Questions

Q1.

Two substances, **A** and **B**, each form a colourless solution.

If the solutions are mixed in a beaker, **A** and **B** react to form a coloured product.
The rate of the reaction between **A** and **B** can be investigated by placing the beaker containing the mixture on a cross on a piece of paper and timing how long it takes for enough coloured product to be produced to make the cross invisible when viewed from above, through the solution.

	experiment 1	**experiment 2**	**experiment 3**
concentration of **A in solution** in g dm^{-3}	10	10	40
temperature in °C	20	40	40
time for cross to become invisible in s	320	80	20

Figure 13

Use the results of these experiments to explain, in terms of the behaviour of particles, the effect of changing temperature and the effect of changing the concentration of **A** in solution on the rate of this reaction.

(Total for question = 6 marks)

Q2.

Magnesium reacts with dilute sulfuric acid to form magnesium sulfate and hydrogen gas.

A student wants to find out the effect of temperature on the rate of this reaction.

The student used the following method.

step 1 pour 25 cm^3 of dilute sulfuric acid into a conical flask
step 2 warm the acid until its temperature is 30 °C
step 3 add a piece of magnesium to the acid
step 4 start a stopwatch
step 5 wait until the reaction has finished
step 6 stop the stopwatch
step 7 repeat steps 1–6 but at 50 °C.

At 50 °C, 15.0 cm^3 of gas was produced during the first 60 seconds of the reaction.

Calculate the average rate of reaction, in $cm^3\ s^{-1}$, for the first 60 seconds of the reaction.

(2)

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average rate of reaction = ... $cm^3\ s^{-1}$

(Total for question = 2 marks)

Q3.

Calcium carbonate reacts with dilute hydrochloric acid to produce carbon dioxide gas.

The rate of reaction between calcium carbonate and dilute hydrochloric acid at room temperature was investigated.

The calcium carbonate powder produced 90 cm^3 of carbon dioxide in five minutes.

Calculate the average rate of reaction in $cm^3\ s^{-1}$.

(3)

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average rate of reaction = ... $cm^3\ s^{-1}$

(Total for question = 3 marks)

Q4.

Hydrogen peroxide decomposes to form water and oxygen.

The rate of this reaction can be found by measuring the volume of oxygen formed after different time intervals.

Hydrogen peroxide solution is placed in a conical flask.
The apparatus is set up as shown in Figure 5.

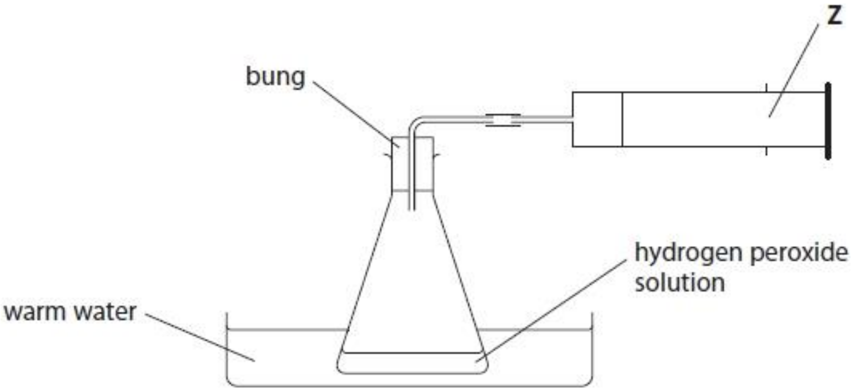

Figure 5

The experiment is repeated three times

once using a more dilute solution of hydrogen peroxide
once using a lower temperature
once using a larger flask

In each case, all other conditions are kept the same.

Circle the word that shows the change in the rate of decomposition in each case.

(2)

	change in rate		
hydrogen peroxide solution is more dilute	faster	slower	unchanged
the temperature used is lower	faster	slower	unchanged
the reaction is carried out in a larger flask	faster	slower	unchanged

(Total for question = 2 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Magnesium reacts with dilute sulfuric acid to form magnesium sulfate and hydrogen gas.

A student wants to find out the effect of temperature on the rate of this reaction.

The student used the following method.

step 1 pour 25 cm^3 of dilute sulfuric acid into a conical flask
step 2 warm the acid until its temperature is 30 °C
step 3 add a piece of magnesium to the acid
step 4 start a stopwatch
step 5 wait until the reaction has finished
step 6 stop the stopwatch
step 7 repeat steps 1–6 but at 50 °C.

Which piece of equipment can be used to find the volume of 25 cm^3 of sulfuric acid?

(1)

☐ **A** balance
☐ **B** measuring cylinder
☐ **C** ruler
☐ **D** thermometer

(Total for question = 1 mark)

Q6.

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

The word equation for this reaction is

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

Some pieces of calcium carbonate were added to dilute hydrochloric acid in a conical flask and the volume of carbon dioxide produced was measured.

Complete the diagram in Figure 7 to show the apparatus to collect the gas produced and measure its volume.

(2)

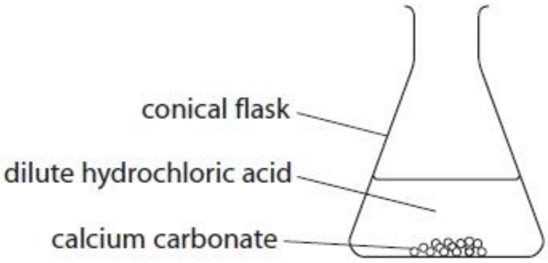

Figure 7

(Total for question = 2 marks)

Q7.

The rate of reaction between magnesium ribbon and dilute hydrochloric acid at room temperature is investigated.

The apparatus used is shown in Figure 11.

The volume of hydrogen gas given off was measured at regular intervals during the reaction.

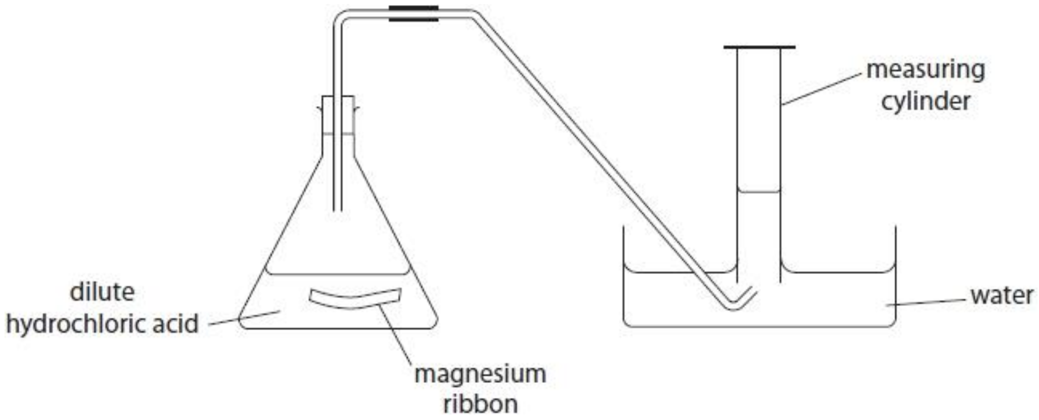

Figure 11

The graph in Figure 12 shows the results of this experiment.

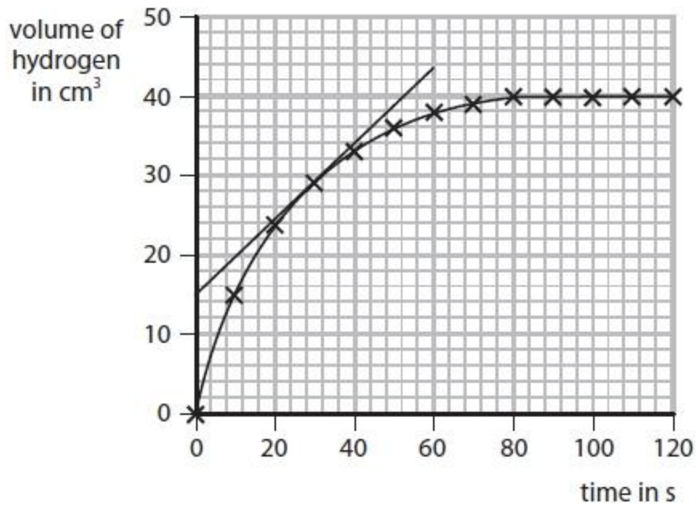

Figure 12

(i) State a change that can be made to the apparatus in Figure 11 to measure the volumes of gas more accurately.

(1)

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....

(ii) A tangent has been drawn to the line on the graph in Figure 12.

Calculate the rate of reaction at this point.

(2)

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....

rate of reaction = ... $cm^3\ s^{-1}$

(iii) On the graph in Figure 12, draw the line you would expect to obtain if the magnesium ribbon in this experiment was replaced with an equal mass of powdered magnesium. All other conditions are kept the same.

(1)

(Total for question = 4 marks)

Q8.

A student used the apparatus in Figure 13 to investigate the rate of the reaction between a metal and dilute hydrochloric acid.

Pieces of the metal were placed in dilute hydrochloric acid in the flask, and the total volume of gas produced was measured every minute.

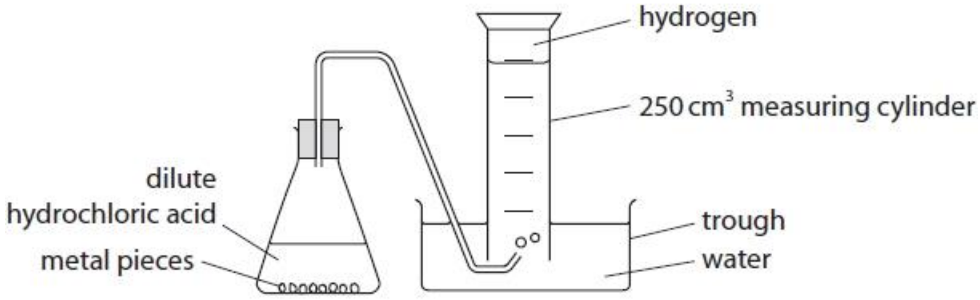

Figure 13

The apparatus in Figure 13 can be used to measure the rate of the reaction between marble chips and hydrochloric acid.

The student needs different sized marble chips.

Describe how the student can make small and medium sized marble chips from large chips.

(2)

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(Total for question = 2 marks)

Q9.

*Zinc metal reacts with dilute hydrochloric acid to produce hydrogen gas.

zinc + hydrochloric acid → zinc chloride + hydrogen

A student investigated the effect of doubling the concentration of the hydrochloric acid on this reaction.

The student made the following prediction.

> When the concentration of the hydrochloric acid is doubled the rate of reaction will double and the reaction will be more exothermic.

Devise a plan, including the apparatus you would use, to test the student's prediction.

You are provided with pieces of zinc and two bottles of dilute hydrochloric acid.
One bottle of hydrochloric acid is double the concentration of the other.

(6)

(Total for question = 6 marks)

Q10.

Explain the advantage of using catalysts made of nanoparticles rather than larger particles.

(2)

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(Total for question = 2 marks)

Q11.

Calcium carbonate reacts with dilute hydrochloric acid to produce calcium chloride, water and carbon dioxide.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

An investigation was carried out into the rate of reaction of calcium carbonate with dilute hydrochloric acid.

5.0 g of small lumps of calcium carbonate were reacted with 50 cm^3 of 0.50 mol dm^{-3} hydrochloric acid.
Another 5.0 g of the same sized lumps of calcium carbonate were reacted with 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid.
The volume of gas collected in two minutes was recorded for each experiment.

The two experiments were then repeated, each using 5.0 g of large lumps of calcium carbonate.

Figure 5 shows the results.

concentration of hydrochloric acid in mol dm^{-3}	volume of gas collected in cm^3	
	small lumps of calcium carbonate	large lumps of calcium carbonate
0.50	17.2	3.1
1.0	35.1	5.6

Figure 5

Explain, in terms of collision of particles, how these results show the effect of the size of the lumps of calcium carbonate and the effect of the concentration of the acid on the rate of this reaction.

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(Total for question = 6 marks)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sodium thiosulfate solution, $Na_2S_2O_3$, reacts with dilute hydrochloric acid.

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

(i) When dilute hydrochloric acid is mixed with sodium thiosulfate solution, the mixture turns cloudy.

Explain why the mixture turns cloudy.

(2)

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(ii) In an investigation, different concentrations of hydrochloric acid are reacted with sodium thiosulfate solution.
The mixture goes cloudy at different rates.

Describe how the rate at which the mixture goes cloudy can be measured.

(3)

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(iii) You are provided with some dilute hydrochloric acid which has a concentration of 50 g dm^{-3}.

For this experiment, dilute hydrochloric acid with a concentration of 20 g dm^{-3} is required.
How much water must be added to 100 cm^3 of 50 g dm^{-3} hydrochloric acid to make dilute hydrochloric acid with a concentration of 20 g dm^{-3}?

(1)

☐ **A** 200 cm^3
☐ **B** 150 cm^3
☐ **C** 100 cm^3
☐ **D** 50 cm^3

(Total for question = 6 marks)

Q13.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

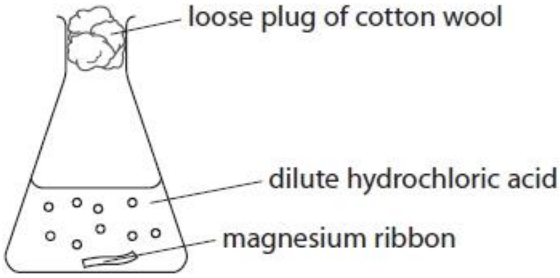

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

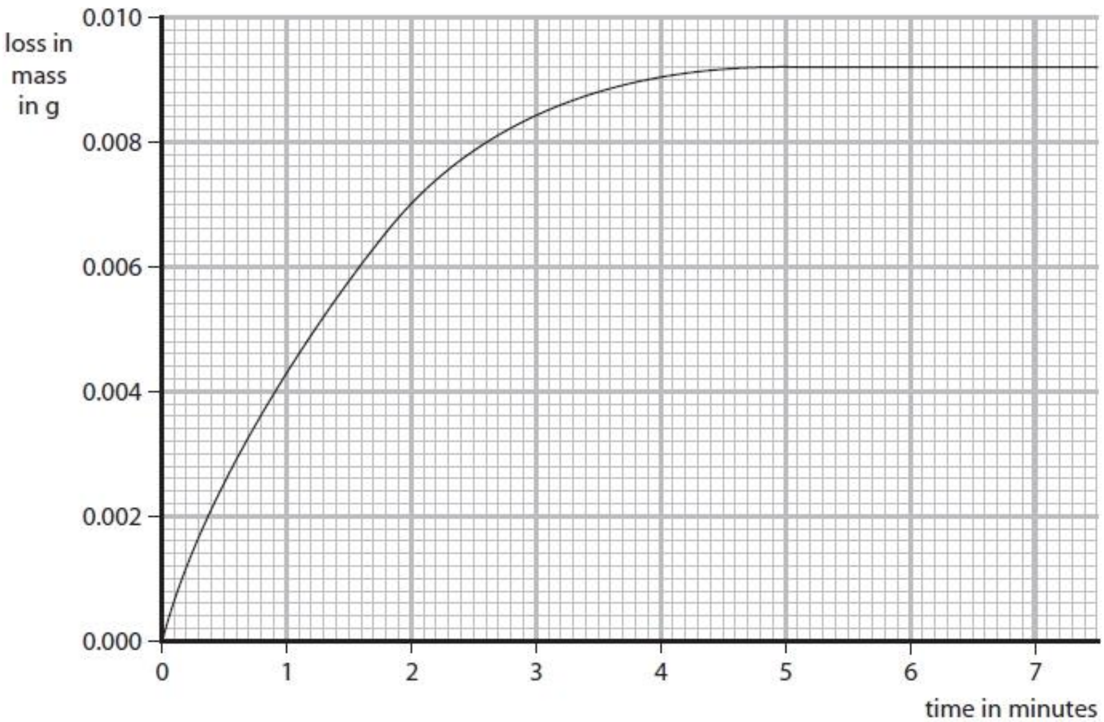

Figure 12

The graph shows that the rate of reaction slows as the reaction takes place.

Explain, in terms of particles, why the rate of reaction between magnesium ribbon and dilute hydrochloric acid slows as the reaction takes place.

(3)

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(Total for question = 3 marks)

Q14.

Some questions must be answered with a cross in a box (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A student used the apparatus in Figure 13 to investigate the rate of the reaction between a metal and dilute hydrochloric acid.

Pieces of the metal were placed in dilute hydrochloric acid in the flask, and the total volume of gas produced was measured every minute.

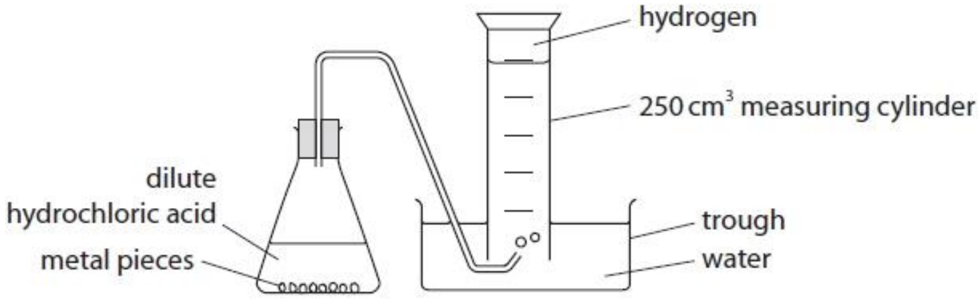

Figure 13

The experiment was repeated, but with acid of a higher concentration.

The rate of reaction was faster.

(i) Explain why the rate of reaction increases when the concentration of acid is increased.

(2)

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....

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(ii) Another student suggests four other ways of increasing the rate of this reaction.

Which one is correct?

(1)

- ☐ **A** use the same acid but at a lower temperature
- ☐ **B** use a larger trough
- ☐ **C** use a smaller flask
- ☐ **D** use the same metal but in a powdered form

(Total for question = 3 marks)

Q15.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

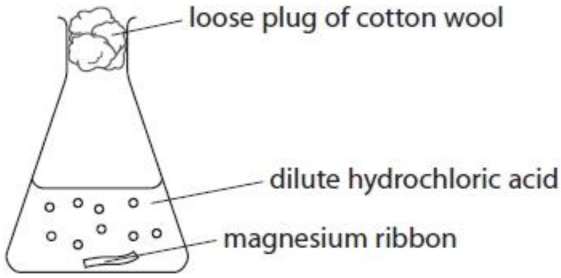

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

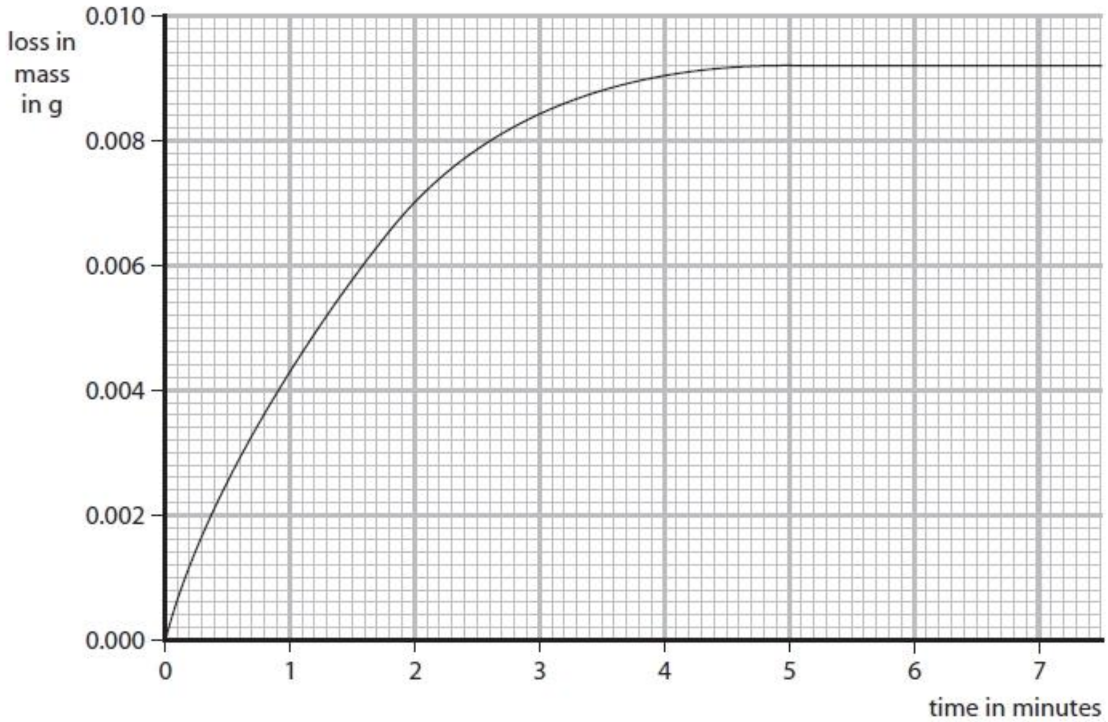

Figure 12

Explain why there is a loss in mass of the flask and contents.

(2)

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(Total for question = 2 marks)

Q16.

Calcium carbonate reacts with dilute hydrochloric acid to produce carbon dioxide gas.

The rate of reaction between calcium carbonate and dilute hydrochloric acid at room temperature was investigated.

The experiments were repeated at a higher temperature.
The rate of reaction for each experiment increased.

Explain, in terms of particles, why the rate of reaction increased when the temperature was increased.

(3)

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(Total for question = 3 marks)

Q17.

Magnesium reacts with dilute sulfuric acid to form magnesium sulfate and hydrogen gas.

A student wants to find out the effect of temperature on the rate of this reaction.

The student used the following method.

step 1 pour 25 cm^3 of dilute sulfuric acid into a conical flask
step 2 warm the acid until its temperature is 30 °C
step 3 add a piece of magnesium to the acid
step 4 start a stopwatch
step 5 wait until the reaction has finished
step 6 stop the stopwatch
step 7 repeat steps 1–6 but at 50 °C.

The reaction at 50 °C was faster than the reaction at 30 °C.

Give **one** reason, in terms of particles, why the reaction at 50 °C was faster than the reaction at 30 °C.

(1)

....

....

(Total for question = 1 mark)

Q18.

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

The word equation for this reaction is

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

The reaction between calcium carbonate and dilute hydrochloric acid was investigated at different temperatures.

(i) State what could be used to keep the temperature of the conical flask and its contents at a temperature of 45 °C throughout the reaction.

(1)

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....

(ii) Figure 8 shows a graph of volume of gas collected in this investigation.

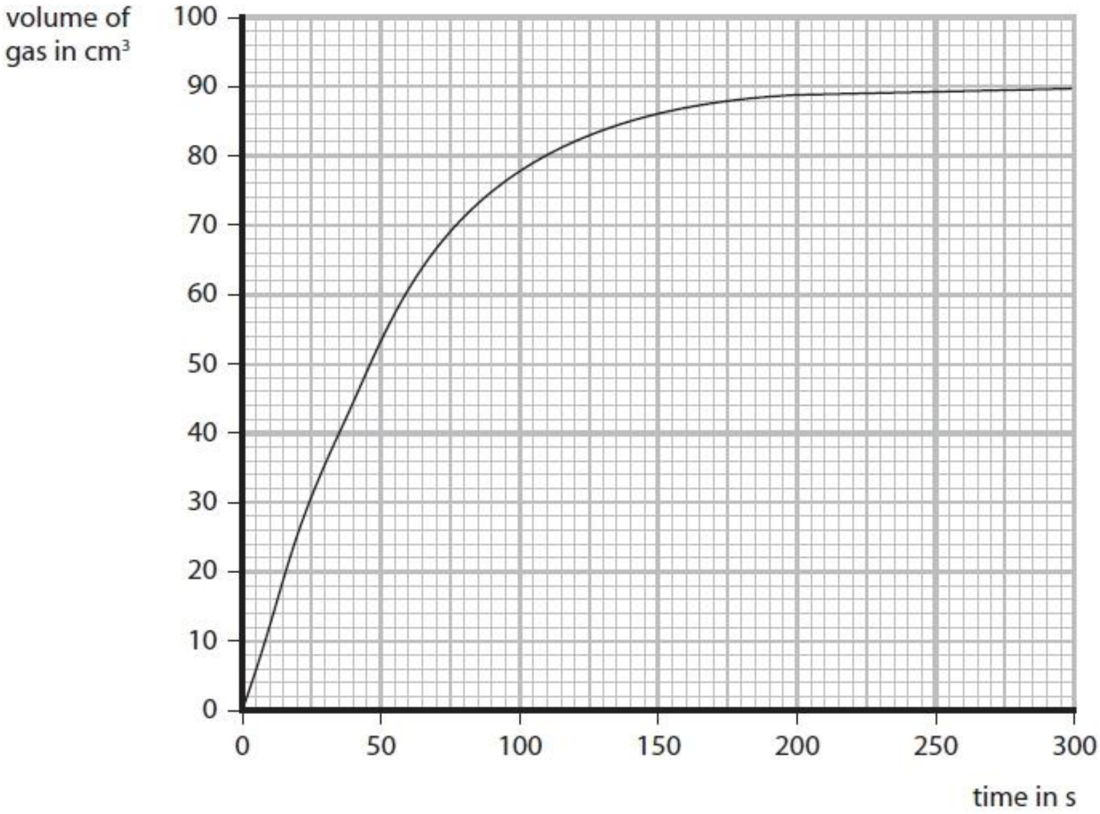

Figure 8

Draw a tangent at 100 seconds on Figure 8.
Use this tangent to calculate the rate of reaction at this time.

(2)

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....

rate of reaction = ... $cm^3\ s^{-1}$

(iii) The temperature of the acid was kept at 45 °C.

State **one** other variable that needs to be controlled during this investigation.

(1)

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(iv) Explain, in terms of particles, how decreasing the temperature affects the rate of this reaction.

(3)

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(Total for question = 7 marks)

Q19.

Hydrogen peroxide decomposes to form water and oxygen.

The rate of this reaction can be found by measuring the volume of oxygen formed after different time intervals.

Hydrogen peroxide solution is placed in a conical flask.
The apparatus is set up as shown in Figure 5.

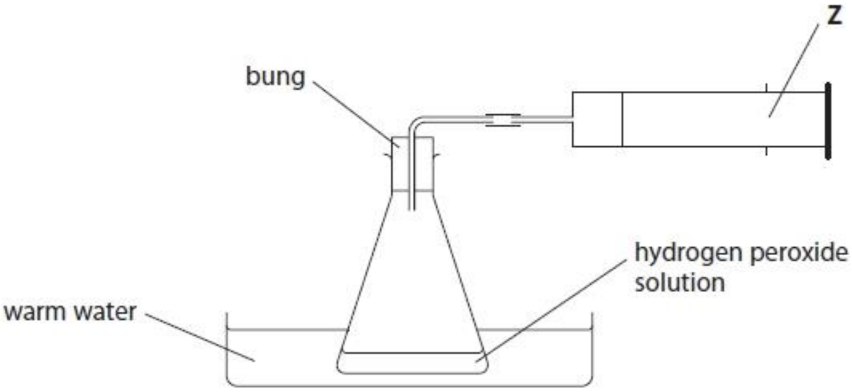

Figure 5

State the name of the piece of apparatus labelled **Z** in Figure 5.

(1)

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....

(Total for question = 1 mark)

Q20.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

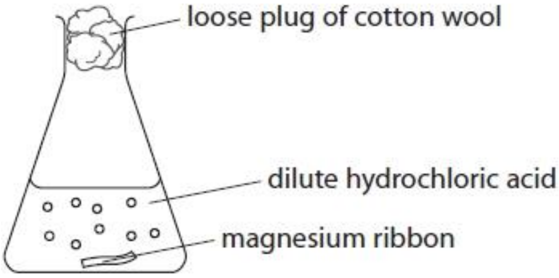

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

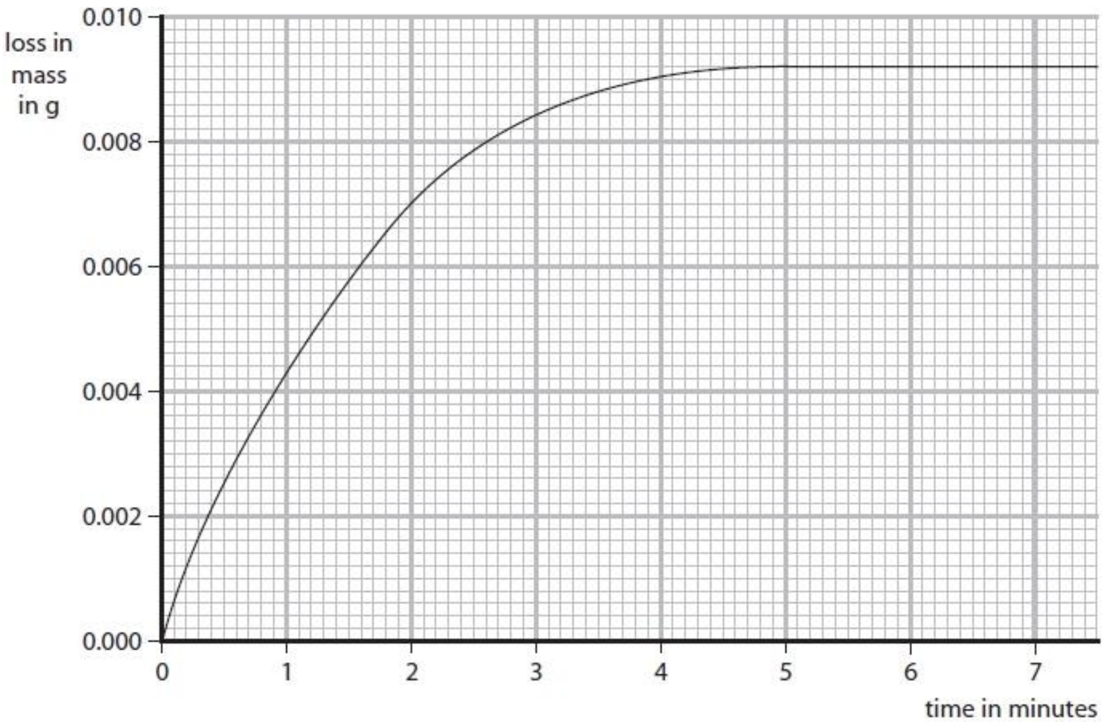

Figure 12

Name the apparatus that could be used to measure out 100 cm^3 of dilute hydrochloric acid.

(1)

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(Total for question = 1 mark)

Q21.

A student used the apparatus in Figure 13 to investigate the rate of the reaction between a metal and dilute hydrochloric acid.

Pieces of the metal were placed in dilute hydrochloric acid in the flask, and the total volume of gas produced was measured every minute.

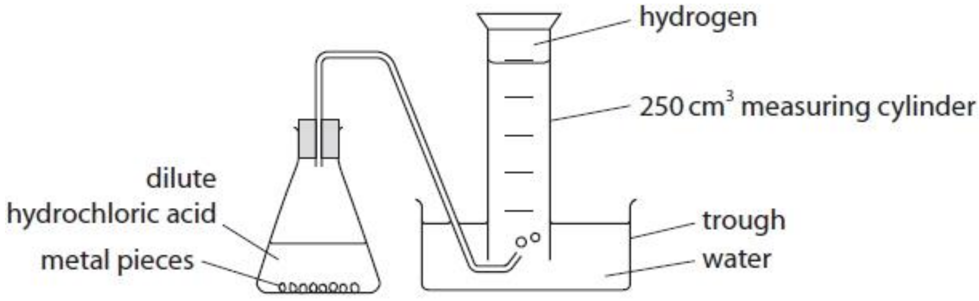

Figure 13

Figure 14 shows a graph of the student's results.

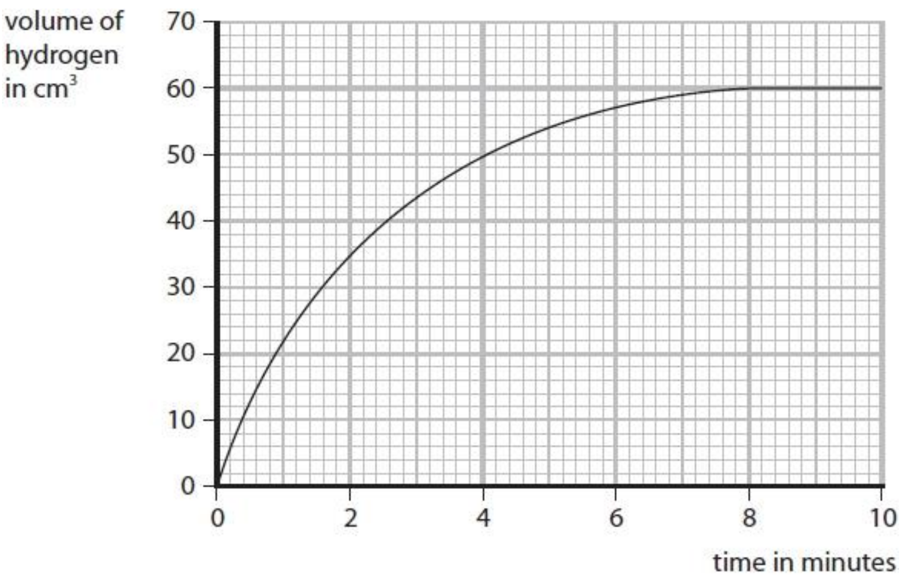

Figure 14

(i) Name a piece of apparatus that would be better to measure the volume of gas produced, instead of the 250 cm^3 measuring cylinder.

Give a reason for your answer.

(2)

name of apparatus

....

reason

....

....

(ii) Calculate the mean rate of production of hydrogen over the first 90 seconds, in cm^3 per second.

(3)

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rate = ... cm^3 per second

(iii) The student measured the volume of gas for 10 minutes.

State why the measurements could have been stopped at 9 minutes.

(1)

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....

(Total for question = 6 marks)

Q22.

Calcium carbonate reacts with dilute hydrochloric acid to produce calcium chloride, water and carbon dioxide.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

A student wanted to measure the amount of gas produced in two minutes.

The student suggested that this could be done by counting the number of bubbles formed. However, the bubbles are produced too quickly to count them.

Figure 4 shows a conical flask in which the calcium carbonate and dilute hydrochloric acid are reacting.

Complete Figure 4 to show the apparatus that could be used to measure accurately the volume of gas given off in two minutes.

(2)

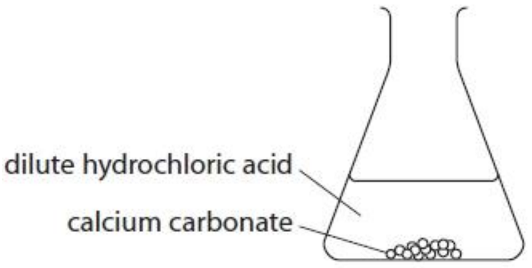

Figure 4

(Total for question = 2 marks)

Q23.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

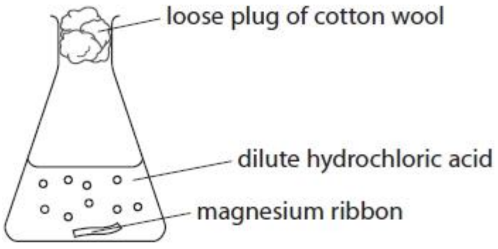

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

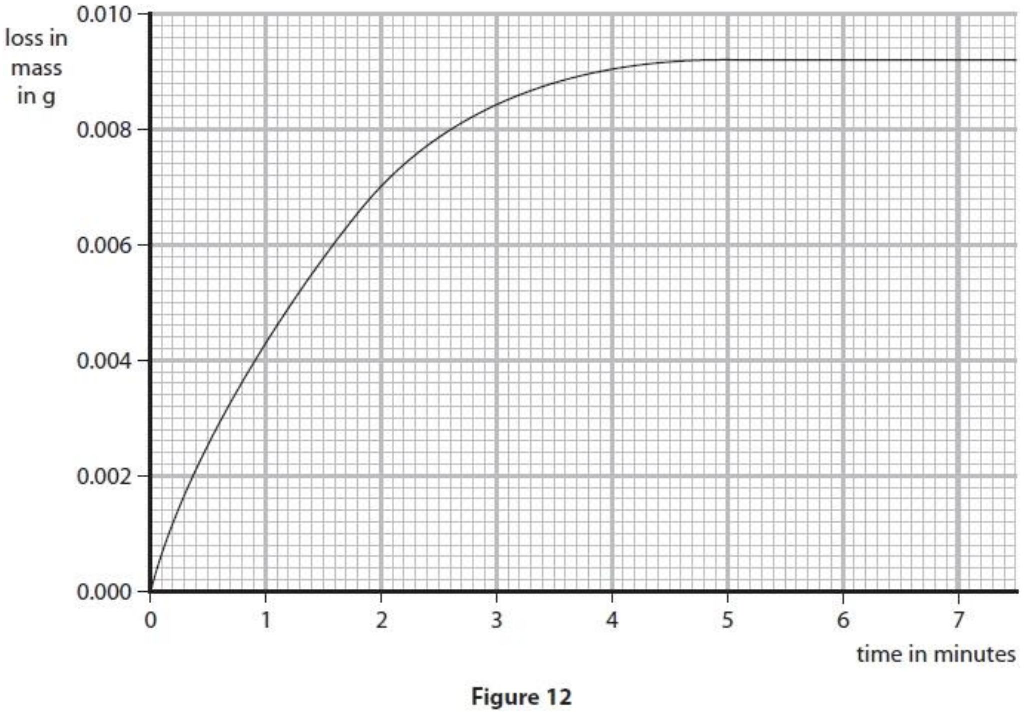

Figure 12

The original experiment was repeated using the same mass of magnesium powder instead of the magnesium ribbon.
All other conditions were kept the same.

Sketch, on the graph in Figure 12, the line you would expect for this experiment.

(2)

(Total for question = 2 marks)

Q24.

Magnesium reacts with dilute sulfuric acid to form magnesium sulfate and hydrogen gas.

A student wants to find out the effect of temperature on the rate of this reaction.

The student used the following method.

step 1 pour 25 cm^3 of dilute sulfuric acid into a conical flask
step 2 warm the acid until its temperature is 30 °C
step 3 add a piece of magnesium to the acid
step 4 start a stopwatch
step 5 wait until the reaction has finished
step 6 stop the stopwatch
step 7 repeat steps 1–6 but at 50 °C.

State how the student will know that the reaction has finished.

(1)

....

(Total for question = 1 mark)

Q25.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

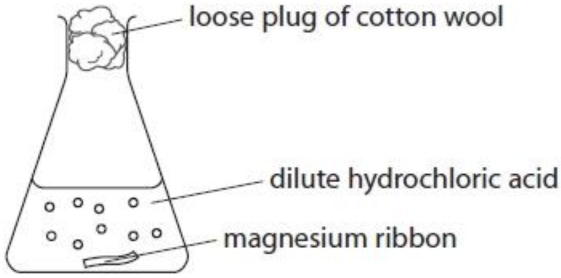

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

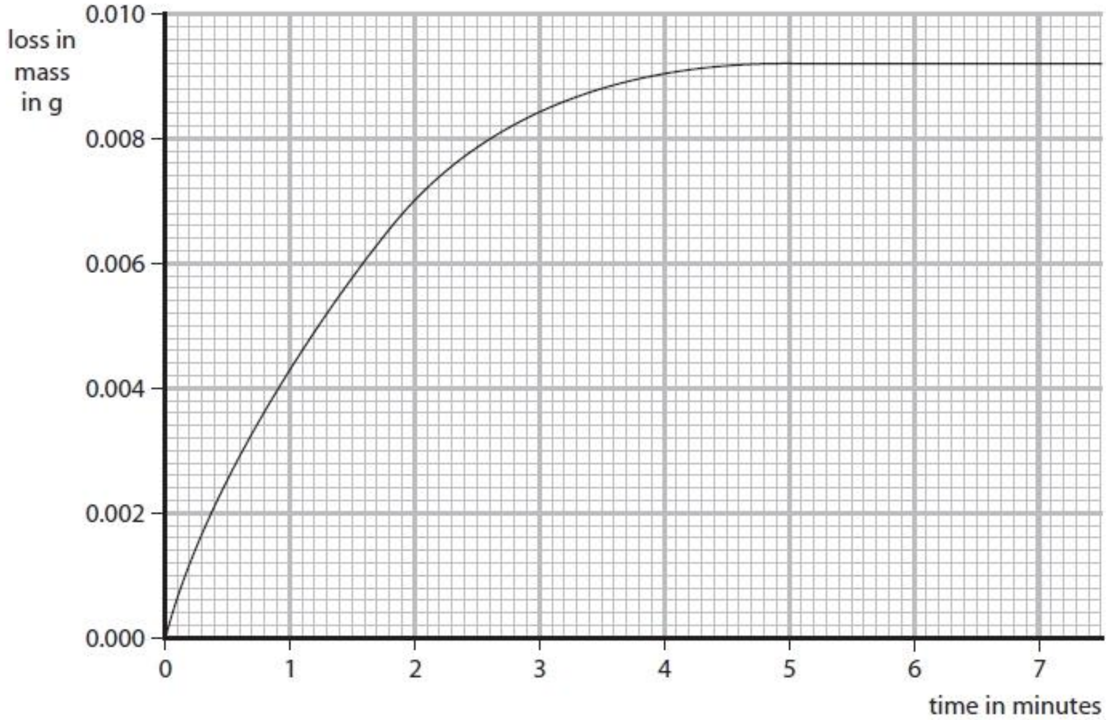

Figure 12

Some reactions are affected by the presence of a catalyst.

(i) State the effect of a catalyst on a reaction.

(1)

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(ii) Devise a simple experiment to find out what happens to the mass of a solid catalyst during a reaction.

(3)

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(Total for question = 4 marks)

Q26.

The word equation for the reaction between magnesium and dilute hydrochloric acid is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

The reaction was carried out using the apparatus shown in Figure 11.

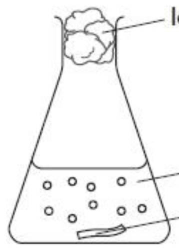

Figure 11

A strip of magnesium ribbon was placed in the conical flask.
100 cm^3 of dilute hydrochloric acid was added to the conical flask.

The mass of the flask and contents was measured at regular intervals.
The loss in mass was calculated.
Figure 12 shows a graph of the results.

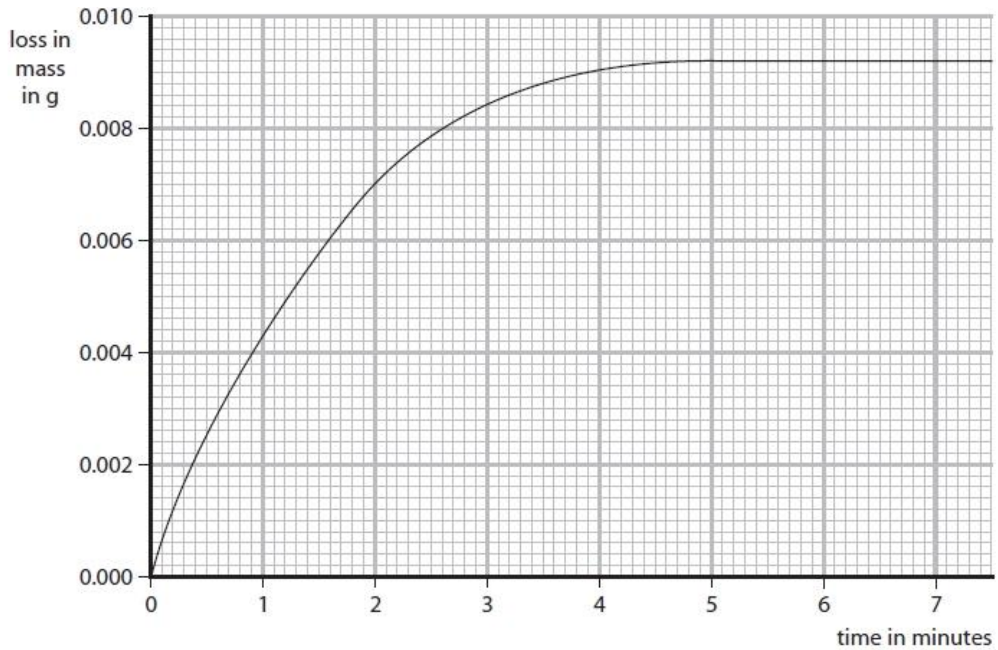

Figure 12

The experiment was repeated using the acid at a higher temperature.
All other conditions were kept the same.

State the effect of the higher temperature on the mass loss after two minutes.

(1)

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....

(Total for question = 1 mark)

Q27.

Calcium carbonate reacts with dilute hydrochloric acid to produce carbon dioxide gas.

The rate of reaction between calcium carbonate and dilute hydrochloric acid at room temperature was investigated.

(i) The investigation was carried out with different sized calcium carbonate pieces.

The mass of calcium carbonate and all other conditions were kept the same.
The results are shown in Figure 15.

size of calcium carbonate pieces used	volume of carbon dioxide gas produced in five minutes in cm^3
large	16
small	48
powder	90

Figure 15

State, using the information in Figure 15, the effect of the surface area of the calcium carbonate on the rate of this reaction.

(1)

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....

....

(ii) The calcium carbonate powder produced 90 cm^3 of carbon dioxide in five minutes.

Calculate the average rate of reaction in $cm^3\ s^{-1}$.

(3)

....

....

....

....

average rate of reaction = ... $cm^3\ s^{-1}$

(iii) The experiments were repeated at a higher temperature.

The rate of reaction for each experiment increased.
Explain, in terms of particles, why the rate of reaction increased when the temperature was increased.

(3)

....

....

....

....

....

(Total for question = 7 marks)

Q28.

Magnesium reacts with dilute sulfuric acid to form magnesium sulfate and hydrogen gas.

A student wants to find out the effect of temperature on the rate of this reaction.

The student used the following method.

step 1 pour 25 cm^3 of dilute sulfuric acid into a conical flask
step 2 warm the acid until its temperature is 30 °C
step 3 add a piece of magnesium to the acid
step 4 start a stopwatch
step 5 wait until the reaction has finished
step 6 stop the stopwatch
step 7 repeat steps 1–6 but at 50 °C.

The student kept the volume of sulfuric acid the same when they repeated the method at 50 °C.

State two other variables that should be kept the same.

(2)

1 ....

2 ....

(Total for question = 2 marks)

Q29.

Hydrogen peroxide decomposes to form water and oxygen.

The rate of this reaction can be found by measuring the volume of oxygen formed after different time intervals.

Hydrogen peroxide solution is placed in a conical flask.
The apparatus is set up as shown in Figure 5.

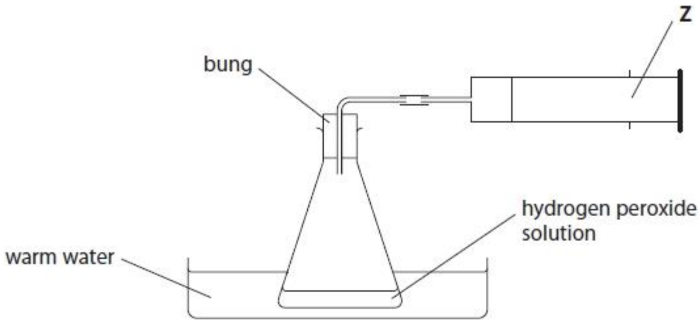


Figure 5

A solid catalyst can be used for this reaction.

(i) The experiment is repeated under identical conditions but with the catalyst added.

(1)

In the experiment **with** the catalyst added

- ☐ **A** the rate of reaction is the same as when no catalyst is present
- ☐ **B** water and oxygen are the only products of the reaction
- ☐ **C** some of the catalyst is used up
- ☐ **D** the volume of oxygen produced when all the hydrogen peroxide is decomposed is larger than when no catalyst is present

(ii) At the end of the experiment with the catalyst added, the mass of the catalyst remaining is found.

The method used to find the mass of the catalyst remaining is
filter the mixture of products and catalyst
determine the mass of the filter paper and solid catalyst
subtract the mass of a filter paper from the mass of filter paper and solid catalyst.
This method would not give the accurate mass of catalyst remaining.
Which of the following needs to be done to give a more accurate mass?

(1)

- ☐ **A** dry the filter paper and catalyst before finding their mass
- ☐ **B** scrape the catalyst off the filter paper and find the mass of the catalyst
- ☐ **C** find the mass of the filtrate and not the filter paper and catalyst
- ☐ **D** repeat the experiment

(iii) A given mass of catalyst is more effective if it has a large surface area.

State how you could increase the surface area of some lumps of solid catalyst.

(1)

....

(Total for question = 3 marks)

Mark Scheme

Q1.

Question Number	Indicative content	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlines in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. • reactions occur when particle collisions have sufficient energy (activation energy) • reaction rates are increased when the energy collisions is increased • and / or the frequency of collisions is increased • two factors in the reaction have been changed (temperature and concentration of one of the reactants) • experiment 2 was carried out at a higher temperature than experiment 1 • concentrations of reactant are the same in experiment 1 and 2 • particles have more (kinetic energy), so move faster • so there are more frequent collisions between particles in solution **A** solution and solution **B** • collisions will also occur with greater energy • so more collisions will have the minimum activation energy to react when they collide • so greater frequency of successful collisions (so decreased reaction time/increased rate in experiment 2 compared to experiment 1) • experiment 3 was carried out at a higher concentration than experiment 2/ a fourfold increase • temperatures of the reactants are the same in experiment 2 and 3 • there are more reacting particles in the same volume of reaction mixture • so there are more frequent collisions between particles in solution **A** and solution **B** • so greater frequency of successful collisions (so decreased reaction time/increased rate in experiment 3 compared to experiment 2) • reaction rate in experiment 3 is greatest due to combined effects of increased temperature and increased concentration	**(6)** AO 2 2 AO 3 2a

Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1-2	• Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. Demonstrates limited synthesis of understanding. (AO3) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3-4	• Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5-6	• Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)

Q2.

Question number	Answer	Additional guidance	Mark
	$\frac{15.0}{60.0}$ (1) = 0.25 (1) ($cm^3\ s^{-1}$)	$\frac{60}{15}$ = 4 (1)	**(2)** **AO2**

Q3.

Question number	Answer	Additional guidance	Mark
	final answer of 0.3 with or without working scores 3 MP1 : conversion of time from minutes into seconds 5 x 60 = 300 (seconds) (1) MP2 : rate = volume / time rate = $\frac{90}{300}$ (1) MP3 : evaluation of the fraction = 0.3 ($cm^3\ s^{-1}$) (1)	allow 90/5 (1) 90/5 = 18 (2) 300/90 = 3.33 (2) 5/90 = 0.0556 (1)	**(3)**

Q4.

Question Number	Answer	Additional guidance	Mark
	• slower • slower • unchanged all 3 rows correct – 2 marks one or two rows correct – 1 mark	may indicate correct answer in any way e.g. by underlining do not credit a row if more than one answer is indicated in a row	**(2)** AO 1 1

Q5.

Question number	Answer	Mark
	B measuring cylinder **A, C** and **D** do not measure volumes	**(1)** **AO2**

Q6.

Question number	Answer	Mark
	diagram of • delivery tube with bung in flask connected to (1) • gas syringe / gas syringe labelled (1) or • delivery tube with bung in flask leading into water trough (below upturned measuring cylinder) (1) • upturned measuring cylinder containing water / measuring cylinder labelled (1) allow • connected delivery tube from flask to upturned test tube in water trough (1)	**(2)** **AO1**

Q7.

Question Number	Answer	Additional guidance	Mark
(i)	(gas) syringe / graduated tube / burette (instead of measuring cylinder)		**(1)** AO 3 3b

Question Number	Answer	Additional guidance	Mark
(ii)	final answer in range 0.44 – 0.52 inclusive with or without working (2) If answer not in range: $\frac{\text{difference in volume}}{\text{difference in time}} = \frac{(43 - 15)}{(60 - 0)}$ (1) = 0.47 / 0.467 (1)	allow ecf throughout where values are less than 1 (1 max) use of inverted gradient expression giving 2.27 – 1.92 scores 1 mark (evidence of working required)	**(2)** AO 2 1

Question Number	Answer	Additional guidance	Mark
(iii)	steeper **curve** to the left of printed curve and same final volume	line must not go above 40 cm^3 and curve back down	**(1)** AO 2 2

Q8.

Question number	Answer	Additional guidance	Mark
	A description including any two from: • {crush/ break} the large chips (1) • in pestle and mortar (1) • use sieves to separate different sized chips/ sort the chips by size (1)	ignore {cut / chop} them up ignore breaking down by cutting / chopping / tearing / heating etc allow any suitable <u>laboratory</u> apparatus/ tool e.g. hammer ignore domestic equipment e.g. scissors / rolling pin allow leave in acid (to reduce size) for MP2 but MP1 cannot score allow pick out the sizes you need allow repeat the method to get even smaller chips	**(2)** **AO1 2**

Q9.

Question number	Indicative content	Mark
	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. A plan to include some of the following points • measure equal masses of zinc using balance • measure equal volumes of acid using measuring cylinder/pipette/suitable named piece of apparatus • pour acid in suitable container • record initial temperature • use of thermometer • add zinc to acid • place bung with delivery tube in container / reaction vessel immediately after the zinc is added • use of timer • start timer on addition of zinc • measure volume of gas evolved using a delivery tube and inverted measuring cylinder/burette over water OR delivery tube and (gas) syringe • record time to collect fixed volume of gas • record final/highest temperature • calculate the temperature increase • repeat for procedure • same initial temperature • same size pieces of zinc • same volume of acid credit use a suitable labelled diagram of apparatus for rate measurement/ temperature of acid	**(6)**

Level	Mark	Additional Guidance	General additional guidance – the decision within levels Eg - At each level, as well as content, the scientific coherency of what is stated backed up by planning detail will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance Identifies relevant practical operations such as • carries out basic reaction – add zinc to acid • measures at least one of mass, time, volume, temperature	Possible candidate responses • put zinc in test tube and add some acid • find the mass of zinc • measure volume of the acid • carries out basic reaction or measures at least one factor with details scores upper part of level
Level 2	3–4	Additional guidance Some correct sequencing of correct operations • carries out basic reaction with dilute acid and repeat with the more concentrated acid and • carries out reaction makes some relevant observation or obtains a result or • measures at least two of mass, time, volume, temperature	Possible candidate responses • put zinc in test tube, add acid and time the reaction • put zinc in test tube, add dilute acid, then repeat experiment and add more concentrated acid • measures mass of zinc and measures volume of acid before adding together • measures temperature of acid before adding to zinc and measures temperature at end of reaction • a similar description, but with detail of apparatus scores the upper part of the level
Level 3	5–6	Additional guidance Sequence of operations of an experiment to include two from • measures temperature and volume of acid, and mass of zinc • repeats expt but with more concentrated acid • measure temperature of reaction mixture at end and finds temperature rise	Possible candidate responses • record temperature of 25 cm^3 dilute acid, add to known mass of zinc, record temperature after reaction • using suitable apparatus measure volume of gas every minute • repeat experiment using same conditions but using the more concentrated acid • work out temperature rises for both reactions • descriptions with detail or workable method scores upper part of level

Q10.

Question number	Answer		Mark
	An explanation linking two from • catalyst particles have much larger surface area (when made from nanoparticles) (1) • leads to increased reaction rate (1)		**(2)** **AO1**

Q11.

Question number	Indicative content	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1 (3 marks) AO3 (3 marks)** • less gas produced with large lumps in same amount of time • therefore, reaction slower ORA • larger lumps have smaller surface area ORA • fewer particles available for reaction • fewer collisions in given time • more gas produced at higher concentration in all experiments • higher concentration there are more particles in same volume • more particles available to react • more frequent collisions • most gas produced in same time with small lumps and highest concentration ORA • therefore, fastest reaction is with small lumps and highest concentration ORA	**(6)**

Level	Mark	Additional Guidance	General additional guidance – the decision within levels Eg - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance One statement (1) Two unlinked statements (2) One simple explanation (2)	Possible candidate responses less gas produced with large lumps (1) more gas produced with higher concentration of acid (1) smaller lumps have larger surface area (1) large lumps produced less gas and higher concentration produced more gas (2) the rate of reaction is higher with smaller lumps because they have a larger surface area (2) more gas at a higher concentration because there are more acid particles (2)
Level 2	3–4	Additional guidance Two simple explanations (4) One full explanation including reference to particles and frequency of collisions for either surface area OR concentration (4)	Possible candidate responses less gas with large lumps, reaction is slower due to smaller surface area. more gas at higher concentrations due to more particles (4) more gas at higher concentrations due to more particles having more frequent collisions (4) more gas at higher concentrations due to more particles having more collisions (3) Less gas with large lumps, reaction is slower due to smaller surface area as fewer particles fewer collisions in given time (4) with large lumps, reaction is slower as lower surface area fewer collisions in a given time (4)
Level 3	5–6	Additional guidance One full explanation including reference to particles frequency of collisions AND one simple explanation. The volume of gas must be referred to in at least one part of the answer. (6)	Possible candidate responses Less gas with large lumps, the reaction is slower due to smaller surface area. Fewer particles are available for reaction and fewer collisions in a given time. Whereas more gas is produced with a higher concentration as there are more particles (6) There is more gas produced at higher concentration because at a higher concentration there are more particles, this means that more particles available to react so there are more frequent collisions. Whereas less gas is produced with large lumps because they have a smaller surface area. (6) with large lumps the reaction is slower so less gas is produced because they have a smaller surface area so there are fewer particles available for reaction and fewer collisions. Whereas there is higher rate with a higher concentration as there are more particles in the same volume of solution (5)

Q12.

Question number	Answer	Additional Guidance	Mark
(i)	An explanation to include • a solid/ precipitate **(1)** • of sulfur **(1)**		**(2)**

Question number	Answer	Additional Guidance	Mark
(ii)	A description to include • flask placed {over/in front of} cross **(1)** • measure time **(1)** • when cross is obscured **(1)**	MP2 dependent on MP1 allow measure how long reaction takes for MP2	**(3)**

Question number	Answer	Mark
(iii)	**B** 150 cm^3 is the only correct answer. **A** is incorrect because this makes 16.7 g dm^{-3} HCl **C** is incorrect because this makes 25.0 g dm^{-3} HCl **D** is incorrect because this makes 33.3 g dm^{-3} HCl	**(1)**

Q13.

Question number	Answer	Additional guidance	Mark
	An explanation linking • MP1 : fewer reacting particles left / some particles reacted (1) • MP2: fewer collisions (1) • MP3: (fewer) frequent (collisions) (1)	for full marks, reference needs to be made to **particles** in answer allow more particles at the start (than at the end) allow less magnesium / less reactants (1) allow 'less' ignore particle speed allow (fewer collisions) per {second / unit time} (less/fewer) frequent collisions scores MP2 and MP3	**(3)**

Q14.

Question number	Answer	Additional guidance	Mark
(i)	An explanation linking • more particles present (in same volume) (1) • so more frequent collisions/ more chance of collision (1)	allow atoms/ molecules/ ions for particles ignore more acid present allow more collisions per {sec/min/unit time} ignore more collisions/ more successful collisions ignore references to energy / moving faster mark independently	**(2)** **AO1 1**

Question number	Answer	Mark
(ii)	**D** use the same metal but in a powdered form is the only correct answer **B** and **C** are incorrect because the reactants are not changed **A** is incorrect because the reaction will be slower	**(1)** **AO2 1**

Q15.

Question number	Answer	Additional guidance	Mark
	An explanation linking • {hydrogen / gas} formed / OWTTE (1) • escapes (from the flask) (1)	allow released (from the flask) ignore references to magnesium reacting	**(2)**

Q16.

Question number	Answer	Additional guidance	Mark
	An explanation linking three of the following		**(3)**
	• particles have more energy (1)	Allow more kinetic energy for MP1 and MP2	
	• so (particles) move faster (1)	needs to be comparative	
	• (so) there are more frequent collisions between particles (1)	allow greater chance of collision	
	• higher proportion of collisions have at least the activation energy to react when particles collide (1)	allow higher {proportion / chance} of collisions are successful / productive allow more particles have activation energy	

Q17.

Question number	Answer	Additional guidance	Mark
	(particles) have more energy / (particles) collide more frequently / more successful collisions	allow particles move faster	**(1)** **AO1**

Q18.

Question number	Answer	Additional guidance	Mark
	conical flask in water bath [could be shown on diagram]	Reject heat with a Bunsen burner warm water alone is not enough.	**(1)** **AO3**

Question number	Answer	Mark
(ii)	Using tangent drawn on graph eg <u>vertical difference</u> (1) <u>(100 − 52)</u> horizontal difference (1) 180 (= 0.267) ($cm^3\ s^{-1}$) calculation will depend on final graph 2 marks for rate being within a range eg 0.250 – 0.290 1 mark for rate being in range 0.230 – 0.249 or 0.291 – 0.310	**(2)** **AO3**

Question number	Answer	Additional guidance	Mark
(iii)	particle size / concentration of acid / volume of acid / mass of calcium carbonate	allow marble chips for calcium carbonate allow amount of calcium carbonate ignore size of container	**(1)** **AO1**

Question number	Answer	Mark
(iv)	An explanation linking • fewer successful collisions (between acid and calcium carbonate particles) / fewer collisions with activation energy (1) and any two from • (because) decreasing temperature (of the acid) particles have lower energy (1) • (because) the particles move slower (1) • (so) rate of reaction decreases (1)	**(3)** **AO1**

Q19.

Question Number	Answer	Mark
	(gas) syringe	**(1)** AO 1 2

Q20.

Question number	Answer	Additional guidance	Mark
	Any suitable container for measuring volume of 100 cm^3 eg measuring cylinder	allow burette / pipette ignore beaker, conical flask, measuring jug	**(1)**

Q21.

Question number	Answer	Additional Guidance	Mark
(i)	• **100 cm^3** measuring cylinder/ (gas) syringe (1) • which has smaller gradations / higher resolution (1)	allow 'smaller measuring cylinder' ignore gas measurer reject (upturned) burette for MP1 MP2 is dependent on MP1 allow (more) precise / (more) accurate allow smaller measurements/ increments ignore easier to use / no gas will escape	**(2)** **AO3 3b**

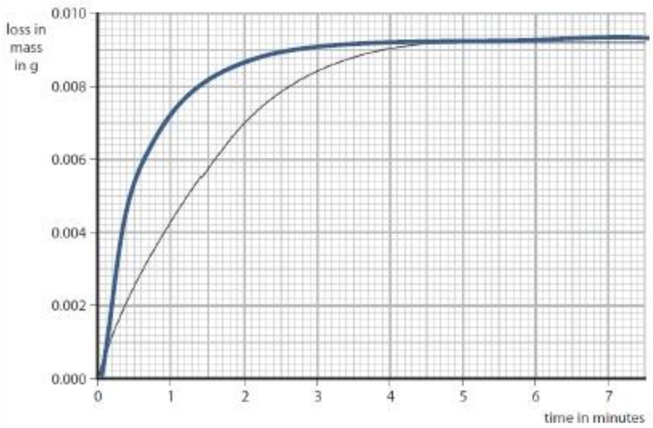
Question number	Answer	Additional guidance	Mark
(ii)	• volume read at 90s = 29 cm^3 (1) • rate = <u>volume</u> (1) / 90 • = 0.3222.... (cm^3 per second) (1)	0.31, 0.32, 0.33 with or without working scores 3 all other answers require working to have marks awarded 0.3 **alone** scores 0 allow any value 28-30 ECF for incorrect volume ECF if fraction inverted ECF if 1.5 used instead of 90 eg <u>28/29/30</u> = 18.66.../ 19.33.../ 20 scores 2 1.5 MP3 must be decimal value correctly rounded – ignore fractions	**(3)** **AO3 2**

Question number	Answer	Additional guidance	Mark
(iii)	volumes were {constant / stopped rising} OR graph was {flat/plateaued/ levelled off}	allow reactant(s) used up / limiting factor allow no more hydrogen evolved allow EVIDENCE that reaction stopped: measurements stayed the same/ no more bubbles allow graph has reached zero gradient ignore graph is a straight line ignore it has reached the highest {point / volume} ignore reaction has stopped / is complete reject reaction is becoming slower	**(1)** **AO3 2**

Q22.

Question number	Answer	Additional guidance	Mark
	delivery tube, not in liquid, connected to flask sealed with a bung/cork (1) gas syringe / measuring cylinder or burette inverted over water (1)	do not allow a single line for a delivery tube allow sealed cross sections (e.g. delivery tube going through solid bung) labels and graduations not required mark independently	**(2)**

Q23.

Question number	Answer	Additional guidance	Mark
	 (2)	line drawn with steeper gradient to left of line (1) levelling off at the same height as the existing line (1)	**(2)**

Q24.

Question number	Answer	Mark
	magnesium has gone / no more bubbles	**(1)** **AO2**

Q25.

Question number	Answer	Additional guidance	Mark
(i)	makes it faster / increases rate / lowers activation energy	accept speeds it up / increases collision rate allow shorter reaction time / alternative reaction pathway / it could be carried out at a lower temperature ignore other aspects of catalysis eg is not used up ignore 'slows down the activation energy' ignore speeds up reaction time	(1)
(ii)	Any three experimental points to include MP1 : use known mass of catalyst in a reaction / find mass of catalyst before reaction (1) MP2 : after reaction {remove / filter}, wash & dry (1) MP3 : find mass of catalyst afterwards / mass of catalyst unchanged (1)	calculate difference in final and initial masses	(3)

Q26.

Question number	Answer	Additional guidance	Mark
	(mass loss will be) greater (1)	Allow more gas Ignore references to reaction rate	(1)

Q27.

Question number	Answer	Additional guidance	Mark
(i)	larger **surface area** {higher /faster} rate /ORA	answer must be comparative	(1)

Question number	Answer	Additional guidance	Mark
(ii)	final answer of 0.3 with or without working scores 3 MP1 : conversion of time from minutes into seconds 5 x 60 = 300 (seconds) (1) MP2 : rate = volume / time rate = $\frac{90}{300}$ (1) MP3 : evaluation of the fraction = 0.3 ($cm^3 s^{-1}$) (1)	allow 90/5 (1) 90/5 = 18 (2) 300/90 = 3.33 (2) 5/90 = 0.0556 (1)	(3)

Question number	Answer	Additional guidance	Mark
(iii)	An explanation linking three of the following • particles have more energy (1) • so (particles) move faster (1) • (so) there are more frequent collisions between particles (1) • higher proportion of collisions have at least the activation energy to react when particles collide (1)	Allow more kinetic energy for MP1 and MP2 needs to be comparative allow greater chance of collision allow higher {proportion / chance} of collisions are successful / productive allow more particles have activation energy	(3)

Q28.

Question number	Answer	Mark
	any two from: concentration of acid (1) {size / shape / surface area / length} area of magnesium ribbon (1) mass of magnesium (1)	(2) AO2

Q29.

Question Number	Answer	Mark
(i)	B water and oxygen are the only products of the reaction **The only correct answer is B** ***A** is not correct because rate increases* ***C** is not correct because catalysts do not get used up* ***D** is not correct because amount of product is unaltered by catalyst*	**(1)** AO 1 1

Question Number	Answer	Mark
(ii)	**A** dry the filter paper and catalyst before finding their mass **The only correct answer is A** ***B** this does not remove the water* ***C** dry residue is needed, not filtrate* ***D** water would still be present*	**(1)** AO 3 3a

Question Number	Answer	Additional guidance	Mark
(iii)	powder / cut up / break up / use smaller pieces	ignore reference to surface area/ squash / flatten	**(1)** AO 1 2