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

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

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Rates of reaction

Time allowed: 1 hour 40 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

/ 89

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 89 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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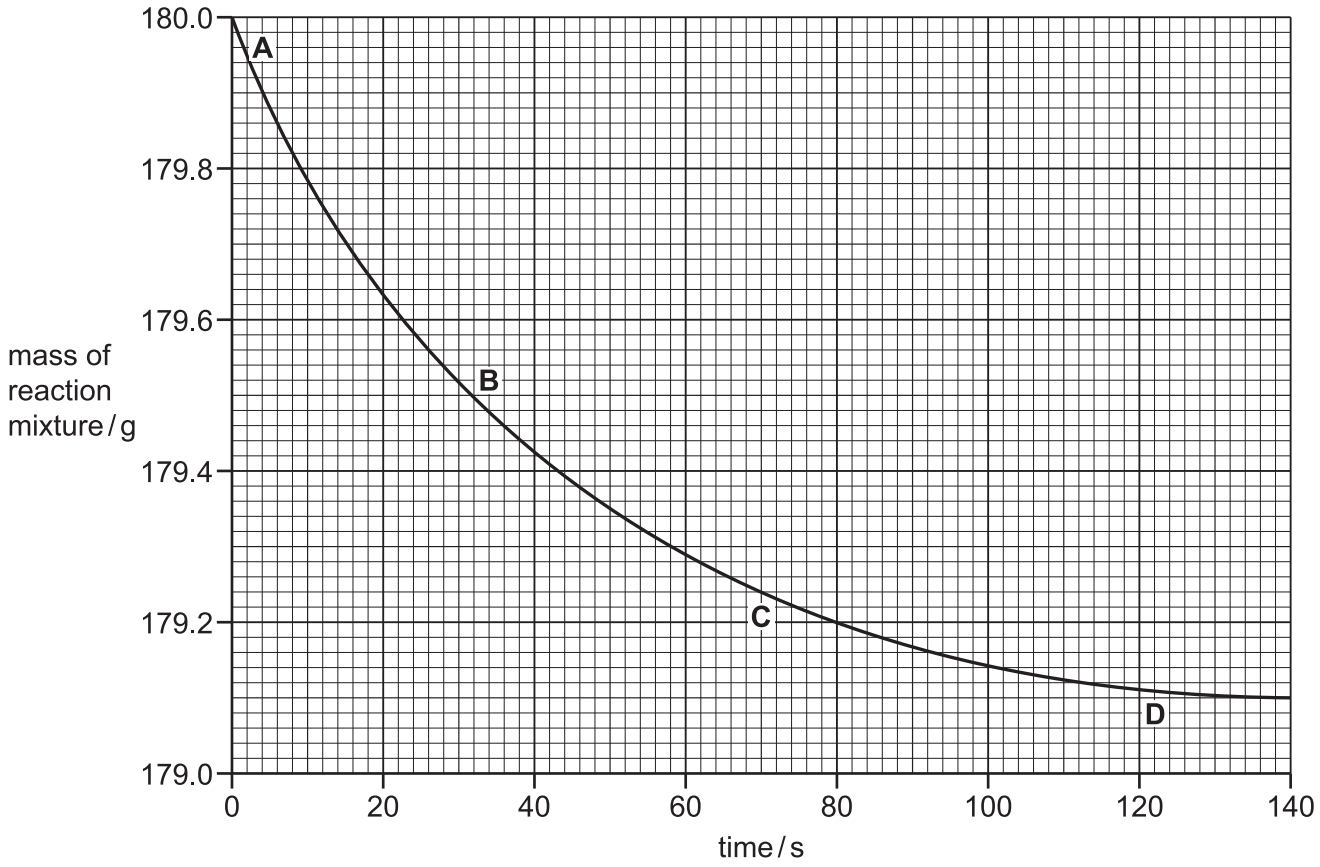
Print at 100% (Actual size) so diagrams keep their real measurements.

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

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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 A student investigated a reaction between a solid and a liquid. The reaction produced a gas. She wanted to know if any of the substances **W**, **X** and **Y** were catalysts for the reaction. Firstly she carried out the reaction without any **W**, **X** or **Y**.
Then she repeated the reaction three times adding a small amount of **W**, **X** or **Y**. In each case she timed how long the reaction took to finish. The results are in the table.

substance added	time of reaction / s
none	277
W	266
X	279
Y	78

(a) How would the student know when the reaction had finished?

..... [1]

(b) **(i)** State the effect of each substance on the speed (rate) of the reaction.

W .....

X .....

Y ..... [3]

(ii) Which substance, **W**, **X** or **Y**, is the best catalyst for this reaction?

..... [1]

(c) How could the student check the reliability of her results?

.....

..... [2]

[Total: 7]

Rates of reaction Click for more variations

2 **(a)** fizzing/bubbles stopped/no more gas produced (1) [1]

(b) **(i)** W little/no effect/slight increase (1)
X no effect/(slight) decrease (1)
Y speeds up reaction (1) [3]
note: The question is about rate, if candidates quote three different time differences, penalise first then allow the 'correct' answers (–11 s, +2 s, –199 s).
It must be clear that the increase in rate is less for W than Y for these 2 marks.

(ii) Y (1) [1]

(c) repeat experiments (1) take average/compare results/see if there is a difference (1) [2]

[Total: 7]

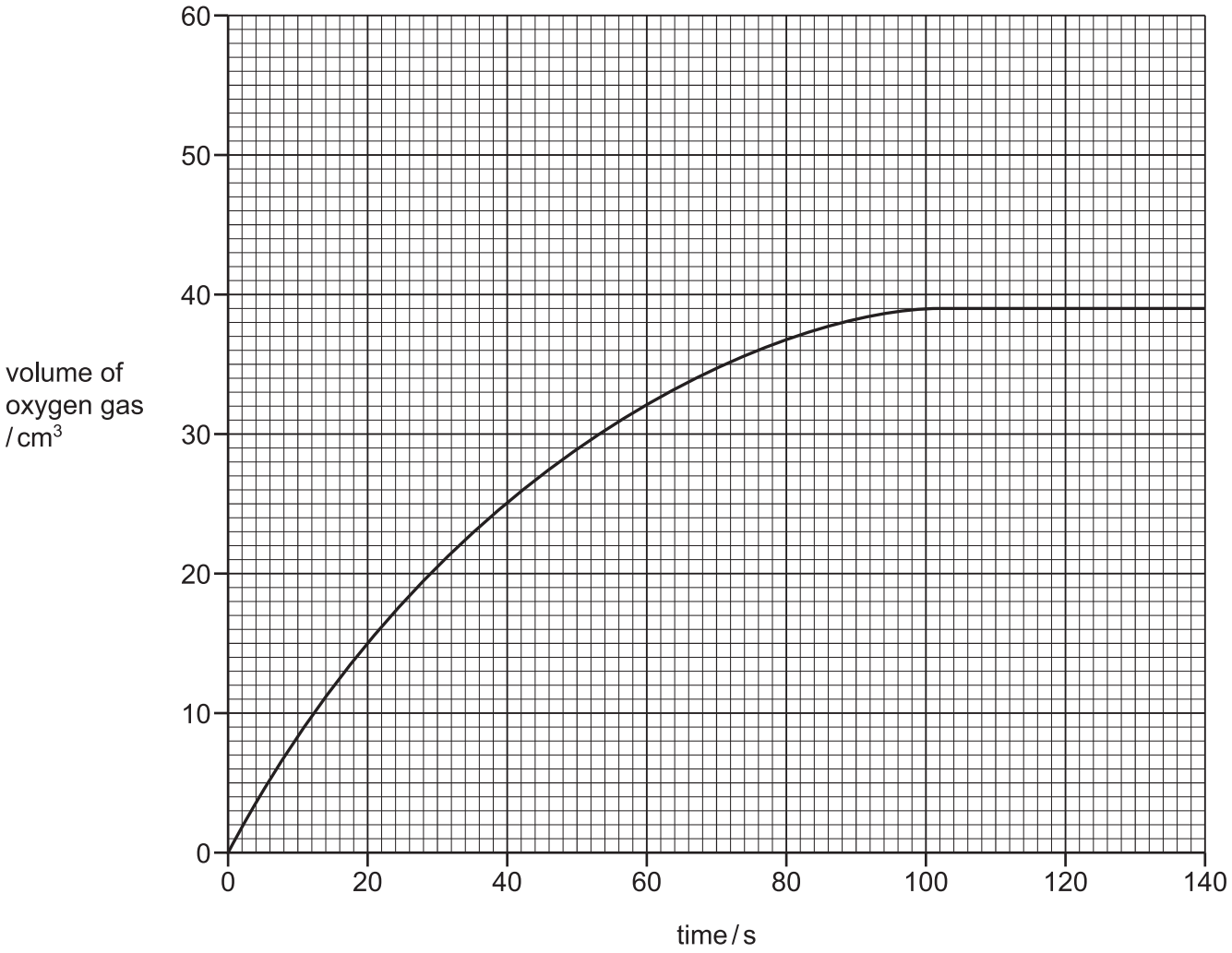
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3 The rate of decomposition of aqueous hydrogen peroxide, H_2O_2, is increased by an enzyme.

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

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

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

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

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4 The table shows some properties of four substances, **A**, **B**, **C** and **D**.

substance	melting point / °C	does the solid conduct electricity?	does a solution of the solid conduct electricity?
A	962	yes	does not dissolve
B	747	no	dissolves and conducts
C	113	no	does not dissolve
D	3550	no	does not dissolve

(a) Which one of these substances has

(i) a giant covalent structure, ☐

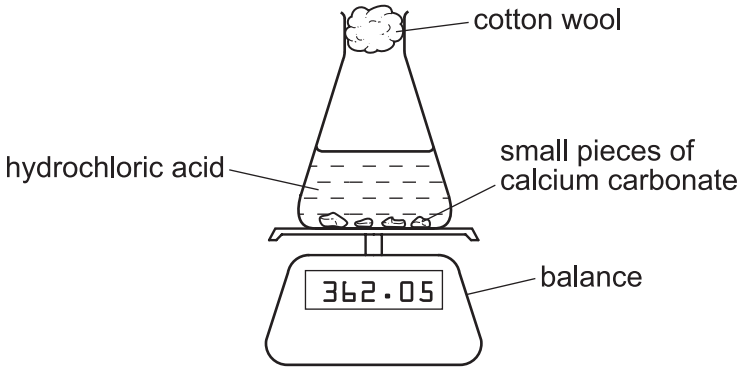
(ii) a simple molecular structure, ☐

(iii) a metallic structure? ☐ [3]

(b) A student carried out an experiment to determine the rate of reaction of calcium carbonate with excess hydrochloric acid.

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

He recorded the loss of mass of the reaction mixture over a period of time.

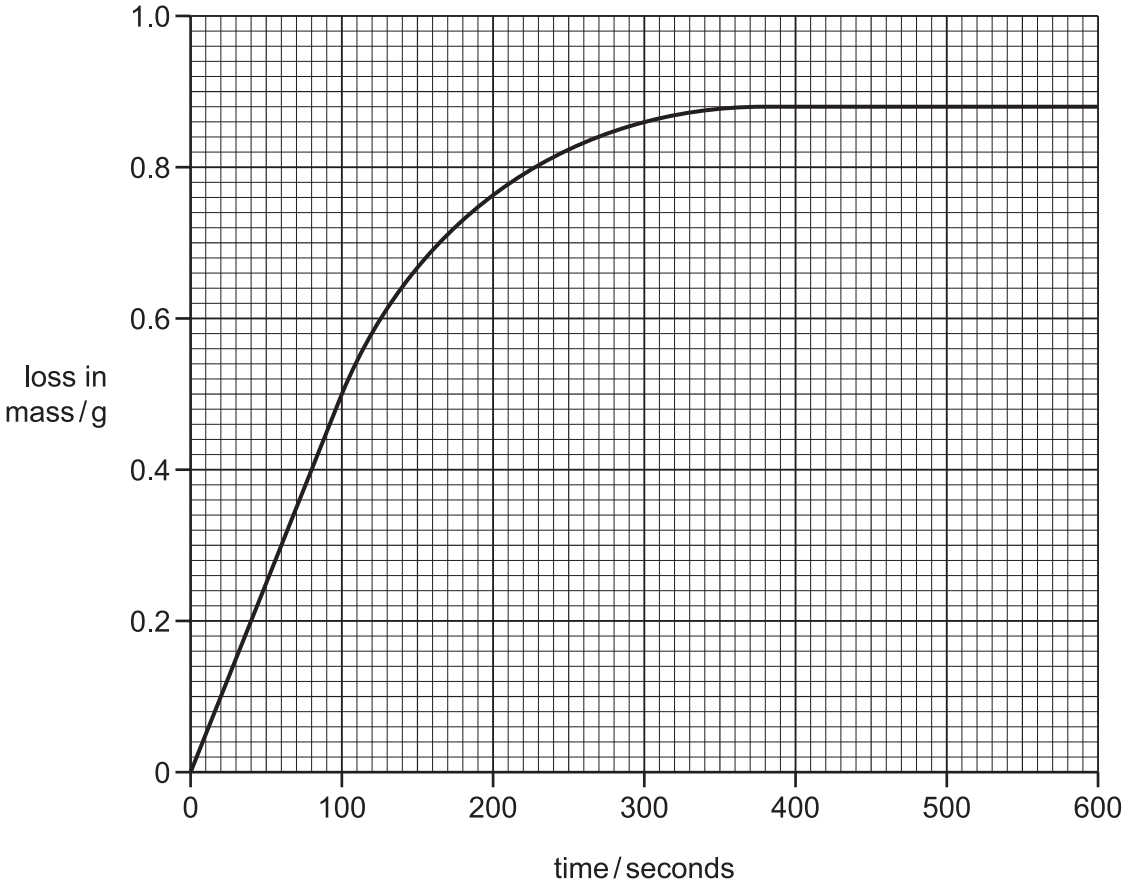


(i) Explain why the reaction mixture decreases in mass.

..... [1]

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He carried out the reaction at constant temperature using 2 g of calcium carbonate in small pieces. The hydrochloric acid was in excess.
He plotted his results on a grid. This is shown below.



(ii) At what time has the reaction just finished?

..... s [1]

(iii) From the graph, deduce the loss in mass in the first 100 seconds.

..... g [1]

(iv) The student repeated the experiment keeping everything the same except for the size of the pieces of calcium carbonate. He used smaller pieces of calcium carbonate but the mass used was the same.

On the grid above, draw a line to show how the loss of mass changes with time when smaller pieces of calcium carbonate are used. [2]

(v) State the effect of increasing the concentration of hydrochloric acid on the rate (speed) of this reaction when all other factors remain constant.

..... [1]

[Total: 9]

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Ionic bonding Click for more variations

4 **(a)** **(i)** **D** [1]

(ii) **C** [1]

(iii) **A** [1]

(b) **(i)** loss of carbon dioxide / loss of gas [1]

(ii) accept values from 360–380 [1]
ALLOW: 6 min to 6 min 20 s / 6⅓ min

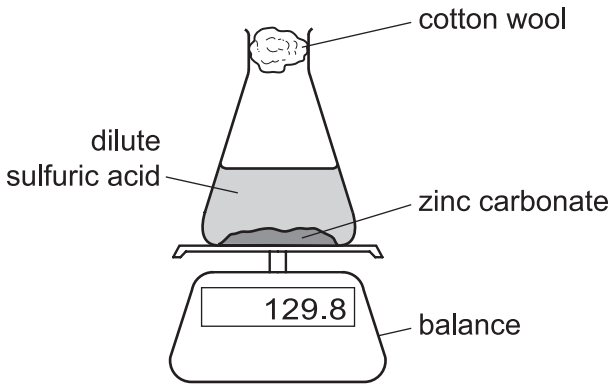
(iii) 0.5 (g) [1]

(iv) (initial) gradient greater / slope greater and starts at 0, 0; [1]
same final volume [1]

(v) (rate) increases [1]
IGNORE: more carbon dioxide per second
ALLOW : (rate) faster

[Total: 9]

5 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

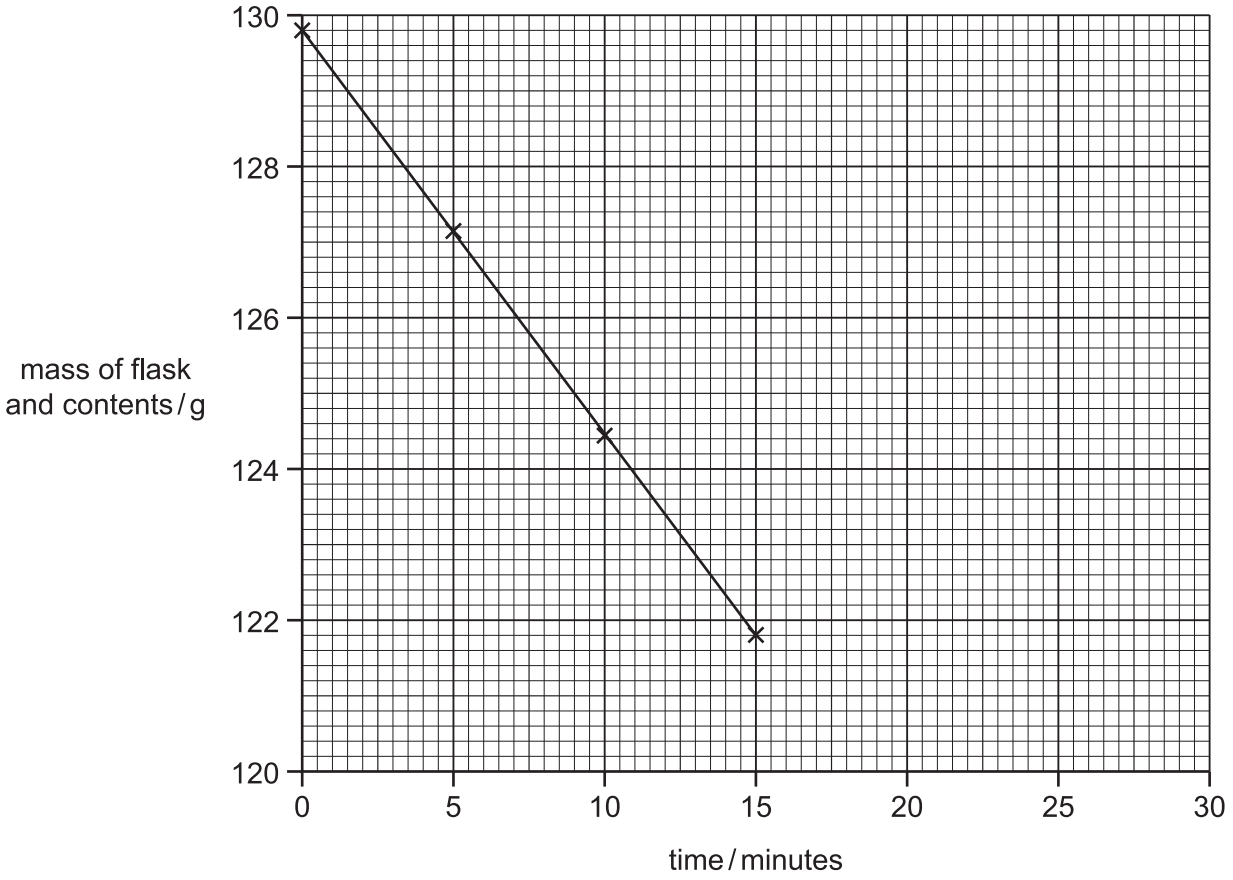
Experiment 1 was repeated but the temperature of the acid was different. The results are shown in the table.

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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5 **(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]

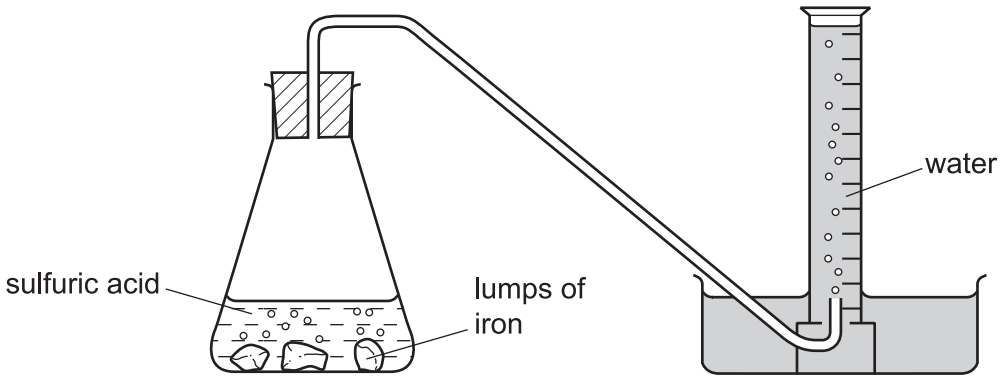
[Total: 10]

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6 A student investigated the reaction of lumps of iron with sulfuric acid.

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$$

She used the apparatus shown below.



(a) (i) Describe how this apparatus can be used to investigate the rate of this reaction.

.....

.....

..... [3]

(ii) Describe how the rate of reaction would differ if smaller lumps of iron were used. All other conditions remain the same.

..... [1]

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

(i) State **three** factors which the student should keep the same in each experiment.

1. .....

2. .....

3. .....

[3]

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(ii) The table shows how the rate of reaction changed with temperature.

temperature /°C	rate of reaction in cm^3/s
20	2.2
30	4.4
40	8.8
50	17.6

Use the information in the table to describe how the rate of reaction changed with temperature.

.....

..... [2]

(c) Iron(II) sulfate can be prepared by adding excess iron to sulfuric acid.

Describe how you could obtain pure dry crystals of iron(II) sulfate from the reaction mixture in the conical flask.

.....

.....

.....

..... [3]

[Total: 12]

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Rates of reaction Click for more variations

6(a)(i)	measure volume of gas / measure amount of gas; gas collected in the measuring cylinder; at different times / use of stopclock to measure time;	**1** **1** **1**
6(a)(ii)	faster reaction / rate increases;	**1**
6(b)(i)	same concentration of acid; same mass of iron; same size of iron pieces;	**1** **1** **1**
6(b)(ii)	rate increases with increase in temperature rate increases with temperature = [1]	**2**
6(c)	any three from: • filter (off the iron); • evaporate water / heat gently; • to crystallisation point / leave to cool (after heating); • filter off / pick out crystals; • dry crystal between filter papers;	**3**

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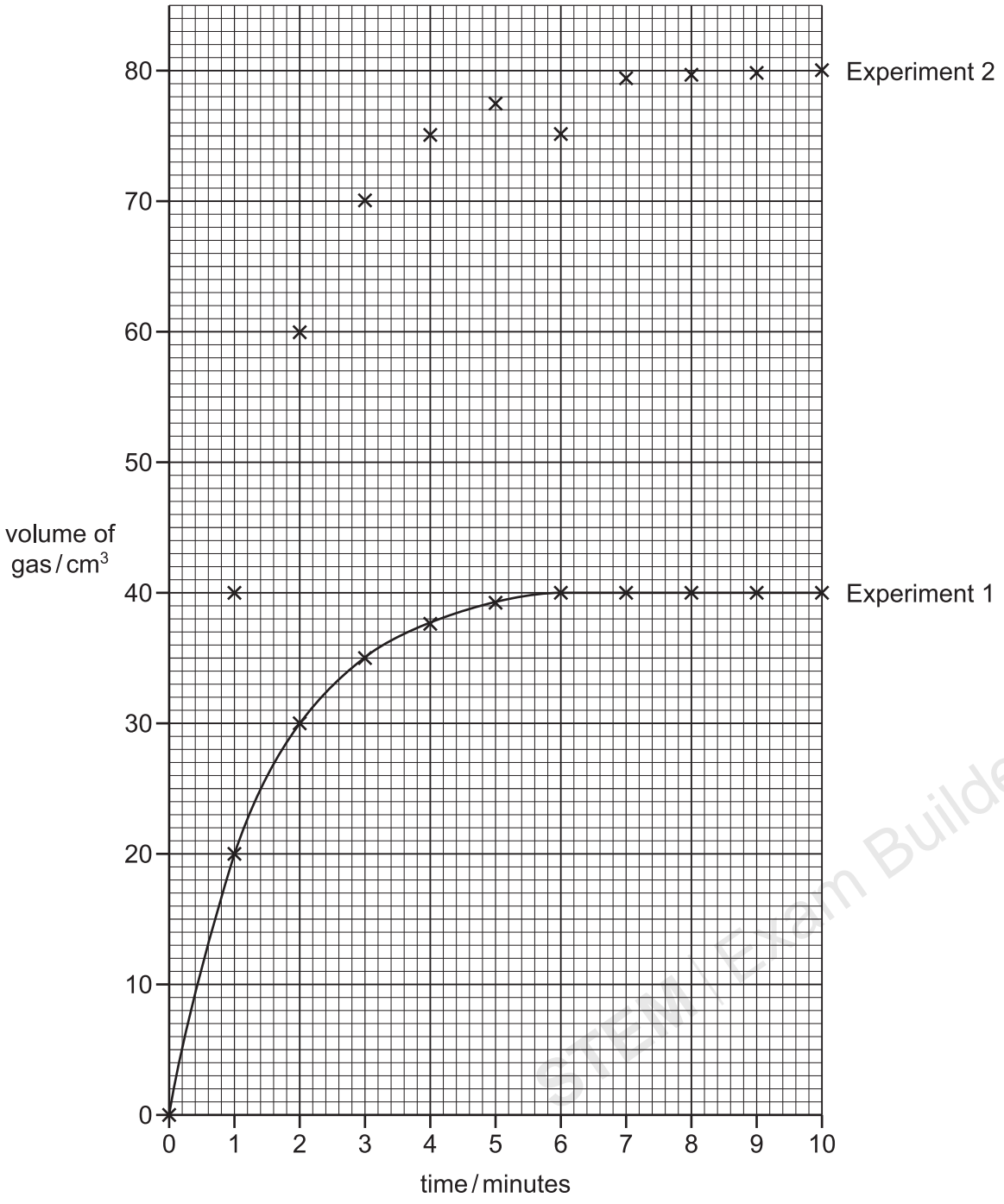
7 Two experiments were carried out to show what factors affect the rate of decomposition of hydrogen peroxide, H_2O_2.
In each experiment the volume of gas produced was measured every minute for ten minutes.

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

7 **(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]

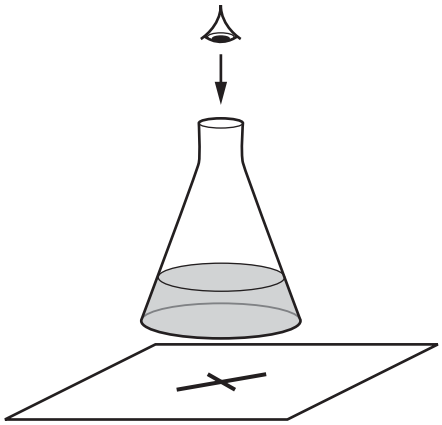
(d) sketch graph less steep than original for Experiment 1 (1)
to same level (1) [2]

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8 When aqueous sodium thiosulfate and dilute hydrochloric acid are mixed, a precipitate of insoluble sulfur is produced. This makes the mixture difficult to see through.

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

The time taken for the cross to disappear from view is measured.



A student adds the following volumes of aqueous sodium thiosulfate, dilute hydrochloric acid and distilled water to the conical flask.

The time taken for the formation of the precipitate of sulfur to make the cross disappear from view is recorded.

experiment number	volume of sodium thiosulfate / cm^3	volume of hydrochloric acid / cm^3	volume of distilled water / cm^3	time taken for cross to disappear from view / s
1	10	10	40	56
2	20	10	30	28
3				

(a) State the order in which the aqueous sodium thiosulfate, hydrochloric acid and distilled water should be added to the flask.

.....

..... [1]

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(b) In experiment 3 the student wanted the sodium thiosulfate to be double the concentration used in experiment 2.

(i) Complete the table to show the **volumes** which should be used and the **expected** time taken for the cross to disappear from view in experiment 3. [2]

(ii) Use collision theory to explain why increasing the concentration of sodium thiosulfate would change the rate of reaction.

.....

.....

.....

..... [2]

(c) The student repeated experiment 1 at a higher temperature.

Use collision theory to explain why the rate of reaction would increase.

.....

.....

.....

..... [3]

[Total: 8]

Rates of reaction Click for more variations

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8(a)	1 $Na_2S_2O_3$ 2 H_2O 3 HCl **OR** 1 HCl 2 H_2O 3 $Na_2S_2O_3$ **OR** 1 H_2O 2 $Na_2S_2O_3$ 3 HCl **OR** 1 H_2O 2 HCl 3 $Na_2S_2O_3$;	**1**
8(b)(i)	**M1** volumes 40 : 10 : 10; **M2** time = 14;	**2** 1 1
8(b)(ii)	**M1** more particles per unit volume / particles are closer together; **M2** increases the rate of collisions / there are more collisions per unit time;	**2** 1 1
8(c)	**M1** particles gain more energy **and** move fast**er**; **M2** increasing rate of collisions / more collisions per unit time; **M3** higher proportion of particles have sufficient energy to react / collisions have sufficient energy to react / are above the activation energy;	**3** 1 1 1

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

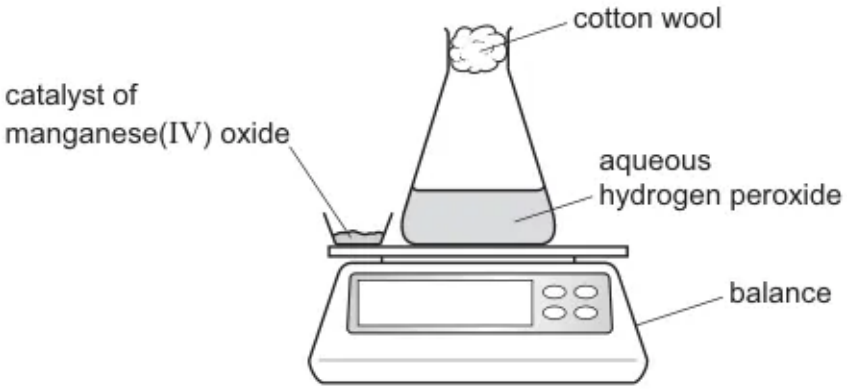
$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

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

.....

..... [2]

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

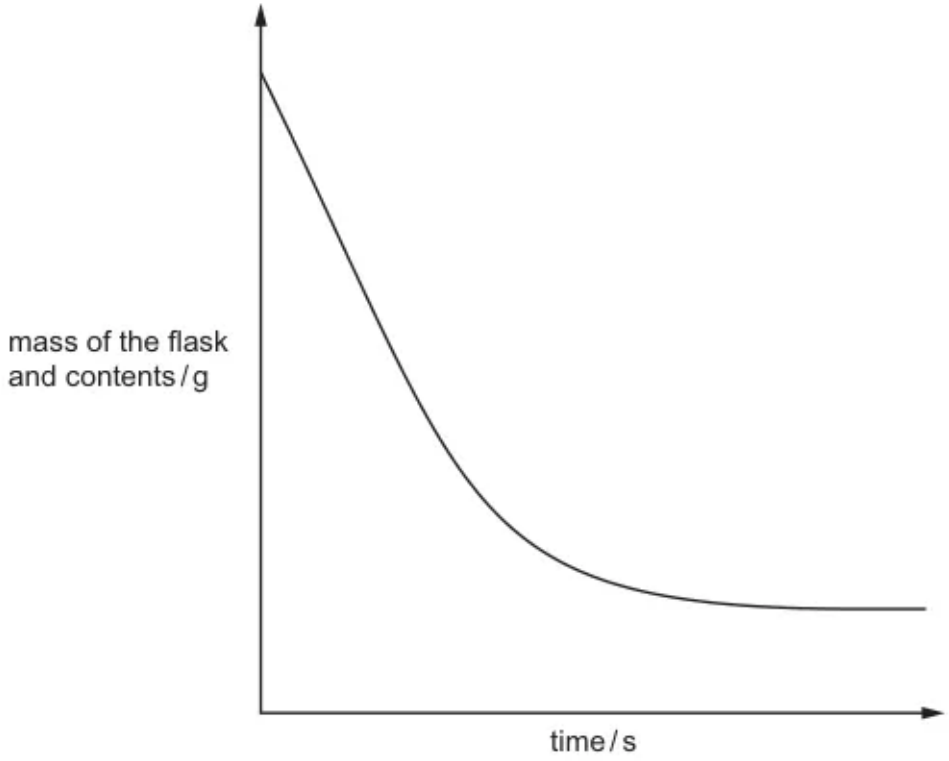


The student uses this method:

- 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

9(a)	**M1** (a substance that) speeds up a reaction / increases the rate of a reaction (1) **M2** unchanged chemically at the end (1)	**2**
9(b)(i)	oxygen gas escapes	**1**
9(b)(ii)	**M1** rate decreases **OR** rate / reaction is fastest at the start (1) **M2** reaction stops **or** rate = zero (1)	**2**
9(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**
9(c)(ii)	**M1** steeper gradient from start (1) **M2** levels off **at the same mass** (1)	**2**

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10 The decomposition of hydrogen peroxide is catalysed by manganese(IV) oxide.

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

To 50 cm^3 of aqueous hydrogen peroxide, 0.50 g of manganese(IV) oxide was added. The volume of oxygen formed was measured every 20 seconds. The average reaction rate was calculated for each 20 second interval.

time / s	0	20	40	60	80	100
volume of oxygen / cm^3	0	48	70	82	88	88
average reaction rate in cm^3 / s	2.4	1.1	.....	0.3	0.0	0.0

(a) Explain how the average reaction rate, 2.4 cm^3 / s, was calculated for the first 20 seconds.

.....

..... [2]

(b) Complete the table. [1]

(c) Explain why the average reaction rate decreases with time.

.....

..... [2]

(d) The experiment was repeated but 1.0 g of manganese(IV) oxide was added.
What effect, if any, would this have on the reaction rate and on the final volume of oxygen?
Give a reason for each answer.

effect on rate ..... [1]

reason .....

..... [2]

effect on final volume of oxygen ..... [1]

reason .....

..... [2]

[Total: 11]

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Rates of reaction Click for more variations

10 **(a)** volume given off (in that 20 s interval) [1]
divided by 20 [1]
accept 48/20 for [2]
Answer to 3 (a) may appear twice, both in 3 (a) and 3 (b). Please ignore in 3 (b).

(b) 0.6 (cm^3/s) [1]

(c) concentration [1]
of hydrogen peroxide decreases [1]

for hydrogen peroxide used up ONLY [1]
not reagent / reactant

(d) rate increases / doubles [1]
catalyst has bigger surface area / more catalyst particles exposed [1]
more collisions [1]
not more catalyst / higher concentration of catalyst / more molecules of catalyst

OR

volume of oxygen the same [1]
oxygen from hydrogen peroxide (not catalyst) [1]
amount / number of moles the same [1]

OR

amount/mass/volume/number of moles of hydrogen peroxide the same [2]

catalyst chemically unchanged ONLY [1]
reactants have not changed (only the catalyst) [1]
accept catalyst does not react [1]

[Total: 11]

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