Write your name, centre number and candidate number in the boxes below.

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

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Rate of reaction graphs

Time allowed: 1 hour 30 minutes

Subject code **0620**

Chemistry

Questions from Paper 3, Paper 4 and Paper 6

You must have: a ruler marked in centimetres and millimetres, a protractor, compasses, a pen, an HB pencil and an eraser.

Total marks

/ 85

Instructions

- Answer every question in the space provided on this paper.
- Write in black or dark blue ink. Pencil may be used for diagrams and graphs.
- Fill in your name, centre number and candidate number above.
- Show your working: a correct method can earn marks even if the answer is wrong.

Information

- This paper has 10 questions worth 85 marks in total.
- The marks for each question or part are shown in brackets, for example [3].

Advice

- Read every question through once before you write anything.
- Use the marks in brackets to judge how long to spend on each part.
- If you finish early, go back and check your working.

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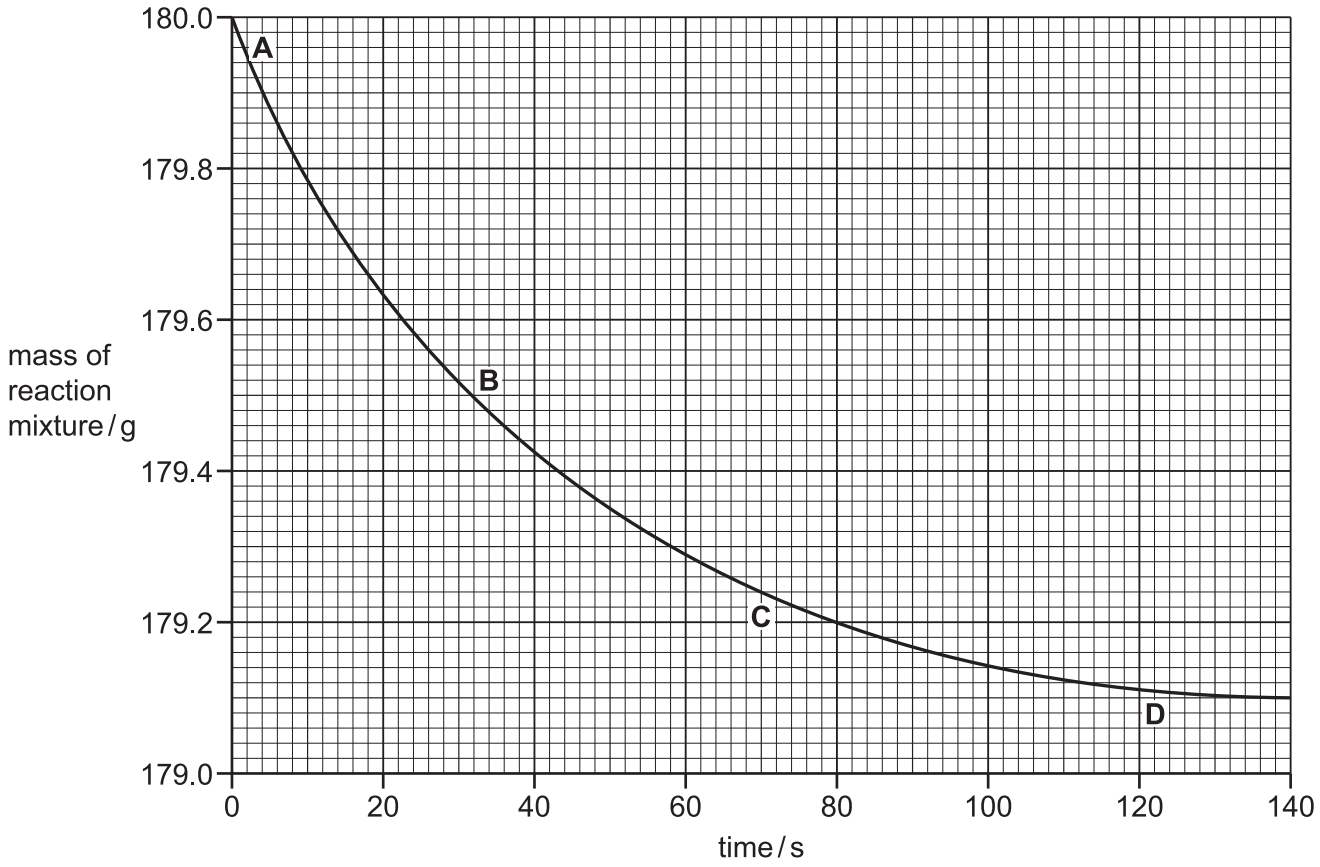
Print at 100% (Actual size) so diagrams keep their real measurements.

1 A student investigated the reaction of magnesium carbonate with an excess of dilute hydrochloric acid.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$$

The rate of reaction can be found by measuring the decrease in the mass of the reaction mixture over time.

The results are shown on the graph.



(a) Determine the mass of the reaction mixture after 58 seconds.

..... [1]

(b) At which point on the graph, **A**, **B**, **C** or **D**, was the rate of reaction the fastest? Use the graph to explain your answer.

.....

..... [2]

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(c) When 0.42 g of magnesium carbonate is used, 120 cm^3 of carbon dioxide is formed.

Determine the volume of carbon dioxide produced when 1.26 g of magnesium carbonate reacts completely.

volume of carbon dioxide = ... cm^3 [1]

(d) What effect do the following have on the rate of this reaction?

- Decreasing the concentration of the acid.
  All other conditions are kept the same.

.....

- Using smaller pieces of magnesium carbonate.
  All other conditions are kept the same.

.....
[2]

[Total: 6]

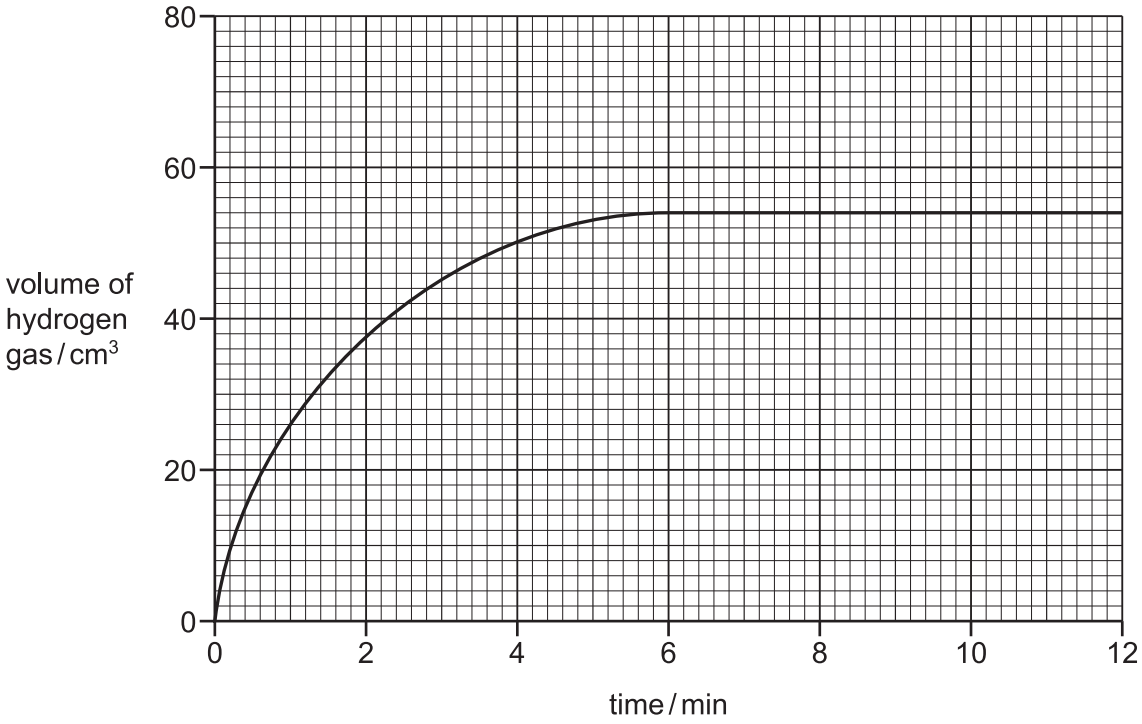
Rates of reaction Click for more variations

Reduced to 74% to fit the page (wider than A4).

1(a)	179.3 (g)	**1**
1(b)	A (1) the gradient / slope is the steep(est) (1)	**2**
1(c)	360 (cm^3)	**1**
1(d)	decreases rate / reaction slower (1) increases rate / reaction faster (1)	**2**

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2 When zinc reacts with hydrochloric acid, hydrogen gas is produced.
The graph shows how the volume of hydrogen gas produced changes with time when an excess of zinc is reacted with 0.2 mol / dm^3 hydrochloric acid.



(a) Explain why the volume of hydrogen gas remains constant after six minutes.

..... [1]

(b) What volume of hydrogen gas was released in the first **two** minutes of the reaction?

..... [1]

(c) The experiment is repeated using the same volume of 0.1 mol / dm^3 hydrochloric acid.
All other conditions are kept the same.

On the grid, draw the graph for the experiment using 0.1 mol / dm^3 hydrochloric acid. [2]

(d) Give the name of the salt formed when zinc reacts with hydrochloric acid.

..... [1]

(e) Which **one** of the following pH values could be the pH of dilute hydrochloric acid?
Draw a circle around the correct answer.

pH 1 pH 7 pH 9 pH 13 [1]

[Total: 6]

Rates of reaction Click for more variations

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2(a)	the reaction is complete / the reaction has finished	**1**
2(b)	any value between and including 37 (cm^3) to 38 (cm^3)	**1**

2(c)	line starts from 0 cm^3 **AND** initial gradient less steep	**1**
	final volume levels off between 24–30 cm^3 **OR** line below 27 cm^3 **AND** gradient becoming less steep at a later point	**1**
2(d)	zinc chloride	**1**
2(e)	pH 1	**1**

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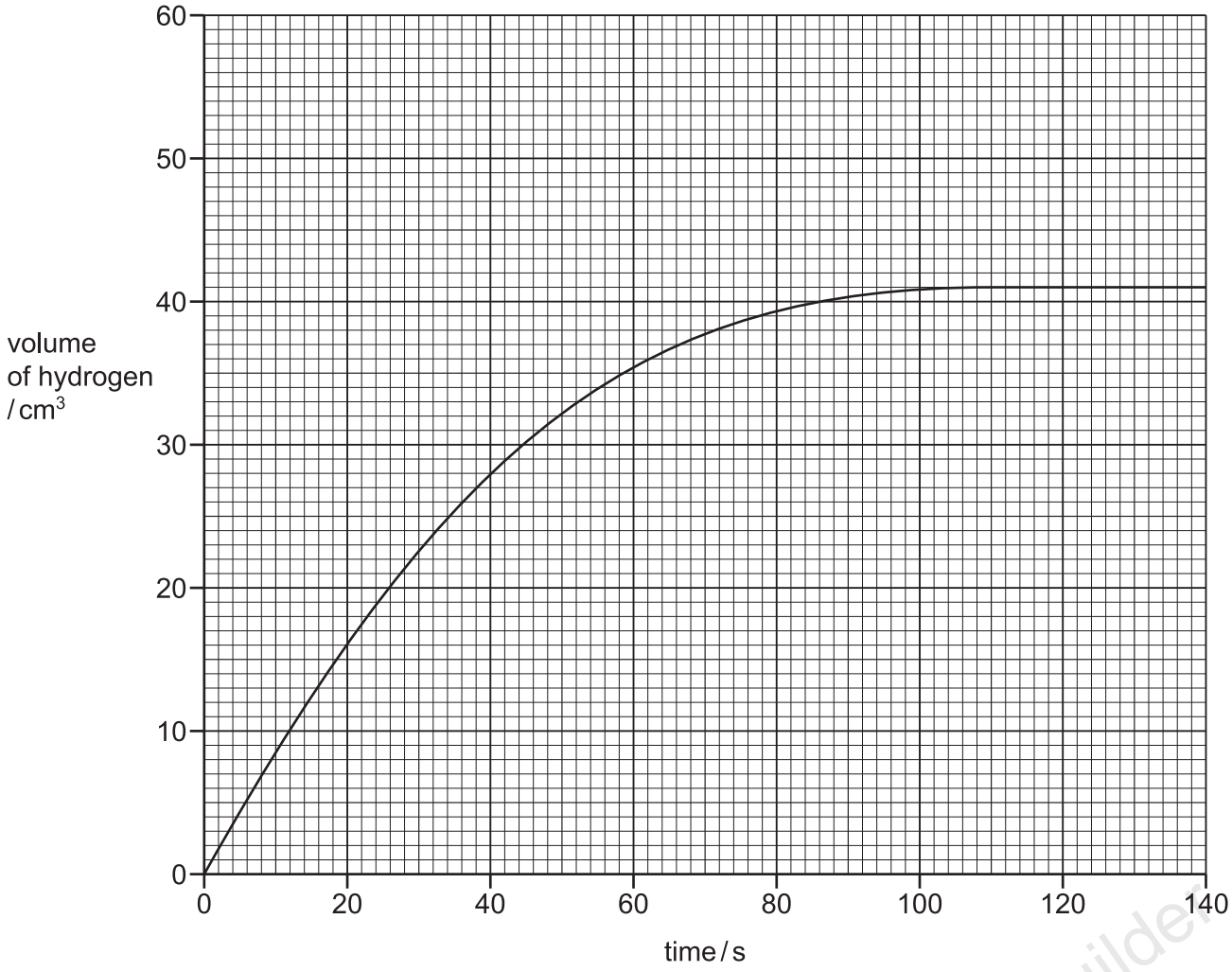
3 A student investigates the rate of reaction of magnesium ribbon with an excess of dilute hydrochloric acid.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

(a) Name the salt formed when magnesium reacts with dilute hydrochloric acid.

..... [1]

(b) The graph shows how the volume of hydrogen produced changes with time.



(i) Describe how the rate of reaction changes with time.
Use the graph to explain your answer.

.....

.....

..... [2]

(ii) How many seconds did it take to collect the first 25 cm^3 of hydrogen?

..... s [1]

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(iii) The experiment is repeated at a higher temperature.
All other conditions are kept the same.

Draw a line **on the grid** for the experiment using a higher temperature. [2]

(iv) If 2.4 g of magnesium is used, 0.2 g of hydrogen is produced.

Calculate the mass of magnesium needed to produce 0.8 g of hydrogen using an excess of dilute hydrochloric acid.

mass of magnesium = ... g [1]

[Total: 7]

Rates of reaction Click for more variations

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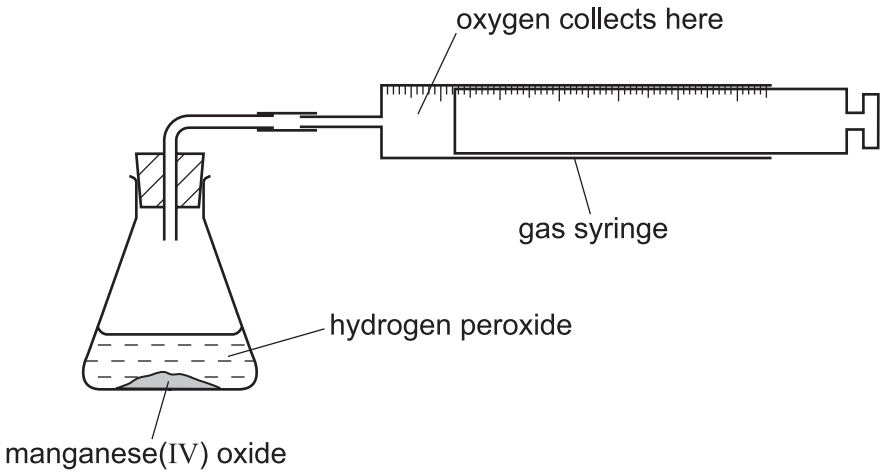
3(a)	magnesium chloride	**1**
3(b)(i)	decreases as reaction proceeds (1) gradient of graph decreases as time increases / gradient of graph is steep at first and less steep later (1)	**2**
3(b)(ii)	34 s	**1**
3(b)(iii)	line steeper than original and starting from 0 (1) line ends up at same final volume **AND** levels off at or before 100 s (1)	**2**
3(b)(iv)	9.6 (g)	**1**

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4 Hydrogen peroxide decomposes slowly at room temperature to form water and oxygen. The reaction is catalysed by manganese(IV) oxide.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

A student used the apparatus shown below to study how changing the concentration of hydrogen peroxide affects the speed of this reaction.



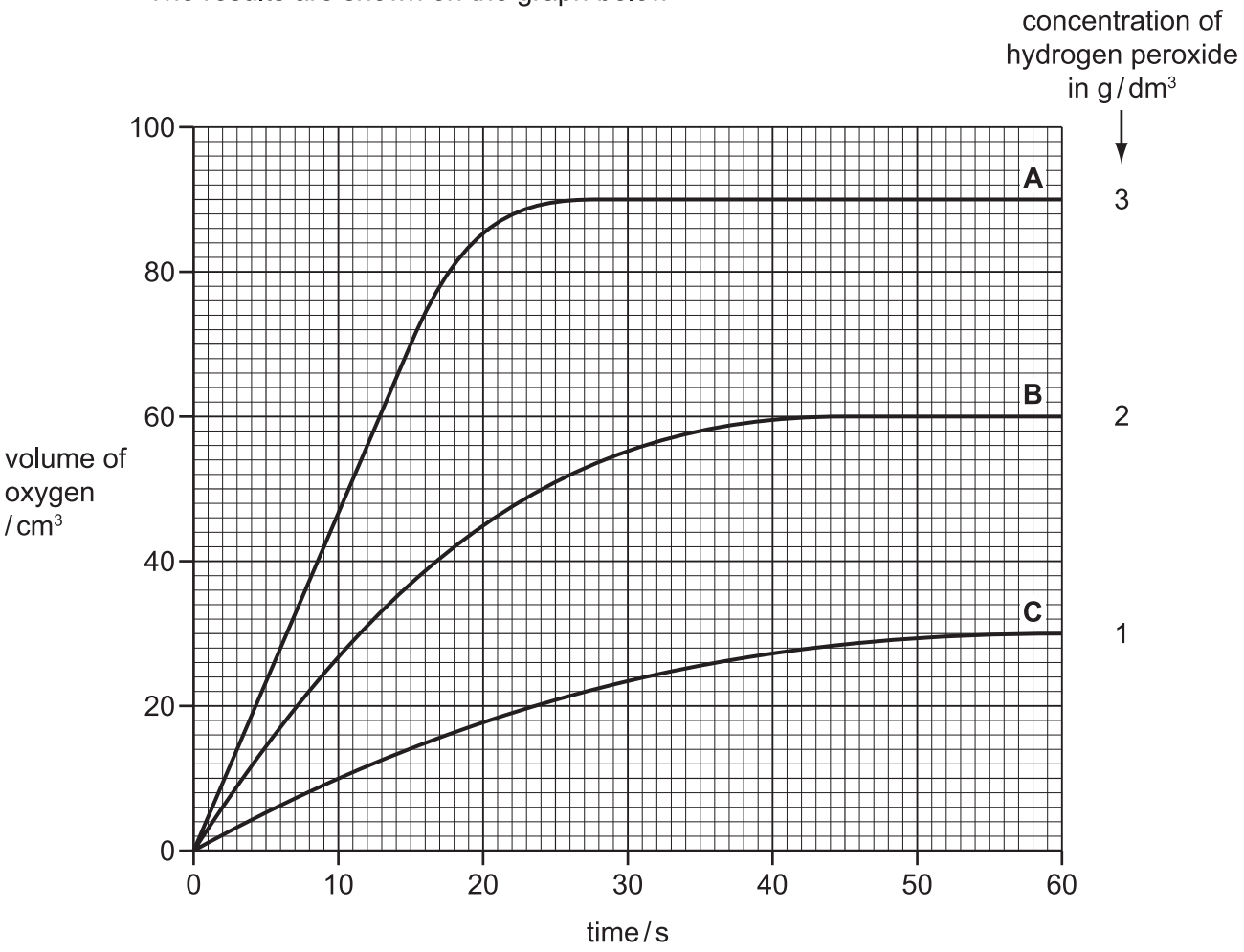
(a) Apart from the volume of hydrogen peroxide, state two things that the student must keep the same in each experiment.

1. .....

2. ..... [2]

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(b) The student measured the volume of oxygen produced using three different concentrations of hydrogen peroxide.
The results are shown on the graph below.



(i) Describe how the speed of the reaction varies with the concentration of hydrogen peroxide.

..... [1]

(ii) Explain why the final volume of oxygen given off is less for graph **B** than for graph **A**.

.....

..... [1]

(iii) From the graph, determine

the time taken for the reaction to be completed when 3 g / dm^3 hydrogen peroxide (line **A**) was used.

..... [1]

the volume of oxygen produced by 2 g / dm^3 hydrogen peroxide (line **B**) in the first 15 seconds.

..... [1]

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(c) The student then tested various compounds to see how well they catalysed the reaction. He used the same concentration of hydrogen peroxide in each experiment.
The table shows the time taken to produce 20 cm^3 of oxygen using each compound as a catalyst.

compound	time taken to produce 20 cm^3 of oxygen / s
copper(II) oxide	130
lead(IV) oxide	15
magnesium oxide	did not produce any oxygen
manganese(IV) oxide	18

Put these compounds in order of their effectiveness as catalysts.

worst catalyst ⟶ best catalyst

[1]

[Total: 7]

Rates of reaction Click for more variations

4 **(a)** Any two of: [2]
temperature
mass / amount of manganese(IV) oxide / volume of manganese(IV) oxide
size of manganese dioxide particles
allow: pressure
ignore: concentration

(b) **(i)** the greater the concentration the greater the speed / rate increases with concentration [1]
ignore: concentration increases speed / more oxygen the grater the concentration

(ii) less hydrogen peroxide present (in B) / more hydrogen peroxide (in A) [1]
allow: hydrogen peroxide less concentrated (in B)

(iii) time taken → 27 (s) [1]
allow: 26 (s)
volume → 37 (cm^3) [1]

(c) magnesium → copper → manganese → lead [1]
ignore: oxide / oxidation numbers

[Total: 7]

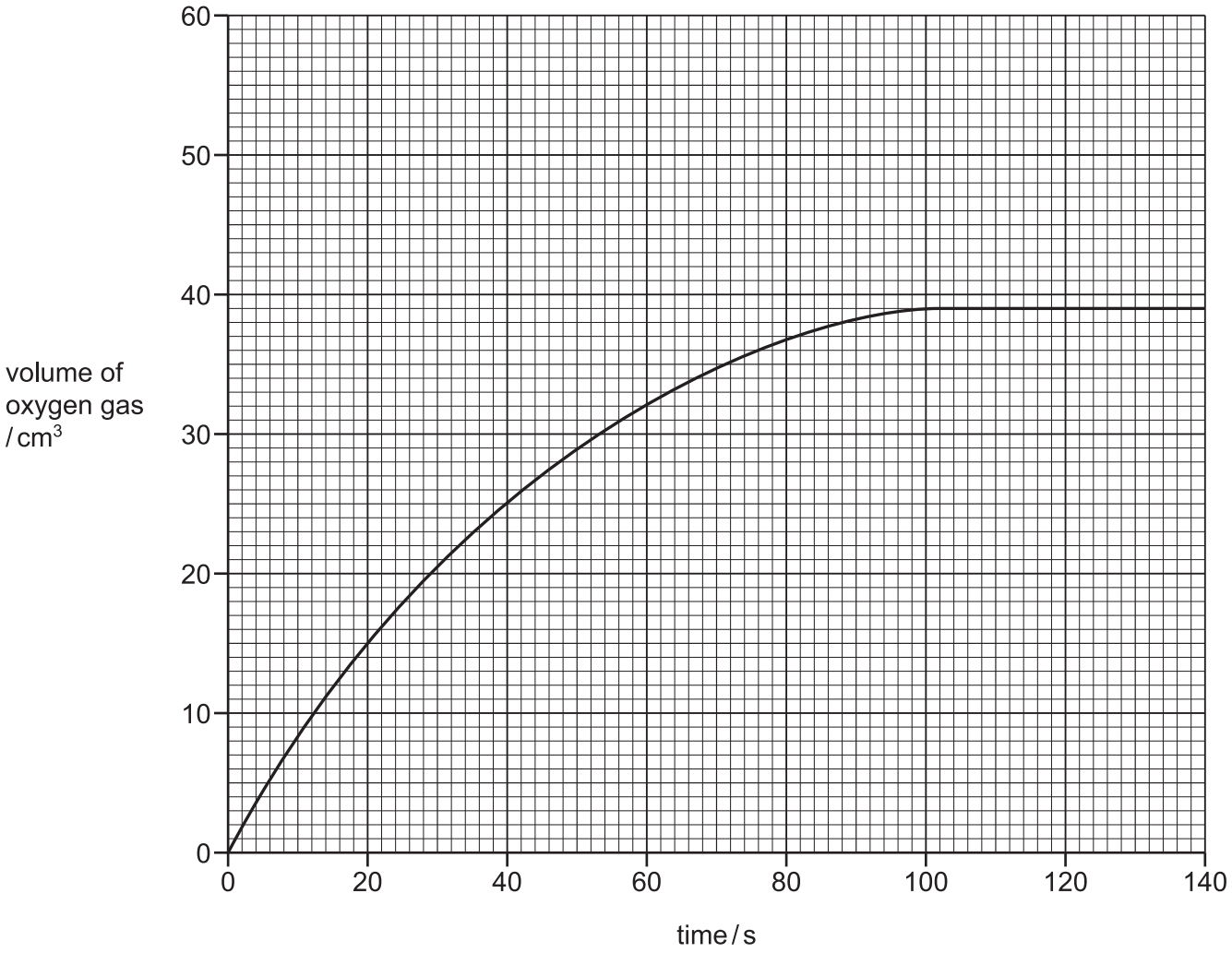
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5 The rate of decomposition of aqueous hydrogen peroxide, H_2O_2, is increased by an enzyme.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

The rate of reaction is found by measuring the volume of oxygen gas given off as the reaction proceeds.

The results are shown on the graph.



(a) (i) Deduce the volume of oxygen gas released when the reaction is complete.

volume = ... cm^3 [1]

(ii) Deduce the volume of oxygen gas produced 50 seconds from the start of the reaction.

volume = ... cm^3 [1]

(b) The experiment was repeated using hydrogen peroxide of a higher concentration.

All other conditions stayed the same.

Draw a line **on the grid** to show how the volume of oxygen changes with time when hydrogen peroxide of a higher concentration is used. [2]

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(c) Describe the effect each of the following has on the rate of decomposition of hydrogen peroxide.

- The reaction is carried out at a lower temperature.

All other conditions stay the same.

.....

- The reaction is carried out without an enzyme.

All other conditions stay the same.

.....

[2]

(d) Some metal oxides catalyse the decomposition of hydrogen peroxide.

The table shows the time taken to produce 20 cm^3 of oxygen gas using three different metal oxide powders as catalysts.

All other conditions stay the same.

metal oxide	time taken to produce 20 cm^3 of oxygen gas / s
iron(III) oxide	26
lead(IV) oxide	12
manganese(IV) oxide	15

(i) Put the three oxides in order of their ability to catalyse the reaction.
Put the **best** catalyst first.

best catalyst ⟶ worst catalyst

[1]

(ii) The experiments with the metal oxide catalysts used powdered oxide.

Describe the effect on the rate of decomposition of hydrogen peroxide when large pieces of catalyst are used instead of powdered catalyst.

All other conditions stay the same.

..... [1]

[Total: 8]

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Rates of reaction Click for more variations

5(a)(i)	39 (cm^3)	**1**
5(a)(ii)	29 (cm^3)	**1**

5(b)	steeper initial gradient starting at 0-0 point (1) final volume of oxygen higher than 39 cm^3 (1)	**2**
5(c)	(rate) decreases / slower (1) (rate) decreases / slower (1)	**2**
5(d)(i)	lead(IV) oxide > manganese(IV) oxide > iron(III) oxide	**1**
5(d)(ii)	decreased / slower (rate with larger pieces)	**1**

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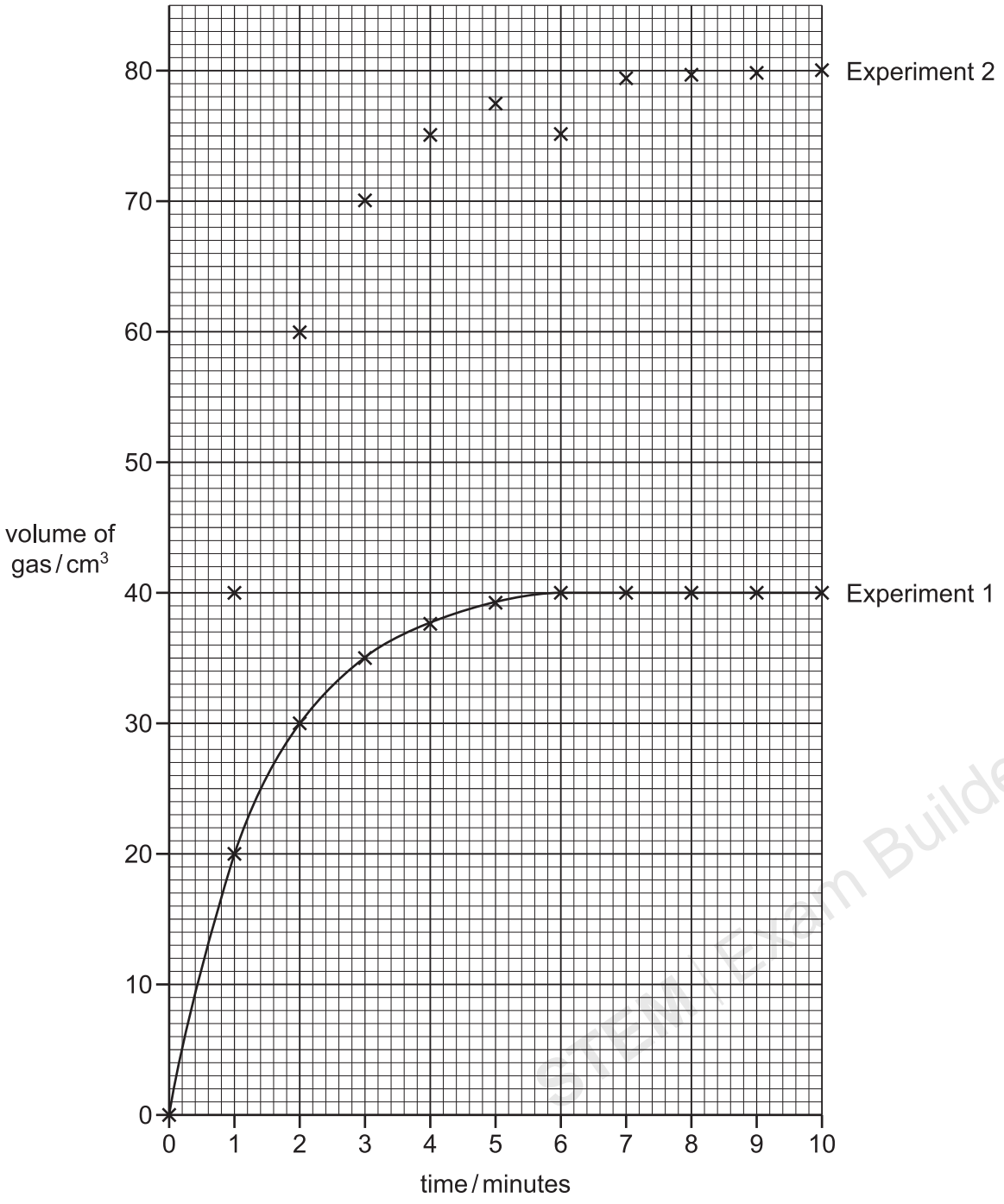
6 Two experiments were carried out to show what factors affect the rate of decomposition of hydrogen peroxide, H_2O_2.
In each experiment the volume of gas produced was measured every minute for ten minutes.

Experiment 1

The student used a mixture of 50 cm^3 of hydrogen peroxide, 50 cm^3 of water and 1 g of manganese(IV) oxide at a room temperature of 20 °C.
The results were plotted to obtain the graph shown.

Experiment 2

The student repeated Experiment 1 but did not record how much of each substance was used. The points were plotted on the grid.



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(a) Complete the graph for Experiment 2. [1]

(b) Suggest the composition of the mixture used in Experiment 2. Explain your suggestion.

composition .....

.....

explanation .....

..... [4]

(c) What is the function of the manganese(IV) oxide?

..... [1]

(d) Sketch on the grid the curve that you would expect if Experiment 1 was repeated at 10 °C. [2]

[Total: 8]

Rates of reaction Click for more variations

6 **(a)** smooth curve missing anomalous point (1) [1]

(b) **composition of mixture**
double volume / 100 cm^3 of hydrogen peroxide (1)
more than 1 g of manganese(IV) oxide / powdered (1) [2]
ignore: references to water
note: double the concentration is valid for (2)

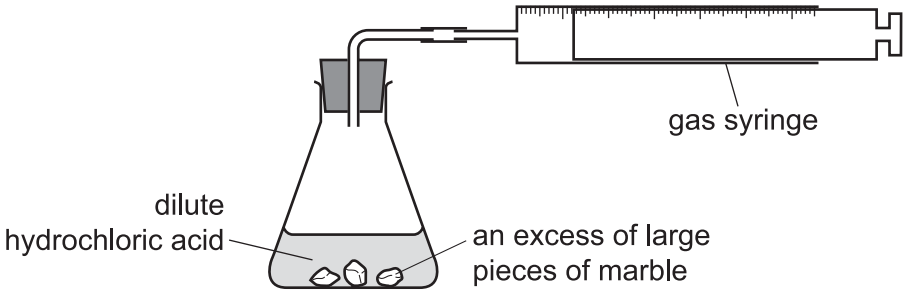
explanation
double volume of gas (1)
faster reaction (1) [2]

(c) catalyst / increase the rate of the reaction (1) [1]

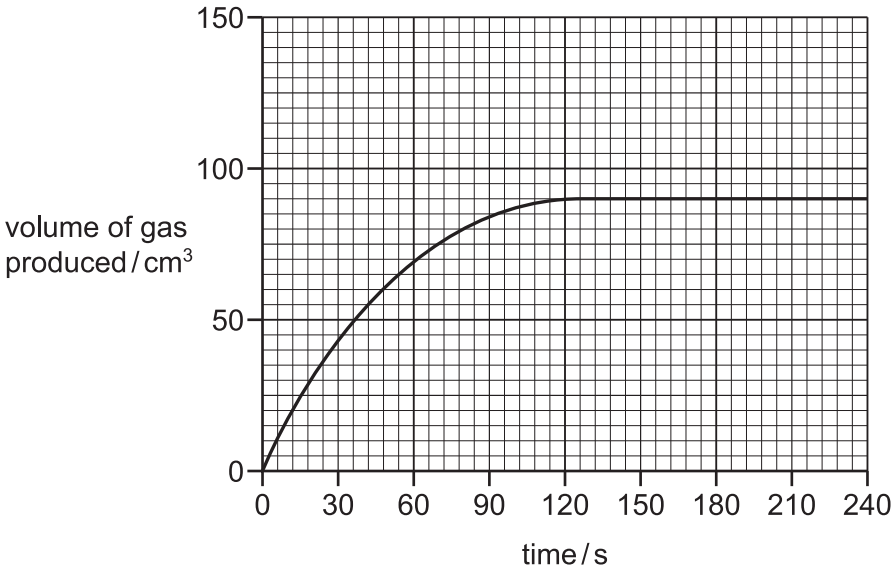
(d) sketch graph less steep than original for Experiment 1 (1)
to same level (1) [2]

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7 A student investigated the progress of the reaction between dilute hydrochloric acid, HC*l*, and an excess of large pieces of marble, $CaCO_3$, using the apparatus shown.



(a) A graph of the volume of gas produced against time is shown.



(i) How does the shape of the graph show that the rate of reaction decreased as the reaction progressed?

.....

..... [1]

(ii) Why did the rate of reaction decrease as the reaction progressed?

..... [1]

(iii) After how many seconds did the reaction finish?

..... s [1]

(b) The experiment was repeated using the same mass of smaller pieces of marble. All other conditions were kept the same.

Draw a graph **on the grid** to show the progress of the reaction using the smaller pieces of marble. [2]

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(c) The original experiment was repeated at a higher temperature. All other conditions were kept the same.

Describe and explain, in terms of collisions between particles, the effect of using a higher temperature on the time taken for the reaction to finish.

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 10]

Rates of reaction Click for more variations

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7(a)(i)	Gradient gets less	**1**
7(a)(ii)	Concentration of HCl is decreasing	**1**
7(a)(iii)	120 seconds	**1**
7(b)	M1 New line steeper than printed line and starts at origin M2 New line reaches same final volume as printed line	**2**
7(c)	M1 **Time** taken is less M2 (particles) have more energy M3 (particles) move faster M4 More collisions (of particles) occur per second / per unit time M5 More (of the) particles / collisions have energy greater than activation energy **or** More (of the) particles / collisions have sufficient energy to react **or** A greater percentage / proportion / fraction of collisions (of particles) are successful	**5**

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8 A student investigates the decomposition of hydrogen peroxide in the presence of a catalyst of manganese(IV) oxide.

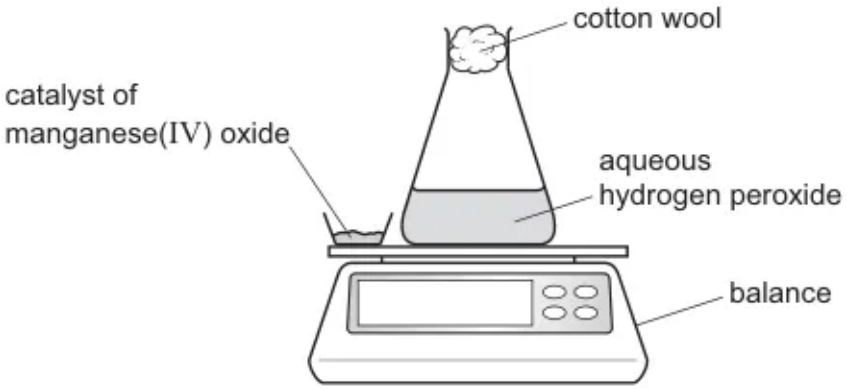
$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

(a) State the meaning of the term *catalyst*.

.....

..... [2]

(b) The diagram shows the equipment the student uses.

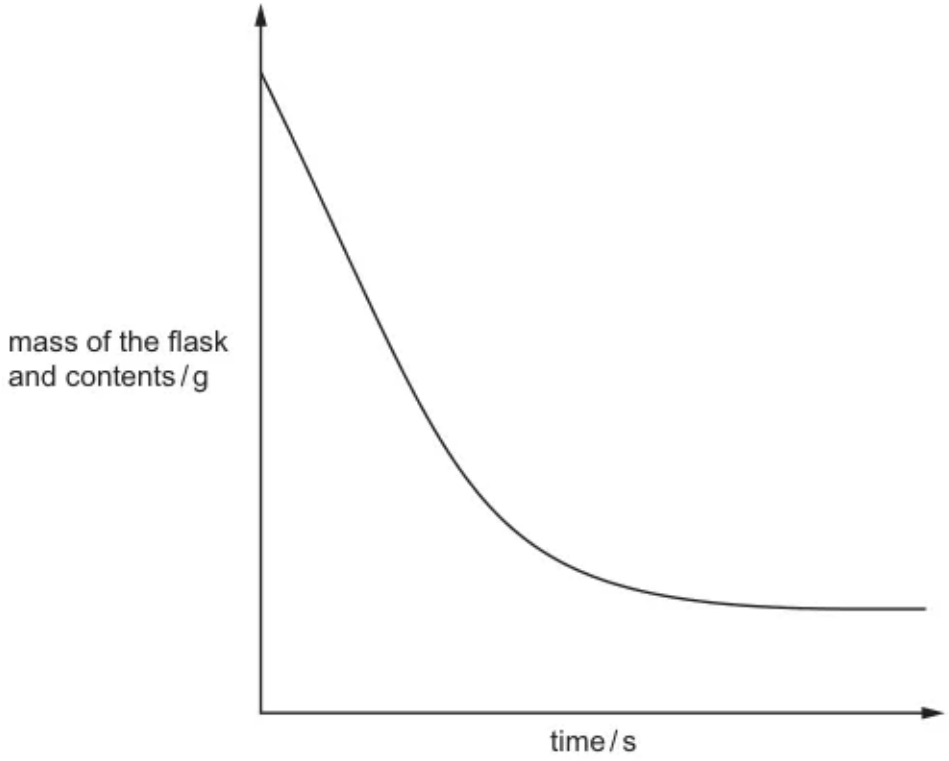


The student uses this method:

- the catalyst is added to the aqueous hydrogen peroxide
- the stop-clock is started
- the mass of the flask and contents is recorded at regular time intervals.

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A graph of the mass of the flask and contents against time is shown.



(i) Suggest why the mass of the flask and contents decreases as time increases.

..... [1]

(ii) Describe what happens to the rate of the reaction as time increases.

.....

..... [2]

(c) The student repeats the experiment at a higher temperature. All other conditions stay the same. The rate of reaction increases.

(i) Explain, in terms of collisions between particles, why the rate of reaction increases at a higher temperature.

.....

.....

.....

..... [3]

(ii) Draw a line on the graph in **(b)** for the experiment at a higher temperature. [2]

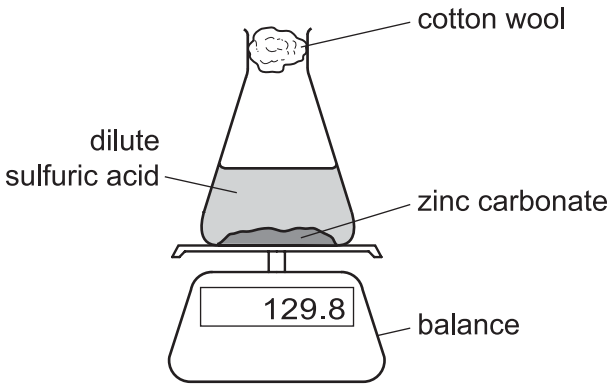
[Total: 10]

Rates of reaction Click for more variations

8(a)	**M1** (a substance that) speeds up a reaction / increases the rate of a reaction (1) **M2** unchanged chemically at the end (1)	**2**
8(b)(i)	oxygen gas escapes	**1**
8(b)(ii)	**M1** rate decreases **OR** rate / reaction is fastest at the start (1) **M2** reaction stops **or** rate = zero (1)	**2**
8(c)(i)	**M1** (particles) have more kinetic energy / particles move faster(1) **M2 more** collisions per unit time (1) **M3 more** particles have energy greater than or equal to activation energy **OR** **more** particles have sufficient energy to react **OR** A greater percentage or greater proportion or greater fraction of collisions have sufficient energy to react **OR** A greater percentage or greater proportion or greater fraction of collisions have energy greater than or equal to activation energy **OR** A greater percentage or greater proportion or greater fraction of collisions are successful (1)	**3**
8(c)(ii)	**M1** steeper gradient from start (1) **M2** levels off **at the same mass** (1)	**2**

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9 Dilute sulfuric acid was added to zinc carbonate in a conical flask as shown.



Two experiments were carried out.

Experiment 1

The flask was placed on a balance and the mass of the flask and contents recorded every five minutes. The temperature of the sulfuric acid was 30 °C.
The results have been plotted on the grid.

Experiment 2

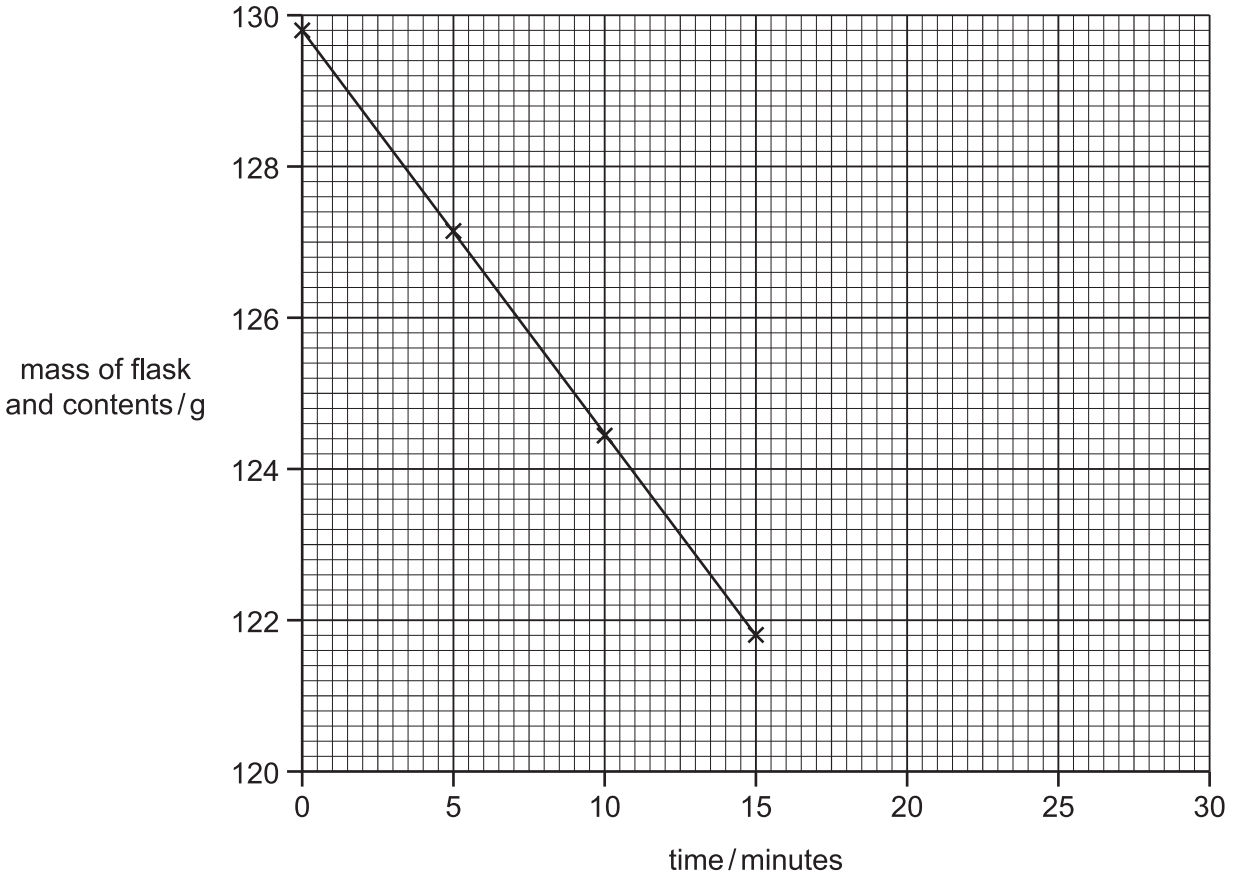
Experiment 1 was repeated but the temperature of the acid was different. The results are shown in the table.

Table of results for Experiment 2

time / minutes	0	5	10	15	20	25	30
mass of flask and contents / g	129.8	128.4	127.0	125.6	124.0	122.6	121.2

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(a) Plot the results for Experiment 2 on the grid and draw a straight line graph.



[3]

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

..... [1]

(c) Suggest the purpose of the cotton wool.

..... [1]

(d) (i) In which experiment was the loss of mass of the flask and contents the fastest?

..... [1]

(ii) Compare the temperature of the sulfuric acid in Experiment 2 with Experiment 1.

..... [1]

(e) Use the graph for Experiment 1 to find the time taken for the mass of the flask and contents to decrease to 120 g. Indicate clearly **on the grid** how you obtained your answer. [2]

(f) On the grid, sketch the graph you would expect if Experiment 1 was repeated using more concentrated sulfuric acid. [1]

[Total: 10]

Practical skills: planning, apparatus, measuring and results Click for more variations

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9 **(a)** all points plotted correctly (2), –1 each incorrect
straight line (1) [3]

(b) gas / carbon dioxide given off [1]
not hydrogen gas given off

(c) prevent loss of acid / liquid [1]

(d) **(i)** Experiment 1 [1]

(ii) (in Experiment 2) the temperature of the acid was lower / converse [1]

(e) 18.5 minutes ±1/2 small square (1) extrapolation on grid (1) [2]

(f) sketched line to the left of Experiment 1 line [1]

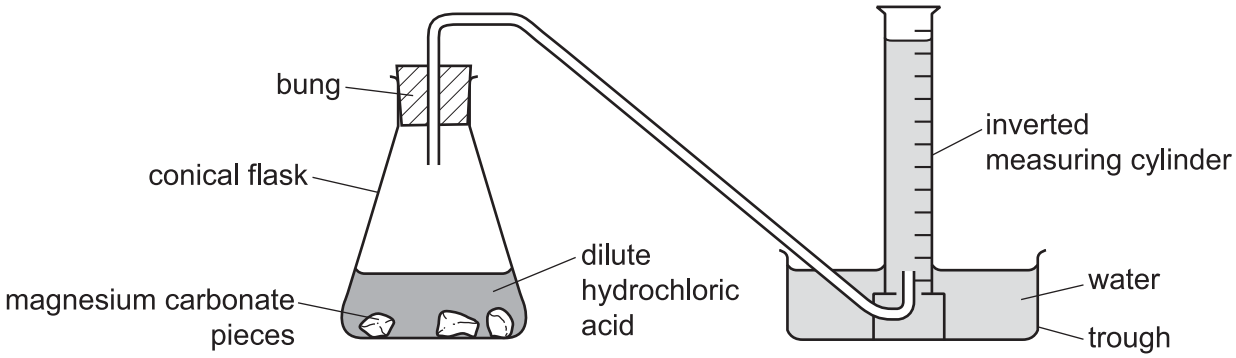
[Total: 10]

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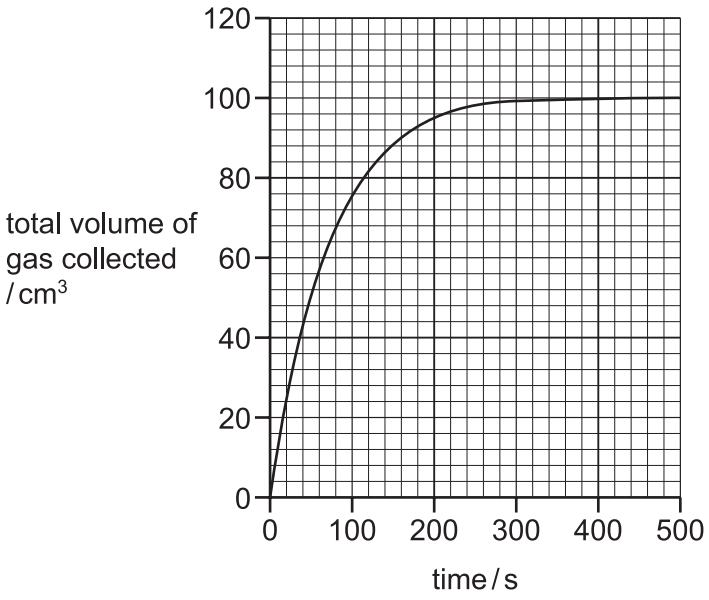
10 Magnesium carbonate reacts with dilute hydrochloric acid.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

An excess of magnesium carbonate pieces was added to dilute hydrochloric acid. The apparatus in the diagram was used to measure the volume of gas produced. The total volume of gas collected was recorded every 20 seconds.



(a) The results obtained are shown on the graph.



(i) Describe how the rate of this reaction changed during the reaction. Explain why the rate changed in this way.

.....

.....

.....

.....

..... [4]

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(ii) The experiment was repeated using the same mass of **powdered** magnesium carbonate with the same volume and concentration of dilute hydrochloric acid.

Explain how the initial rate of reaction and total volume of gas collected would compare to the first experiment.

initial rate of reaction .....

.....

.....

total volume of gas .....

.....

.....

[4]

(b) A piece of magnesium ribbon was cleaned. The experiment was repeated using this clean magnesium ribbon instead of magnesium carbonate.

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

This reaction is exothermic.
The rate of the reaction gradually increased over the first 2 minutes.

Explain why the rate of the reaction increased.

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 13]

Rates of reaction Click for more variations

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10(a)(i)	any 4 from: slowed down acid became less concentrated **OR** fewer particles per unit volume fewer collisions per second **OR** lower collision rate (then the reaction) stopped all the hydrochloric acid reacted	**4**
10(a)(ii)	any 4 from: faster (reaction) (powder has) larger surface area more collisions per second **OR** higher collision rate same volume of gas amount / moles hydrochloric acid is not changed	**4**
10(b)	any 5 from: temperature increased particles have more energy (particles) move faster more collisions per second **OR** higher collision rate more particles have sufficient energy to react / activation energy more of the collisions are successful	**5**

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