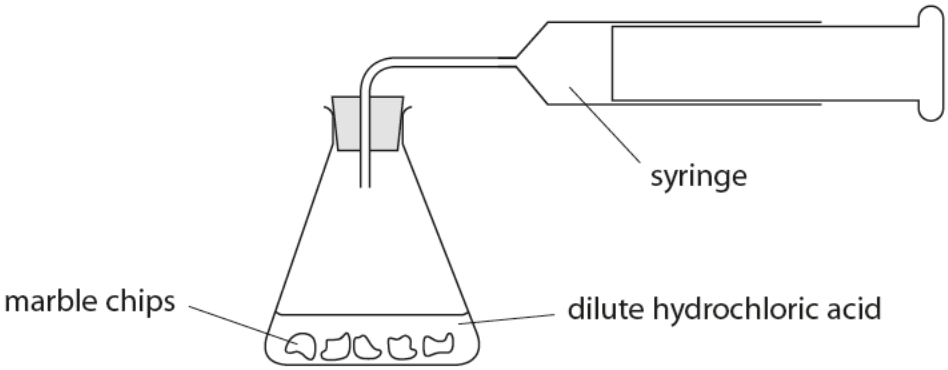
			
A ☒	**B** ☒	**C** ☒	**D** ☒

(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.

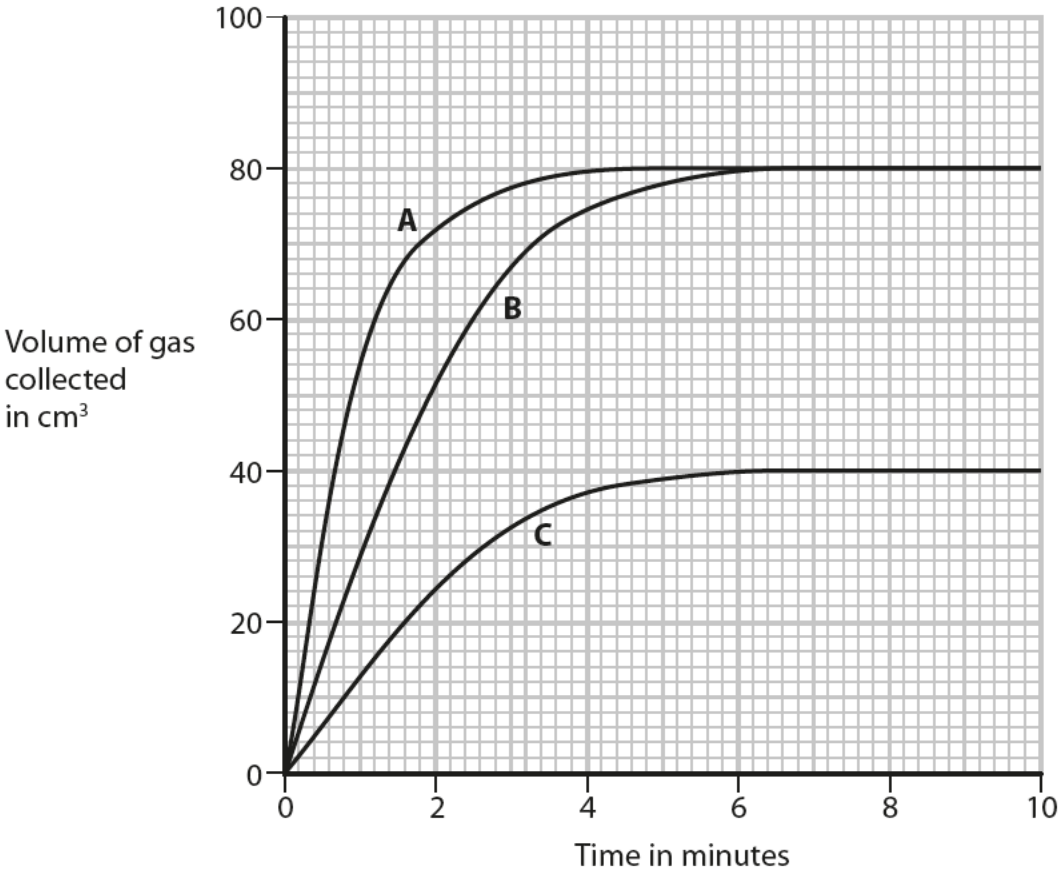
She kept the number and size of marble chips the same in each experiment.

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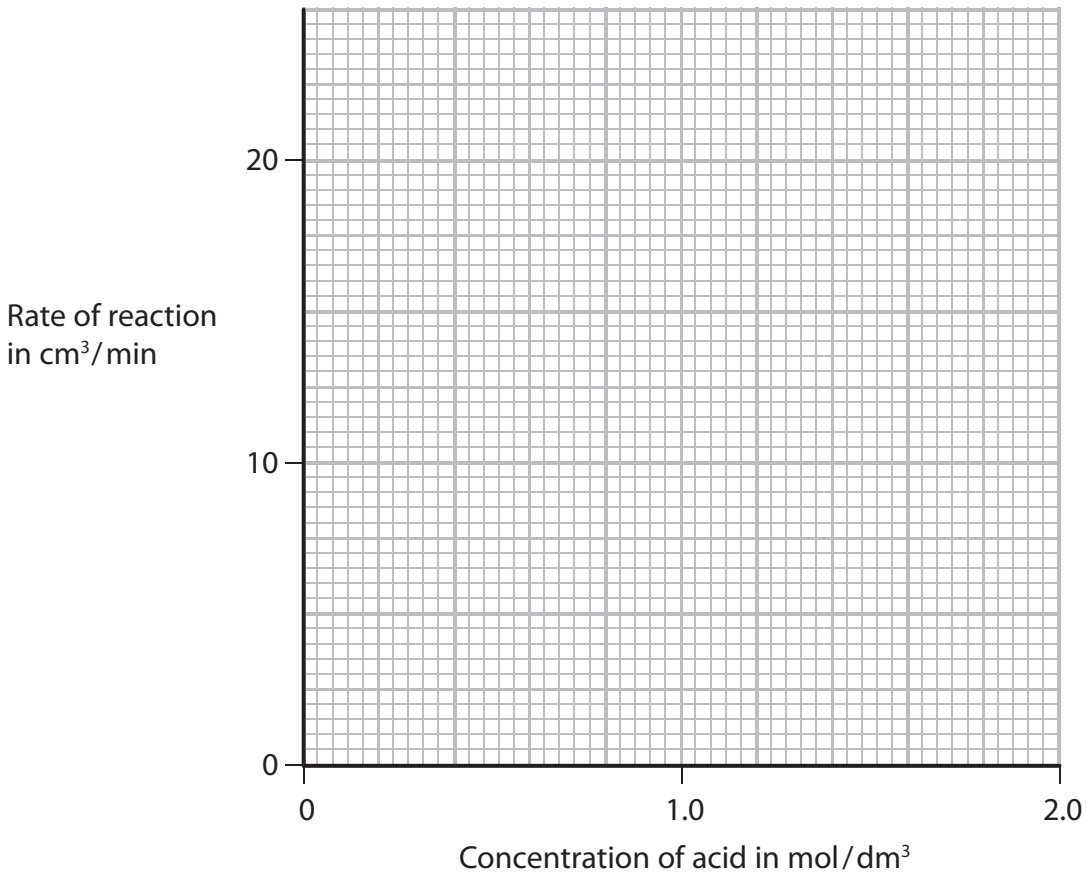
(d) (i) A third student calculated the rate of reaction in his experiments.

The table shows his results.

Rate of reaction in cm^3/min	4.0	9.0	13.5	18.5	23.0
Concentration of acid in mol/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 2 = 16 marks)

3 A student investigates the rate of the reaction between marble chips (calcium carbonate) and dilute hydrochloric acid. She is given a bottle containing hydrochloric acid labelled 100%.

She uses this method to find out how changing the concentration of the acid affects the rate of reaction.

- add some marble chips to a conical flask
- pour 50.0 cm^3 of dilute hydrochloric acid into the flask
- place the flask on a balance and start a timer
- record the time taken for the mass of the flask and contents to decrease by 1.0 g
- repeat the experiment using different concentrations of hydrochloric acid

(a) Suggest two features of the marble chips that the student should keep the same to ensure that the results are valid (a fair test).

(2)

1 .....

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2 .....

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(b) Why does the mass of the flask and contents decrease during the experiment?

(1)

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(c) The student should have put some cotton wool in the neck of the conical flask after placing the flask on the balance.

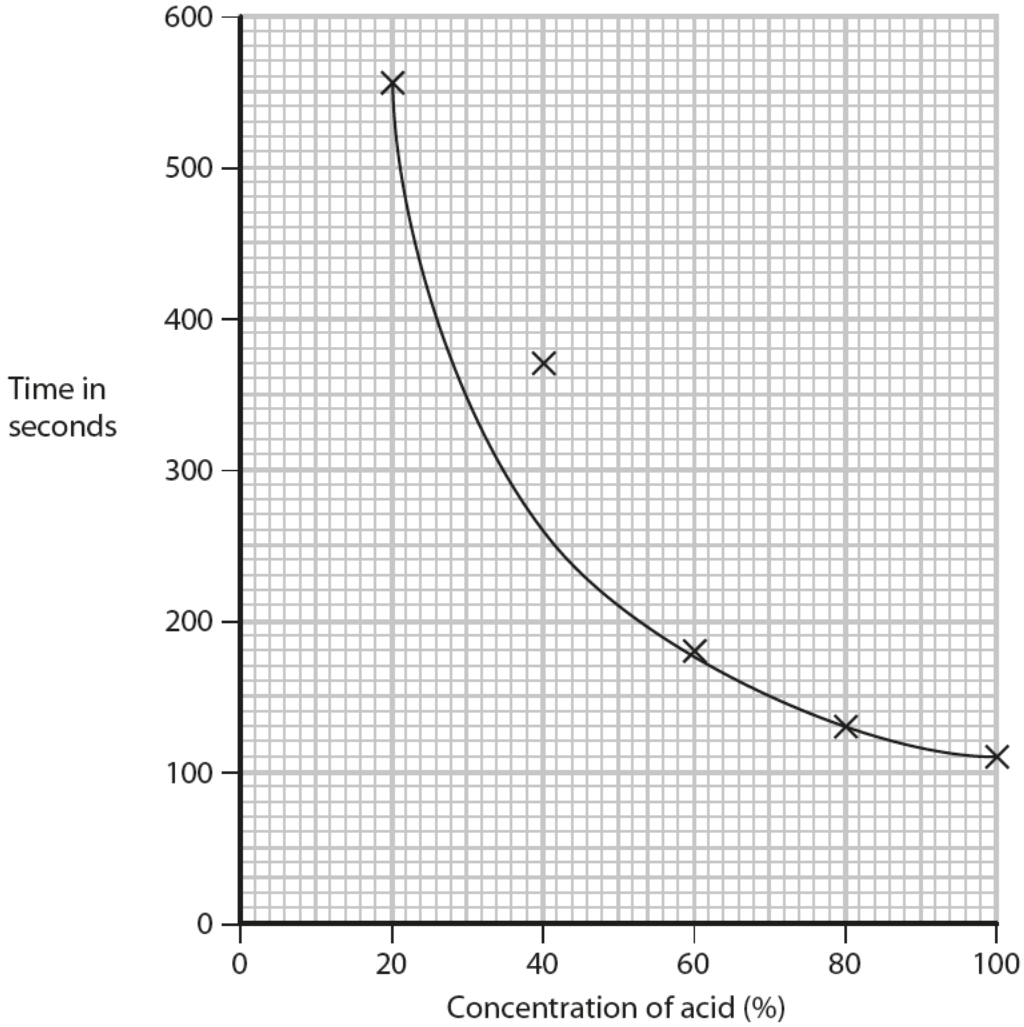
How would this improve the accuracy of the results?

(1)

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(d) The graph shows the student's results for the decrease in the mass of the flask and contents by 1.0 g.



(i) Use the graph to find the time taken for the loss of 1.0 g of mass from the flask when the concentration of acid is 50%.

Show on the graph how you obtained your answer.

(2)

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

What could have caused this anomalous result?

(1)

- ☒ **A** the concentration of acid was more than 40%
- ☒ **B** the loss of mass was greater than 1.0 g
- ☒ **C** the mass of marble chips was more than 10 g
- ☒ ed the timer too late

(e) The results of each experiment can be used to calculate the rate of reaction using the expression

$$\text{rate of reaction in grams per second} = \frac{1.0\ \text{g}}{\text{time to lose 1.0 g in seconds}}$$

Calculate the rate of reaction when the concentration of acid is 50%.

(2)

rate of reaction = ... g/s

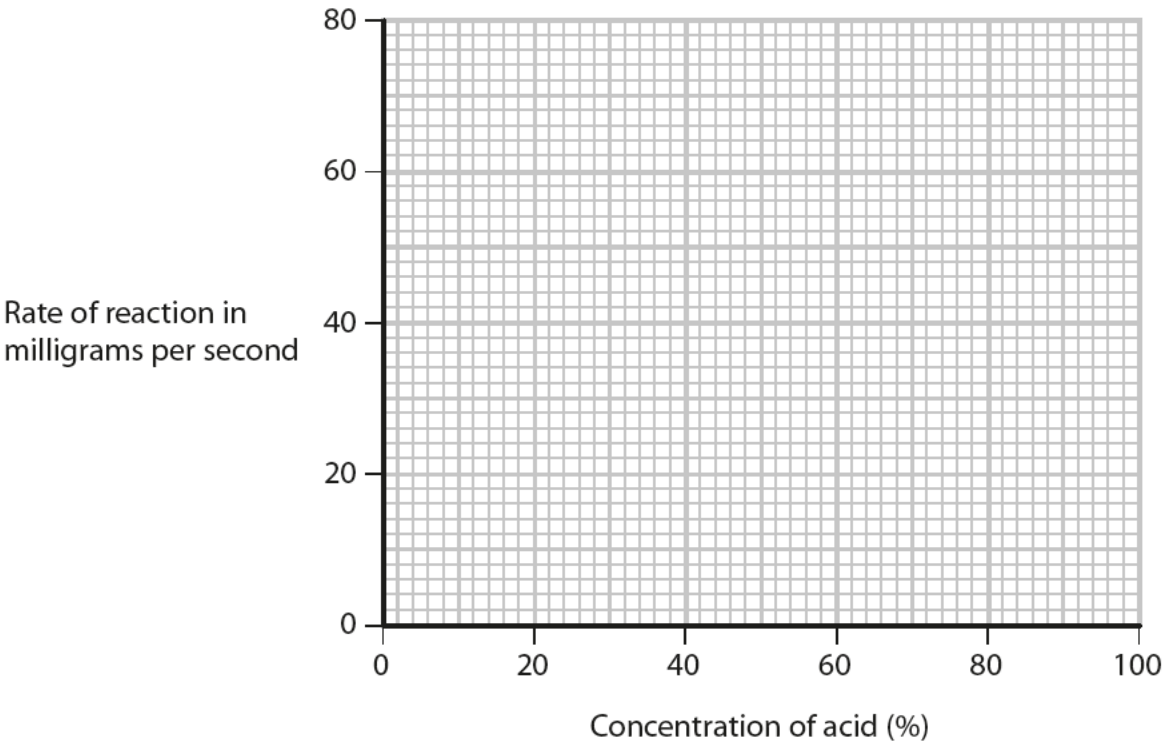
(f) The student is given a bottle of hydrochloric acid with a concentration different from that used in the previous experiments.
She repeats the investigation using different concentrations of hydrochloric acid.
She calculates the rate of reaction for each experiment.

The table shows her results.

Rate of reaction in milligrams per second	15	29	40	56	70
Concentration of acid (%)	20	40	60	80	100

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

(3)



(g) The rate of reaction increases as the concentration of the acid increases.

Explain this relationship in terms of particles.

(3)

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(Total for Question 3 = 15 marks)

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

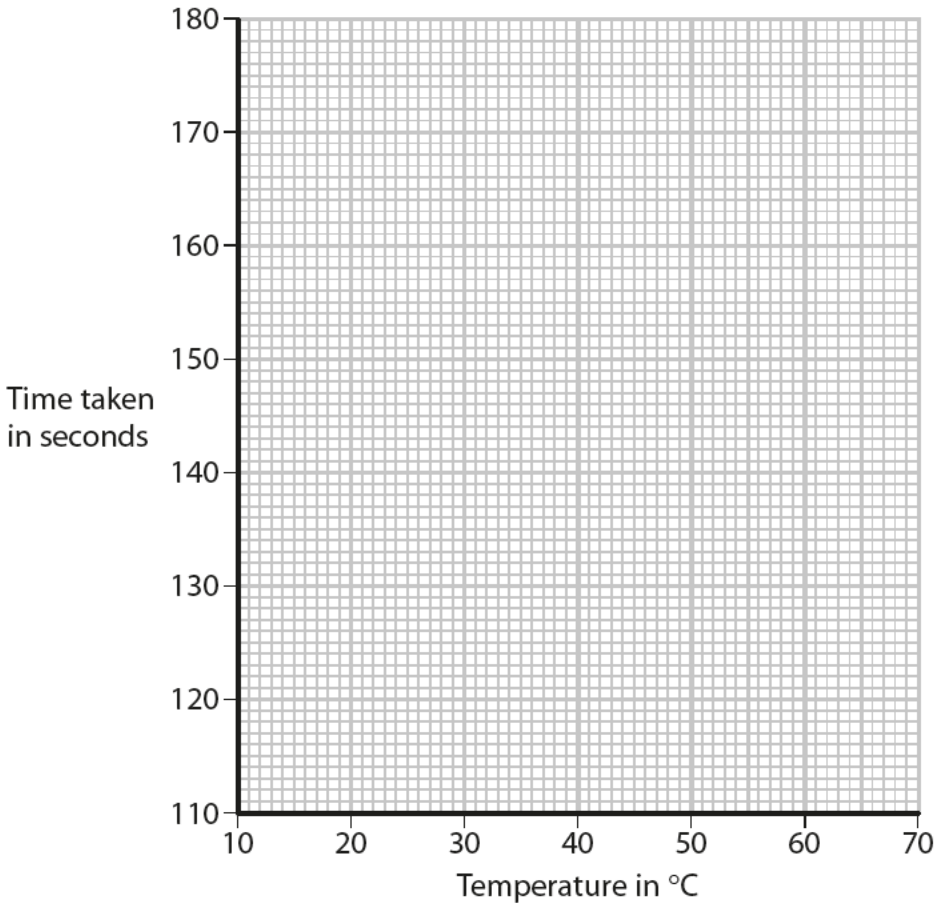
When he mixes the solutions, a reaction takes place between the ions and after a while the mixture suddenly turns blue. He performs the experiment at five different temperatures and on each occasion he measures the time taken for the mixture to turn blue.

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)

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

(1)

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(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 4 = 9 marks)