

1

This question is about reversible reactions and chemical equilibrium.

(a) Reversible reactions can reach equilibrium in a closed system.

(i) What is meant by a closed system?

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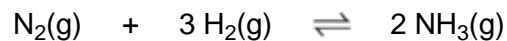
(1)

(ii) Explain why, when a reversible reaction reaches equilibrium, the reaction appears to have stopped.

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(2)

- (b) In the Haber process, the reaction of nitrogen with hydrogen to produce ammonia is reversible.



- (i) Name a natural resource from which hydrogen is produced.

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(1)

- (ii) The Haber process uses a catalyst to speed up the reaction.

Explain how a catalyst speeds up a reaction.

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(2)

- (iii) What happens to the amount of ammonia produced at equilibrium if the pressure is increased?

Give a reason for your answer.

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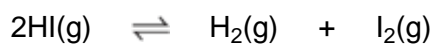
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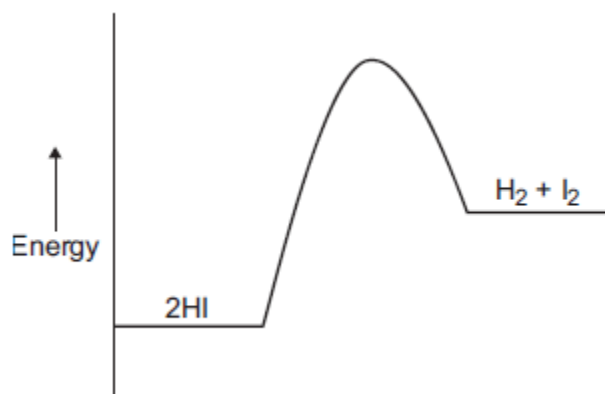
(2)

(c) The decomposition of hydrogen iodide into hydrogen and iodine is reversible.



The forward reaction is endothermic.

The energy level diagram shown below is for the forward reaction.



(i) Draw an arrow to show the activation energy on the diagram.

(1)

(ii) How does the diagram show that the reaction is endothermic?

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(1)

(iii) Suggest what effect, if any, increasing the temperature will have on the amount of hydrogen iodide at equilibrium.

Give a reason for your answer.

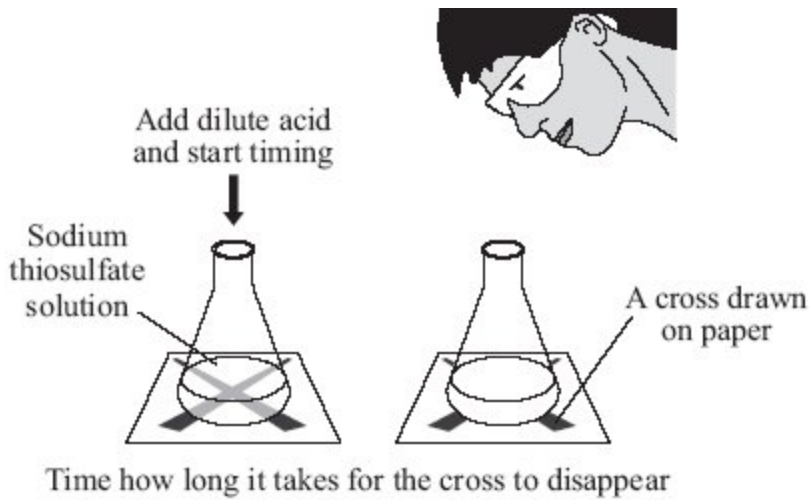
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(2)
(Total 12 marks)

2

Sodium thiosulfate solution reacts with hydrochloric acid. As the reaction takes place the solution slowly turns cloudy.

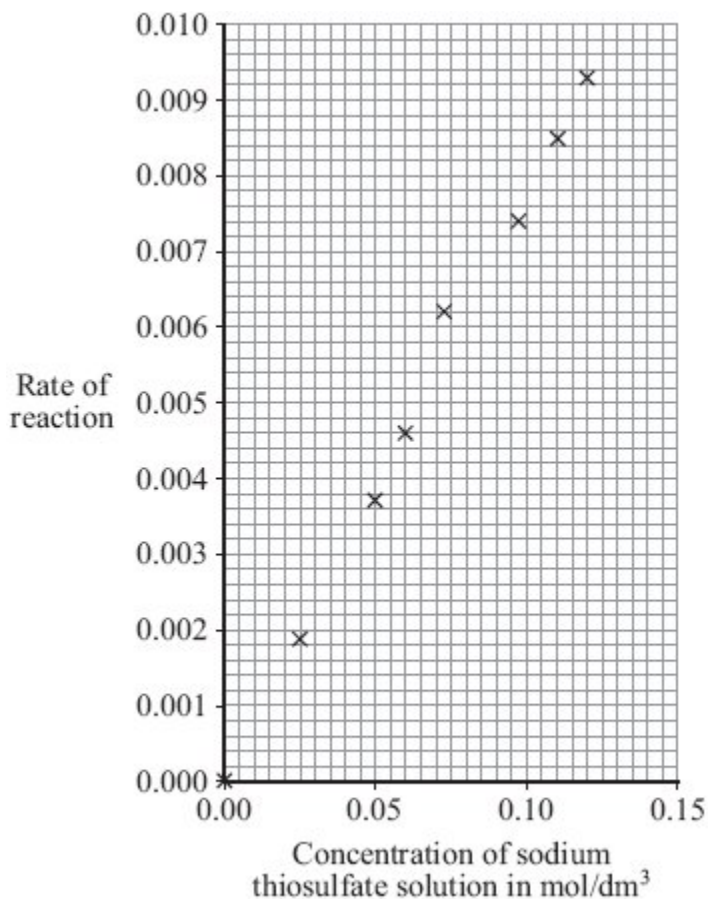
The diagram shows a method of measuring the rate of this reaction.



A student used this method to investigate how changing the concentration of the sodium thiosulfate solution affects the rate of this reaction.

The student used different concentrations of sodium thiosulfate solution. All the other variables were kept the same.

The results are shown on the graph below.



(a) (i) Draw a line of best fit on the graph.

(1)

(ii) Suggest **two** reasons why all of the points do not lie on the line of best fit.

1

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(2)

(b) (i) In a conclusion to the investigation the student stated that:

'The rate of this reaction is directly proportional to the concentration of the sodium thiosulfate solution.'

How does the graph support this conclusion?

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(1)

- (ii) Explain, in terms of particles, why the rate of reaction increases when the concentration of sodium thiosulfate is increased.

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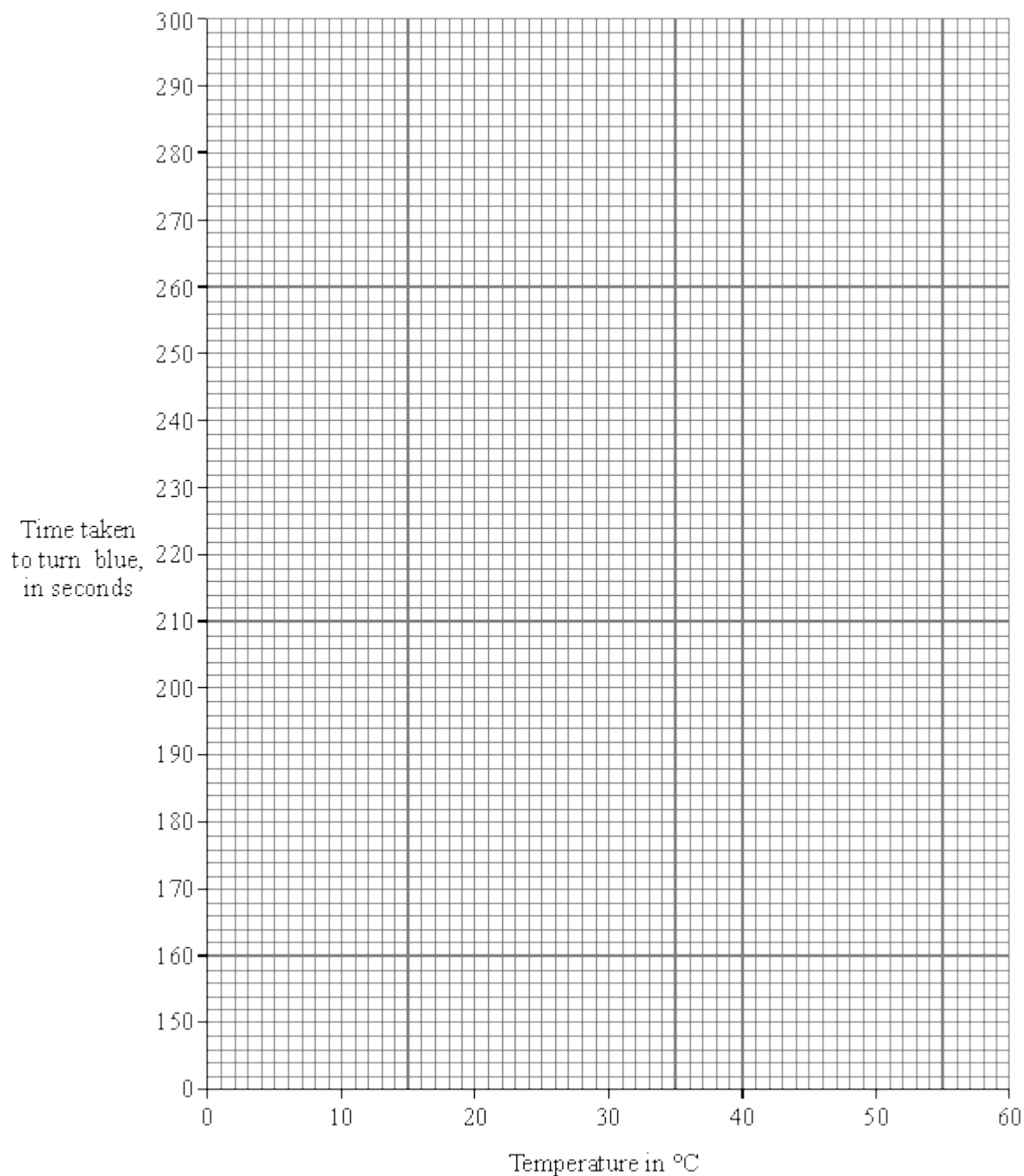
(2)
(Total 6 marks)

3 Solutions **A** and **B** are colourless. When they are mixed, they react and turn blue after a period of time. A student investigated how temperature affected the rate of reaction between solutions **A** and **B**. The rate was measured by timing how long the mixture took to turn blue.

The results are shown in the table.

Temperature in °C	22	25	34	45	51
Time taken to turn blue, in seconds	290	250	200	170	160

(a) (i) Draw a graph for these results.



(3)

(ii) Use your graph to find how long it takes the solution to turn blue at 40°C.

Time = s

(1)

(b) (i) How does the rate of reaction change as the temperature is increased?

.....

.....

(1)

(ii) Explain, in terms of particles, why temperature has this effect on the rate of reaction.

*To gain full marks in this question you should write your ideas in good English.
Put them into a sensible order and use the correct scientific words.*

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(3)

(c) State **one** variable that must be kept constant to make this experiment a fair test.

.....

(1)

(Total 9 marks)

4

The picture shows a lump of phosphate rock.



Rob Lavinsky, iRocks.com – CC-BY-SA-3.0 [CC-BY-SA-3.0], via Wikimedia Commons

Phosphoric acid is made by reacting phosphate rock with sulfuric acid.

Only **three** of the methods shown below will **increase** the rate of this reaction.

Put a **tick (✓)** next to each of the **three** methods that will **increase** the rate of this reaction.

Method	Tick (✓)
Use a more concentrated solution of sulfuric acid	
Use larger lumps of phosphate rock	
Cool the mixture of phosphate rock and sulfuric acid	
Grind the phosphate rock into a powder before adding the acid	
Increase the temperature of the sulfuric acid	
Dilute the sulfuric acid solution with water	

(3)
(Total 3 marks)

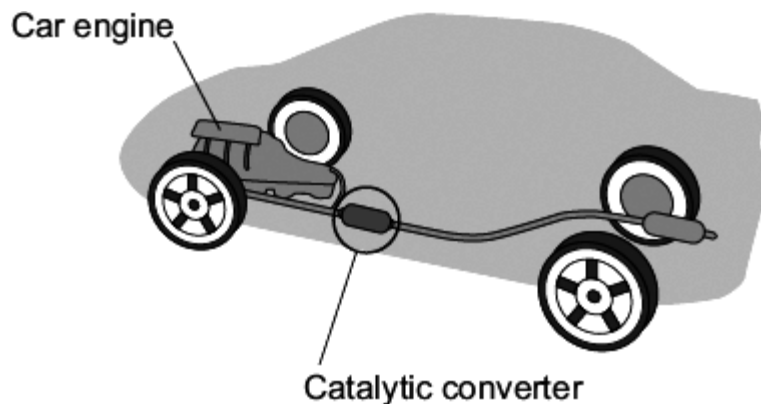
5

Read the information about car engines.

Burning petrol in air is an exothermic reaction. This reaction is used in car engines.

When petrol burns it produces harmful substances such as nitrogen oxides and carbon monoxide.

A catalytic converter stops these harmful substances being released into the air.



(a) Draw a ring around the correct answer to complete each sentence.

(i) The exothermic reaction makes the temperature of the engine

decrease.
increase.
stay the same.

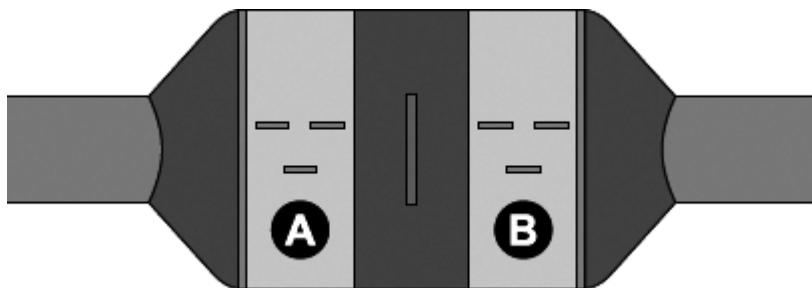
(1)

(ii) This is because during exothermic reactions

energy is taken in from the surroundings.
energy is given out to the surroundings.
there is no energy change.

(1)

- (b) The diagram shows a catalytic converter which removes harmful substances. The catalytic converter has two parts, **A** and **B**, which contain different catalysts.



- (i) The equation for the reaction that takes place in part **A** is:



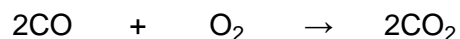
Which **one** of the substances shown in the equation is a compound?

Give the formula of this compound.

.....

(1)

- (ii) The equation for the reaction that takes place in part **B** is:



Why is it important to stop carbon monoxide (CO) from being released into the air?

.....

.....

(1)

- (c) The table lists some statements about catalysts. Only **two** statements are correct.

Tick (✓) the **two** correct statements.

Statement	Tick (✓)
A catalyst can speed up a chemical reaction.	
A catalyst is used up in a chemical reaction.	
Different reactions need different catalysts.	
A catalyst does not change the rate of a chemical reaction.	

(2)

(d) Modern catalytic converters contain nanosized particles of catalyst.
Less catalyst is needed when nanosized catalyst particles are used.

(i) Complete the sentence.

The size of nanosized particles is than normal sized particles.

(1)

(ii) The catalysts contain platinum.

Suggest why a manufacturer of catalytic converters would want to use less catalyst.

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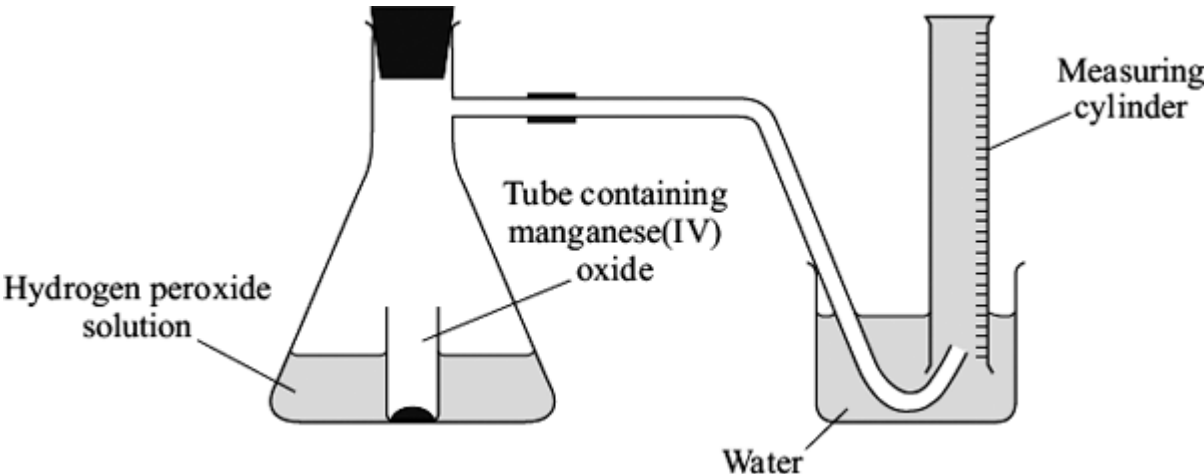
(1)
(Total 8 marks)

6

A student investigated the effect of temperature on the decomposition of hydrogen peroxide. Hydrogen peroxide decomposes to oxygen and water when a manganese(IV) oxide catalyst is added.

The student measured the time taken to collect 5 cm³ of oxygen gas.

The apparatus shown below was used for the investigation. The reaction was started by shaking the flask so that the manganese(IV) oxide and hydrogen peroxide were mixed.



The student did the investigation at two different temperatures. All the other variables were kept constant.

The student's results are shown in the table.

Temperature of the hydrogen peroxide solution in °C	Volume of oxygen collected in cm ³	Time taken to collect the oxygen in seconds	Rate of reaction in cm ³ per second
20	5	40	0.125
25	5	25	

(a) (i) Calculate the rate of reaction at 25 °C.

.....

Rate of reaction = cm³ per second

(2)

(ii) The teacher said that the student should repeat the investigation to get more results.

Suggest why.

.....

.....

(1)

(b) The student concluded that:

'the rate of reaction increases when the temperature is increased'.

Explain, in terms of particles, why the rate of reaction increases.

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.....

(2)
(Total 5 marks)

7

The picture shows a lump of phosphate rock.



Rob Lavinsky, iRocks.com – CC-BY-SA-3.0 [CC-BY-SA-3.0], via Wikimedia Commons

Phosphoric acid is made by adding sulfuric acid to phosphate rock.

(a) The rate of reaction between sulfuric acid and phosphate rock can be increased if the mixture is heated to a higher temperature.

Explain, in terms of particles, why an increase in temperature increases the rate of reaction.

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(2)

(b) State **one** other way in which the rate of reaction between sulfuric acid and phosphate rock can be increased.

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(1)
(Total 3 marks)

8

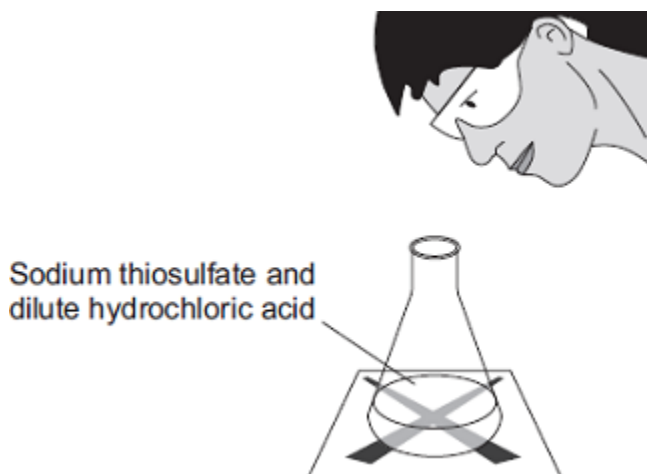
A student investigated the rate of reaction between sodium thiosulfate and dilute hydrochloric acid.

The student placed a conical flask over a cross on a piece of paper.

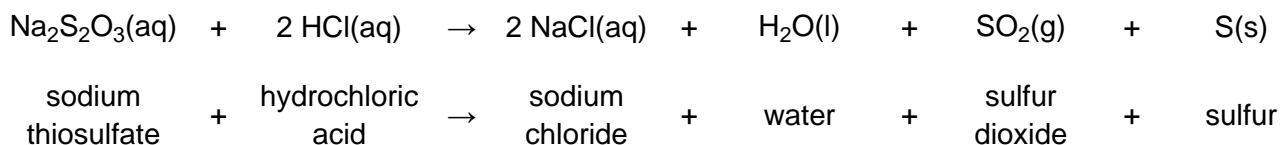
The student mixed the solutions in the flask.

The solution slowly went cloudy.

The student timed how long it took until the cross could not be seen.



The equation for the reaction is:



(a) Explain why the solution goes cloudy.

.....
.....
.....
.....

(2)

(b) The student repeated the experiment with different concentrations of sodium thiosulfate.

Concentration of sodium thiosulfate in moles per dm ³	Time taken until the cross could not be seen in seconds			
	Trial 1	Trial 2	Trial 3	Mean
0.040	71	67	69	69
0.060	42	45	45	44
0.080	31	41	33	

(i) Calculate the mean time for 0.080 moles per dm³ of sodium thiosulfate.

.....

Mean = seconds

(2)

(ii) Describe and explain, in terms of particles and collisions, the effect that increasing the concentration of sodium thiosulfate has on the rate of the reaction.

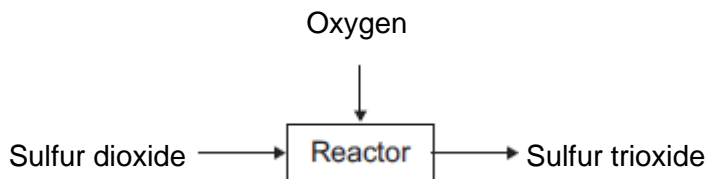
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(3)

(Total 7 marks)

9

(a) The figure below represents the reaction of sulfur dioxide with oxygen.



(i) Complete the word equation for the reaction of sulfur dioxide with oxygen.

sulfur dioxide + →

(1)

(ii) Draw a ring around the correct answer to complete the sentence.

Sulfur dioxide (SO₂) is

- | |
|-------------|
| a compound. |
| an element. |
| a mixture. |

(1)

(b) The reactants are gases.

When the pressure of the gases is increased, the reaction gets faster.

Complete the sentence.

When the pressure of the gases is increased,

the frequency of the collisions

(1)

(c) The particles need energy to react.

Complete the sentence.

The minimum amount of energy that particles need to react is called

the energy.

(1)

(d) Give **one** way of increasing the rate of the reaction other than changing the pressure.

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(1)

(Total 5 marks)

10

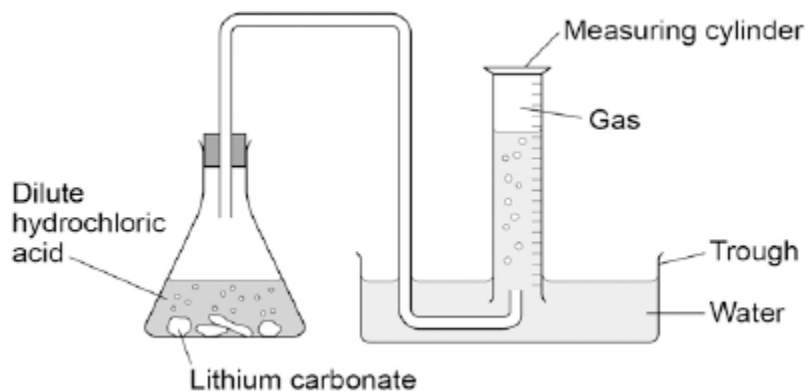
Lithium carbonate reacts with dilute hydrochloric acid.

A group of students investigated the volume of gas produced.

This is the method used.

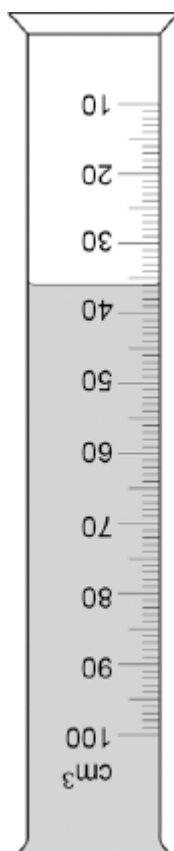
1. Place a known mass of lithium carbonate in a conical flask.
2. Measure 10 cm^3 of dilute hydrochloric acid using a measuring cylinder.
3. Pour the acid into the conical flask.
4. Place a bung in the flask and collect the gas as shown in **Figure 1**.

Figure 1



- (a) **Figure 2** shows the measuring cylinder.

Figure 2



What volume of gas has been collected?

Volume = cm³

(1)

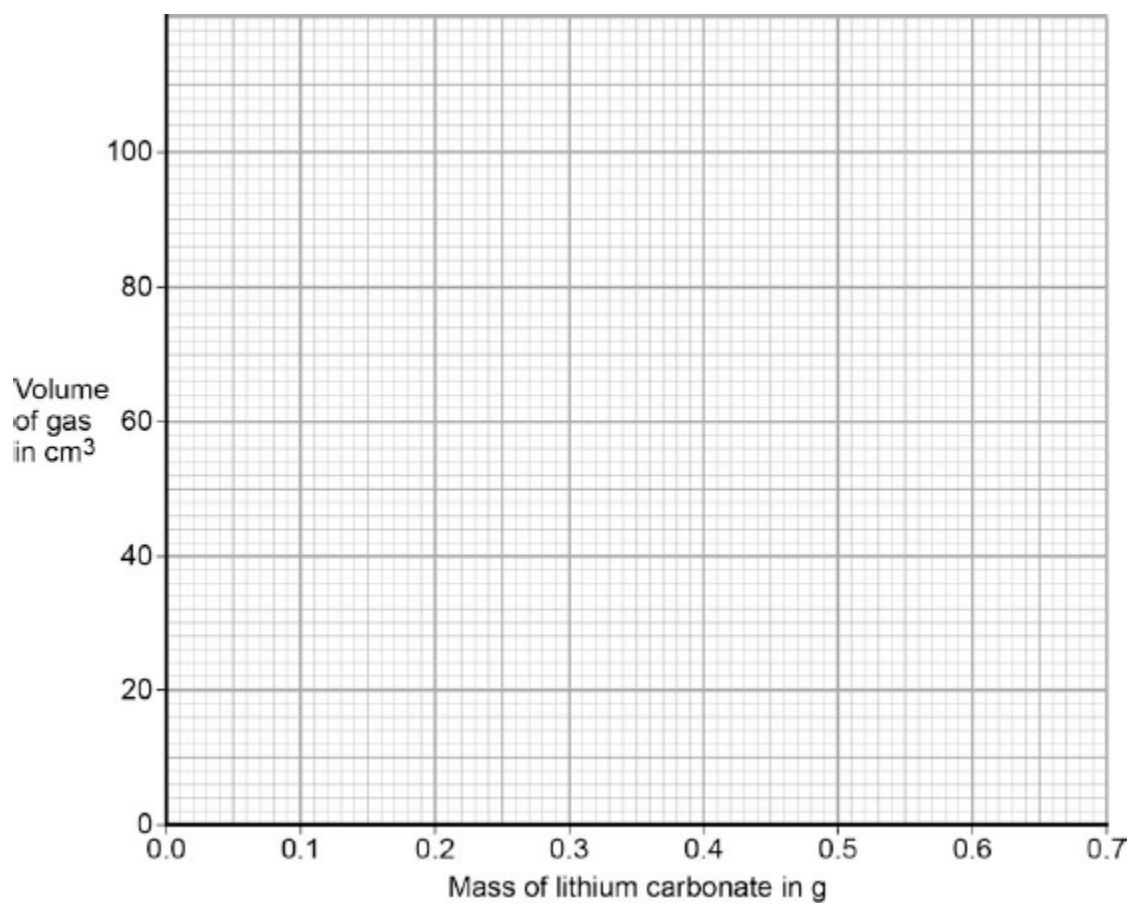
(b) The table below shows the students' results.

Mass of lithium carbonate in g	Volume of gas in cm ³
0.0	0
0.1	22
0.2	44
0.3	50
0.4	88
0.5	96
0.6	96
0.7	96

On **Figure 3**:

- Plot these results on the grid.
- Complete the graph by drawing **two** straight lines of best fit.

Figure 3



(4)

(c) What are **two** possible reasons for the anomalous result?

Tick **two** boxes.

Too much lithium carbonate was added.

The bung was not pushed in firmly enough.

There was too much water in the trough.

The measuring cylinder was not completely over the delivery

The conical flask was too small.

(2)

(d) Describe the pattern the graph shows up to 0.4 g of lithium carbonate added.

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(2)

- (e) Lithium carbonate decomposes when heated.

The equation shows the decomposition of lithium carbonate.

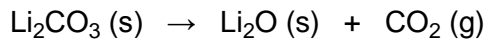
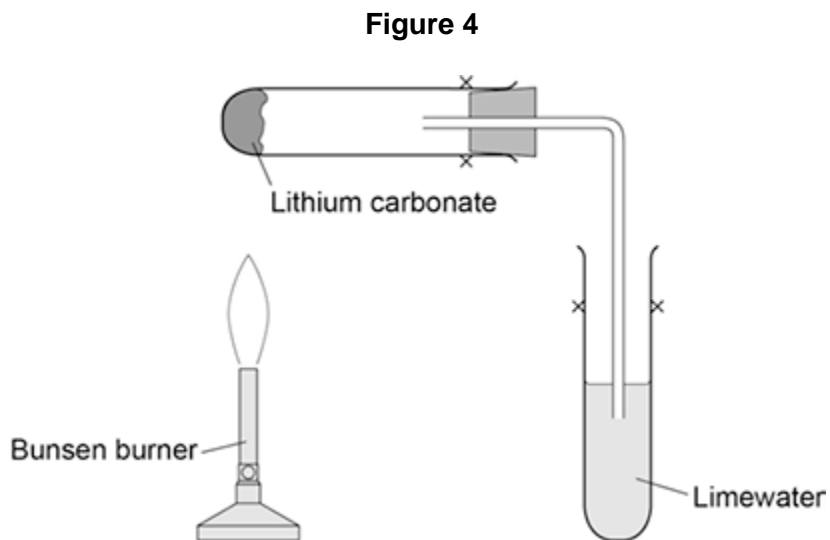


Figure 4 shows the apparatus a student used to decompose lithium carbonate.



Why does the limewater bubble?

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.....

(1)

- (f) The student repeated the experiment with potassium carbonate.
The limewater did not bubble.

Suggest why there were **no** bubbles in the limewater.

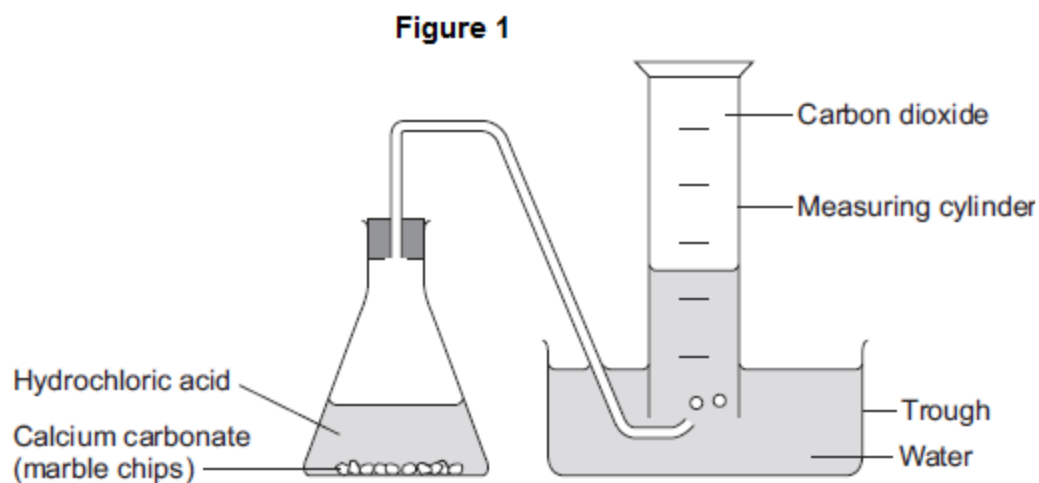
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(1)
(Total 11 marks)

11

A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

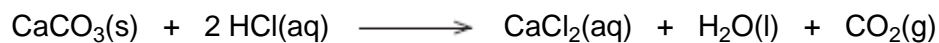
The student used the apparatus shown in **Figure 1**.



The student:

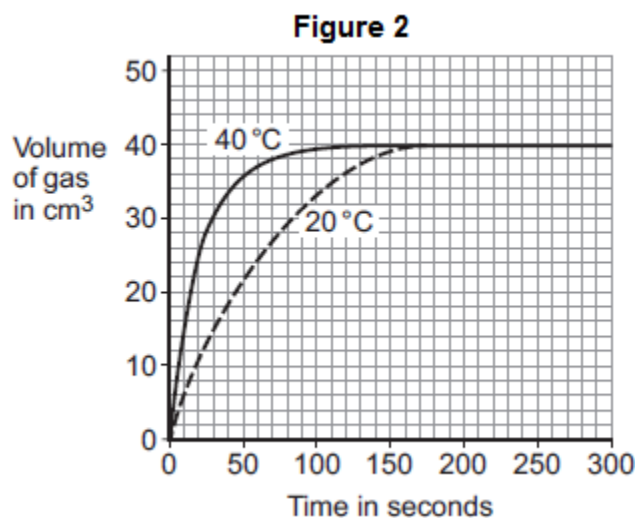
- recorded the volume of gas collected every 5 seconds
- repeated the experiment using hydrochloric acid at different temperatures.

The equation for the reaction is:



- (a) The student plotted results for the hydrochloric acid at 20 °C and 40 °C on a graph.

Figure 2 shows the student's graph.



Use information from **Figure 2** to answer these questions.

- (i) State **one** conclusion the student could make about the effect of temperature on the rate of the reaction.

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.....

(1)

- (ii) Give **one** reason why the student could make this conclusion.

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.....

(1)

- (iii) For the hydrochloric acid at 60 °C the student had collected 30 cm³ after 15 seconds.

Calculate the average rate of reaction from 0 to 15 seconds.

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.....

Rate of reaction = cm³ per second

(1)

(b) The student then investigated how the surface area of marble chips affected the rate of reaction.

(i) Which **two** variables should the student keep constant?

Tick (✓) **two** boxes.

- | | |
|-------------------------------|--------------------------|
| Amount of water in the trough | <input type="checkbox"/> |
| Concentration of acid | <input type="checkbox"/> |
| Mass of marble chips | <input type="checkbox"/> |
| Size of marble chips | <input type="checkbox"/> |
| Volume of measuring cylinder | <input type="checkbox"/> |

(2)

(ii) Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction.

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(2)

(c) Calcium carbonate is a catalyst for the industrial production of biodiesel.

Give **one** reason why using a catalyst reduces costs.

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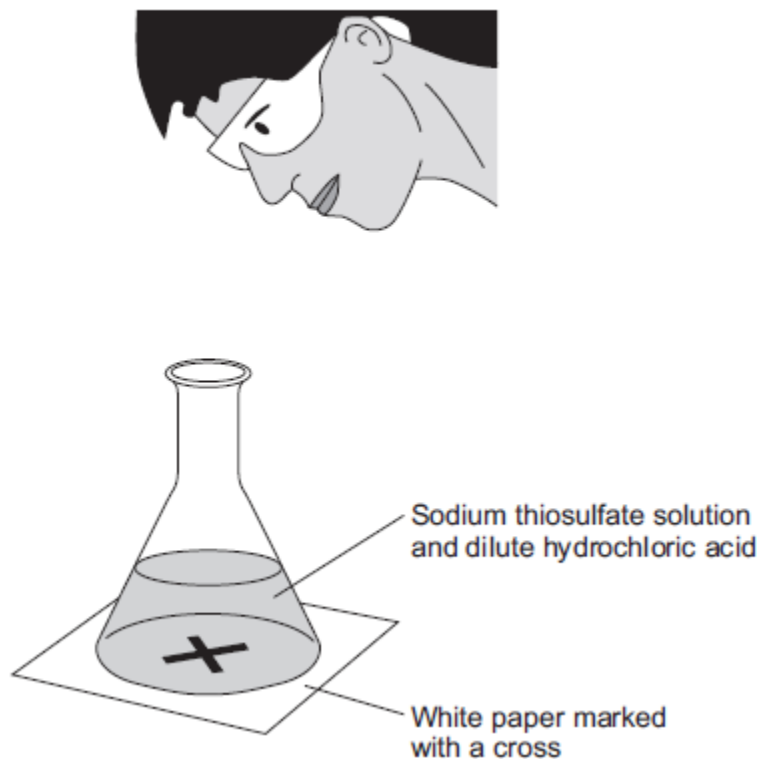
(1)

(Total 8 marks)

12

A student investigated the rate of reaction between sodium thiosulfate solution and dilute hydrochloric acid, as shown in **Figure 1**.

Figure 1



The reaction produced a precipitate, which made the mixture turn cloudy.

The student timed how long it took until she could no longer see the cross.

She calculated the rate of the reaction.

(a) The equation for the reaction is:



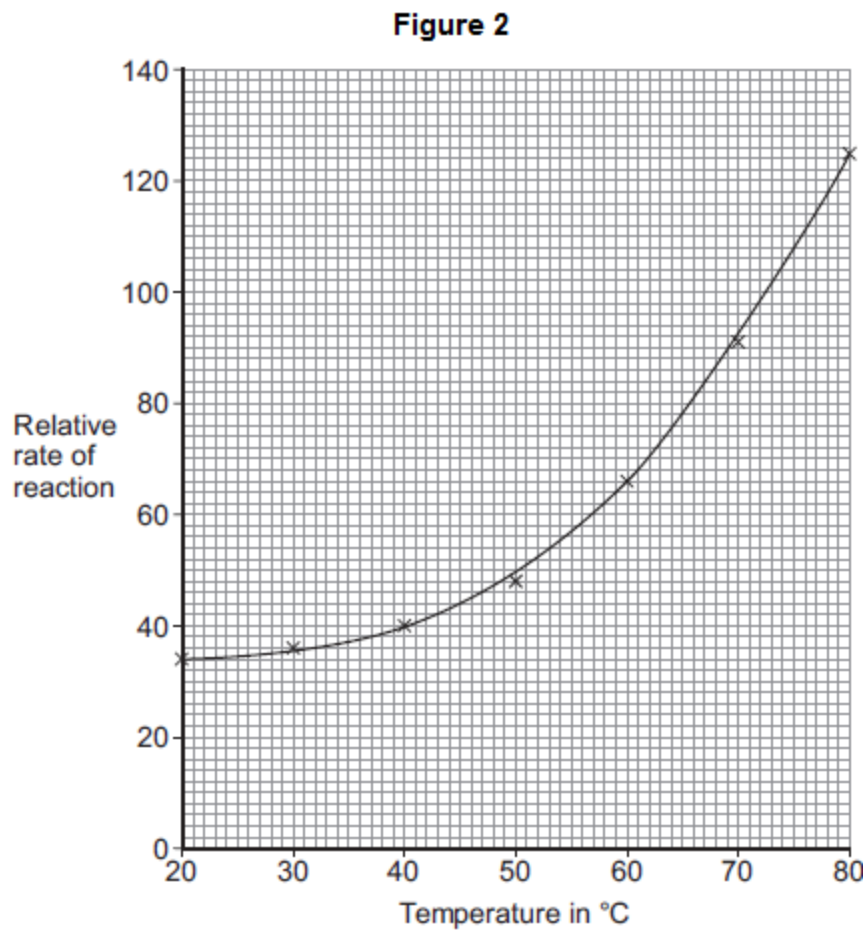
Name the product that made the mixture go cloudy.

.....

(1)

- (b) The student investigated the effect of changing the temperature of the sodium thiosulfate solution on the rate of reaction.

She plotted her results on a graph, as shown in **Figure 2**.



Describe the trends shown in the student's results.

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(2)

(c) The student then investigated the effect of changing the concentration of sodium thiosulfate solution on the rate of the reaction.

(i) Suggest **two** variables the student would need to control to make sure that her results were valid.

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.....
.....

(2)

(ii) From this investigation the student correctly concluded:

‘As the concentration of sodium thiosulfate solution doubles, the rate of reaction doubles.’

Explain the student’s conclusion in terms of particles.

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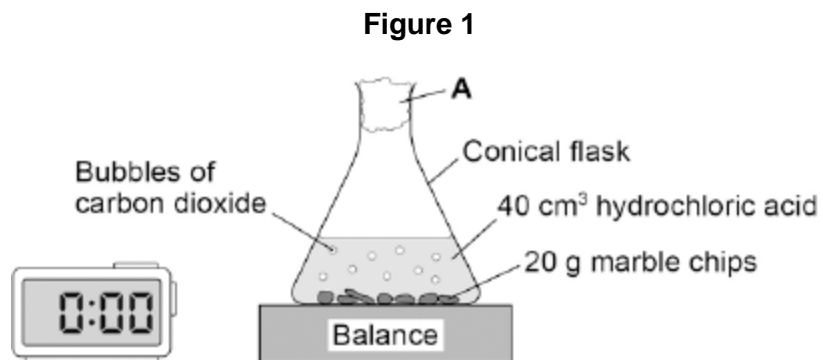
(3)

(Total 8 marks)

13

A student investigated the rate of reaction between marble chips and hydrochloric acid.

Figure 1 shows the apparatus the student used.



(a) What is **A**?

Tick **one** box.

cotton wool

limestone

poly(ethene)

rubber bung

(1)

(b) **Table 1** shows the student's results for one investigation.

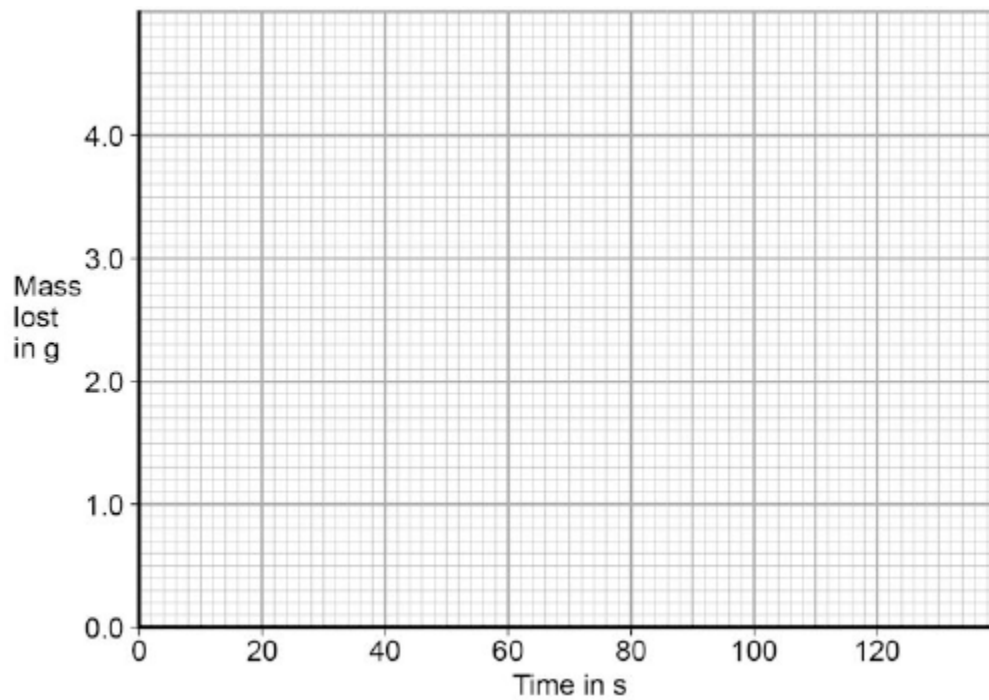
Table 1

Time in s	Mass lost in g
0	0.0
20	1.6
40	2.6
60	2.9
80	3.7
100	4.0
120	4.0

On **Figure 2**:

- Plot these results on the grid.
- Draw a line of best fit.

Figure 2



(3)

(c) Use **Figure 2** to complete **Table 2**.

Table 2

Mass lost after 0.5 minutes g
Time taken to complete the reaction s

(2)

(d) The equation for the reaction is:



Explain why there is a loss in mass in this investigation.

.....
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(2)

(e) Another student investigated the rate of a different reaction.

Table 3 shows the results from the different reaction.

Table 3

Mass lost when the reaction was complete	9.85 g
Time taken to complete the reaction	2 minutes 30 seconds

Calculate the mean rate of the reaction using **Table 3** and the equation:

$$\text{mean rate of reaction} = \frac{\text{mass lost in g}}{\text{time taken in s}}$$

Give your answer to two decimal places.

.....
.....

Mean rate of reaction = g / s

(2)

(f) The student measured the change in mass of the reactants.

Describe another method, other than measuring the change in mass of the reactions, that the student could have used to find the rate of the reaction between marble chips and hydrochloric acid.

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.....

(2)

(g) Another student planned to investigate the effect of temperature on the rate of reaction. The student predicted that the rate of reaction would increase as the temperature was increased.

Give **two** reasons why the student's prediction is correct.

Tick **two** boxes.

The particles are more concentrated.

The particles have a greater mass.

The particles have a larger surface area.

The particles have more energy.

The particles move faster.

(2)
(Total 14 marks)

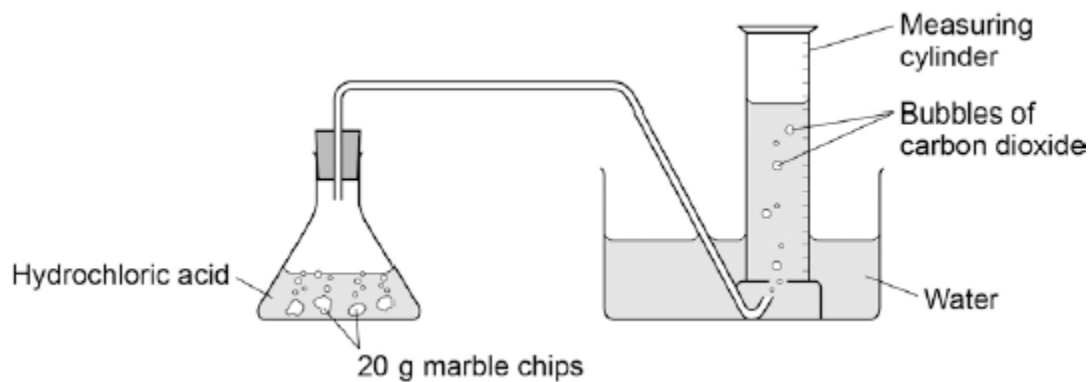
14

Marble chips are mainly calcium carbonate (CaCO_3).

A student investigated the rate of reaction between marble chips and hydrochloric acid (HCl).

Figure 1 shows the apparatus the student used.

Figure 1



- (a) Complete and balance the equation for the reaction between marble chips and hydrochloric acid.



(2)

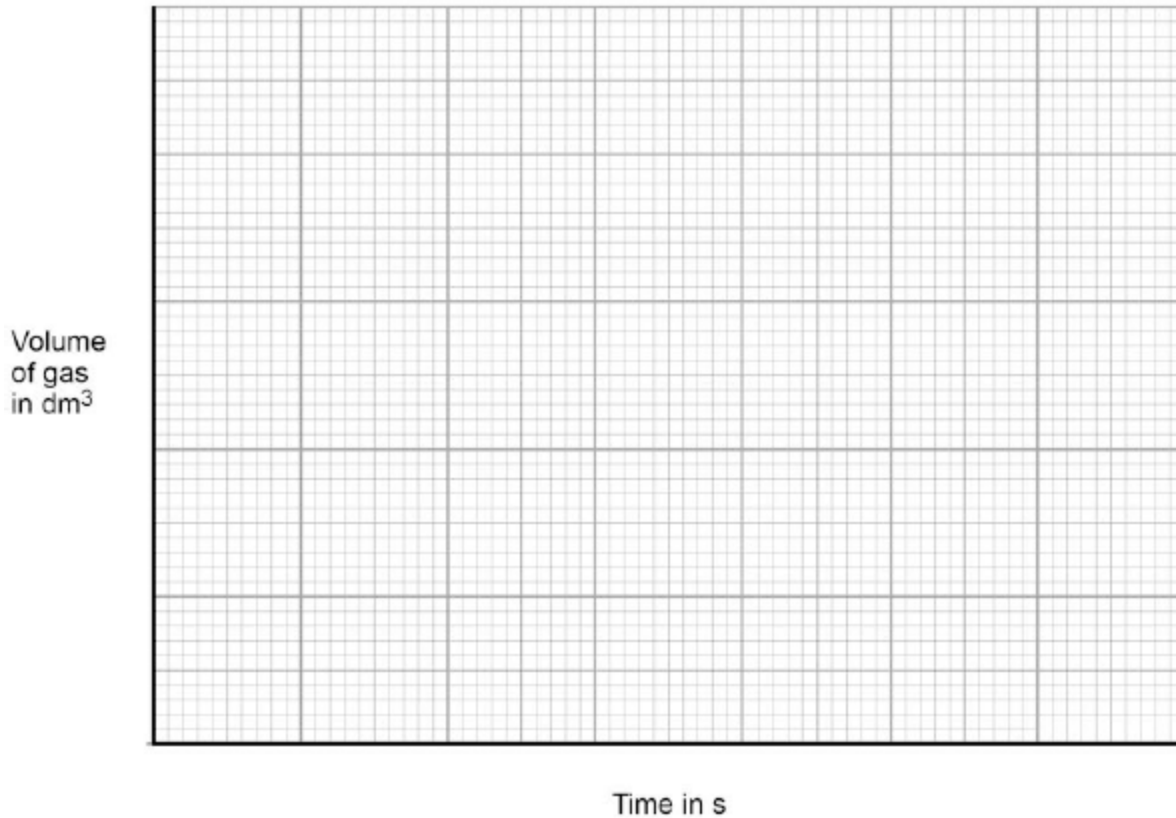
(b) The table below shows the student's results.

Time in s	Volume of gas in dm ³
0	0.000
30	0.030
60	0.046
90	0.052
120	0.065
150	0.070
180	0.076
210	0.079
240	0.080
270	0.080

On **Figure 2**:

- Plot these results on the grid.
- Draw a line of best fit.

Figure 2



(4)

- (c) Sketch a line on the grid in **Figure 2** to show the results you would expect if the experiment was repeated using 20 g of smaller marble chips.

Label this line **A**.

(2)

- (d) Explain, in terms of particles, how and why the rate of reaction changes during the reaction of calcium carbonate with hydrochloric acid.

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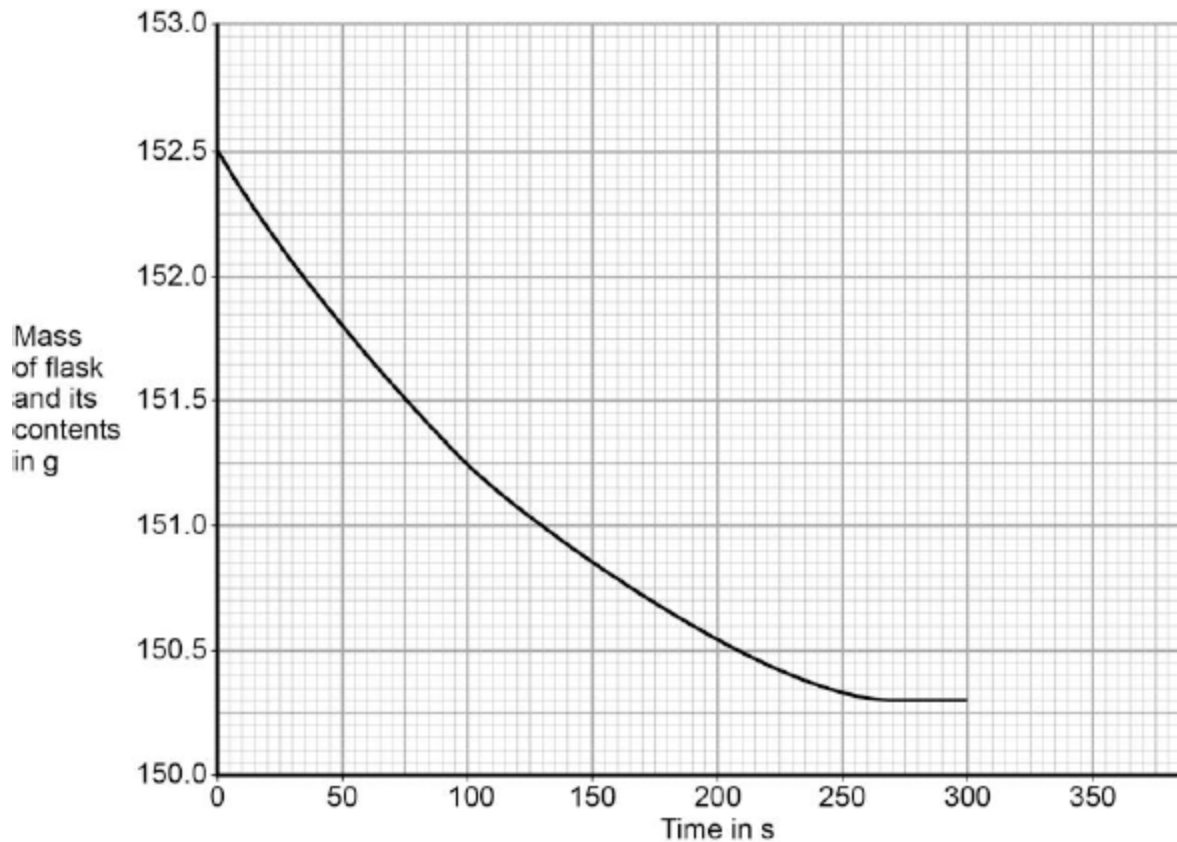
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(4)

(e) Another student investigated the rate of reaction by measuring the change in mass.

Figure 3 shows the graph plotted from this student's results.

Figure 3



Use **Figure 3** to calculate the mean rate of the reaction up to the time the reaction is complete.

Give your answer to three significant figures.

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Mean rate of reaction = g / s

(4)

(f) Use **Figure 3** to determine the rate of reaction at 150 seconds.

Show your working on **Figure 3**.

Give your answer in standard form.

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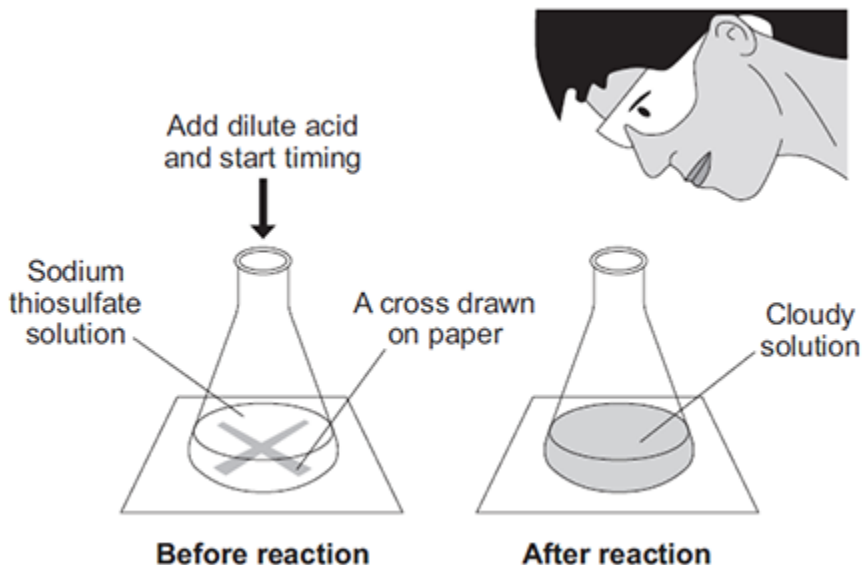
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Rate of reaction at 150 s = g / s

(4)
(Total 20 marks)

15

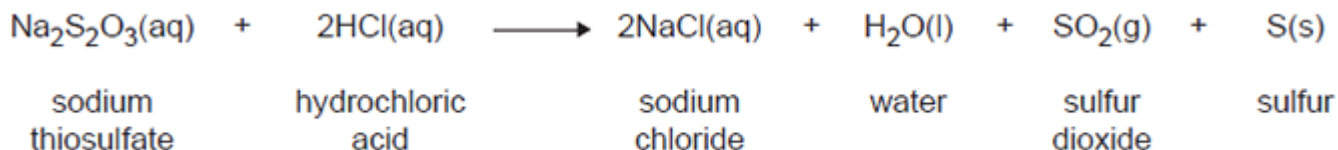
A student investigated the effect of temperature on the rate of a reaction. The picture below shows an experiment.



The student:

- put sodium thiosulfate solution into a conical flask
- heated the sodium thiosulfate solution to the required temperature
- put the flask on a cross drawn on a piece of paper
- added dilute hydrochloric acid and started a stopclock
- stopped the stopclock when the cross could no longer be seen
- repeated the experiment at different temperatures.

The equation for the reaction is:



(a) Explain why the solution goes cloudy.

.....

.....

.....

.....

(2)

(b) Give **two** variables the student must control to make the investigation a fair test.

1

2

(2)

(c) State the effect that increasing the temperature of the sodium thiosulfate solution has on the rate of the reaction.

Explain this effect in terms of particles and collisions.

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.....

(4)

(d) Suggest how the student should change the method to investigate the rate of reaction at 5°C.

.....
.....

(1)

(Total 9 marks)

Mark schemes

- 1** (a) (i) nothing can enter **and** nothing can leave the reaction
allow sealed reaction vessel 1
- (ii) forward and backward reactions have same rate 1
- so there is no (overall) change in quantities of reactants and products
allow concentrations of reactants and products 1
- (b) (i) natural gas
allow methane / CH₄
allow fossil fuels / hydrocarbons
allow water 1
- (ii) provides an alternative reaction pathway 1
- which has a lower activation energy
ignore references to collisions 1
- (iii) the amount (of ammonia) increases
allow yield increases 1
- the equilibrium moves to the side (of the equation) with fewer (gaseous) molecules / moles
allow it favours the forward reaction 1
- (c) (i) vertical arrow from reactants to maximum 1
- (ii) (energy of) products higher than (energy of) reactants
allow converse 1
- (iii) amount of hydrogen iodide decreases 1
- equilibrium moves in the direction of the endothermic reaction
allow it favours the forward reaction 1
- [12]**
- 2** (a) (i) a continuous straight line missing anomalous point
allow a line which does not start at zero / origin 1

(ii) any **two** sensible errors eg

- timing errors and / or example(*)
- measurement errors and / or example(*)
- apparatus errors and / or example(*)
- human / experimental / random error and / or example
or 'did not do it right'(*)
()could be two from **same** category eg two timing errors – watch
not started at the same time plus difficulty in deciding when the
cross has disappeared.*
- temperature fluctuation
- anomalous point
accept outlier / wrong result
- results not recorded correctly
- plotting error
- rate calculated incorrectly
ignore 'not repeated'
*ignore systematic / zero error / weighing error **or** error unqualified*

2

(b) (i) straight line

or

as concentration increases the rate goes up **or** converse

accept numerical example

accept positive correlation

accept same gradient

ignore 'most points near / on line of best fit'

1

- (ii) more collisions
accept greater chance of collisions
accept collide more successfully
accept alternative versions of collide eg 'bump / hit'
ignore references to energy / speed of particles / surface area

1

- more particles (in each volume of solution)(i.e. an attempt at defining concentration)
accept 'particles are closer together'
allow ions / atoms / molecules for particles ignore reactants
*accept greater frequency of collisions **or** greater number of collisions per second for **2** marks*

1

[6]

3

- (a) (i) accurate plotting of points ($\pm \frac{1}{2}$ square)
2 marks for all points
1 mark for 3 or 4 points

2

- sensible smooth curve
reasonable attempt
*do **not** accept double lines **or** dot to dot*

1

- (ii) accurately read from their graph to $\pm \frac{1}{2}$ square

1

- (b) (i) (as temperature increases) rate increases
accept speeds up, gets faster, gets quicker
accept higher speed
*do **not** accept gets bigger / higher unqualified*
*do **not** accept answers about time on its own*

1

- (ii) **Quality of Written Communication**
The answer to this question requires ideas in good English in a sensible order with correct use of scientific terms. Quality of written communication should be considered in crediting points in the mark scheme.

maximum 2 marks if ideas not expressed well

any **three** from:

for converse maximum 2 marks

particles have more energy

higher kinetic energy

particles move faster

*do **not** accept move more or vibrate more*

3

more collisions

accept greater rate of collisions

more energetic / successful / harder collisions

more particles have activation energy

(c) concentration (of solutions) **or** volume (of solutions)

accept 'how much of'

accept references to intensity of colour

accept same endpoint

accept rate of stirring / shaking

*do **not** accept reference to solids **or** catalysts etc*

ignore containers

*do **not** accept pH*

1

[9]

4

use a more concentrated solution of sulfuric acid

1

grind the phosphate rock into a powder before adding the acid

1

increase the temperature of the sulfuric acid

1

[3]

5

(a) (i) increase

1

(ii) energy is given out to the surroundings

1

(b) (i) NO

allow 2NO

ignore nitrogen oxide

*do **not** allow equations*

1

(ii) harmful / poisonous (owtte)
allow dangerous
ignore reference to pollution / global warming
*do **not** accept references to ozone layer*

1

(c) a catalyst can speed up a chemical reaction

1

different reactions need different catalysts

1

(d) (i) smaller
accept less / tiny / very small
allow 10^{-9}
*do **not** allow small unless qualified*

1

(ii) reduce cost (owtte) **or**
ignore references to energy
save resources / raw materials (owtte)

1

[8]

6

(a) (i) 0.2
correct answer gains 2 marks with or without working
accept answer in table
if answer incorrect 5/25 gains 1 mark

2

(ii) any **one** from:

- wider range of temperatures (owtte)
- (repeat at the same temperature) to improve accuracy / reliability
allow to make it reliable / accurate
- reveal anomalous results (owtte)
allow to eliminate random / human errors / to check results owtte
- so you can get an average / better average
ignore to make it a fair test / to get better results
ignore precision and validity

1

(b) any **two** from:

allow atoms / molecules / they instead of particles throughout

- particles gain energy / have more energy
ignore increases particles activation energy
- particles move faster
ignore move more / vibrate more
- particles collide more
- more of the particles have the activation energy **or** more of the collisions are successful (owtte)
ignore increases / decreases activation energy

or

particles collide with more force / harder / more energy

allow more successful collisions

alone for 1 mark

2

[5]

7

(a) particles move faster

accept molecules / atoms / ions instead of particles

or

particles have more energy

ignore move / vibrate more

1

so they collide more often / frequently

allow particles collide harder / with more force

ignore collide quicker

or

more of the collisions are successful / have the activation energy

ignore collide more / more collisions

1

(b) any **one** from:

- increase surface area (of the rock)
accept crush / powder the rock
- increase the concentration (of the acid)
ignore increase the pressure / temperature
- add a catalyst
- stir / mix the mixture

1

[3]

8

(a) because sulfur / S forms

1

which is insoluble / a solid / a precipitate

1

(b) (i) 32

correct answer with or without working gains 2 marks

accept evidence of 31 + 33 / 2 for 1 mark

allow 35 for 1 mark

2

(ii) reaction rate increases

if incorrect reference to energy = max 2

1

because of more particles (per unit volume)

allow because particles are closer together

1

and because there is an increase in frequency of collisions

*accept because particles are more likely to collide **or** higher chance of collision*

ignore more (successful) collisions

1

[7]

9	(a) (i) oxygen, sulfur <u>tr</u> ioxide <i>both needed for mark</i>	1
	(ii) compound	1
	(b) increases <i>accept (goes) higher / (goes) up / (is) faster / (are) more frequent</i>	1
	(c) activation	1
	(d) catalyst or increase temperature	1
		[5]
10	(a) 36 cm ³	1
	(b) all points correct <i>± ½ small square</i> <i>allow 1 mark if 6 or 7 of the points are correct</i>	2
	2 best fit lines drawn <i>must not deviate towards anomalous point</i> <i>allow 1 mark if 1 line correct</i>	2
	(c) The bung was not pushed in firmly enough.	1
	The measuring cylinder was not completely over the delivery tube.	1
	(d) as mass of lithium carbonate increases volume of gas produced increases linear / (directly) proportional	1
	(e) A gas / carbon dioxide is produced. <i>allow because the air in the tube expands</i>	1
	(f) any one from: <ul style="list-style-type: none"> • Potassium carbonate does not decompose to produce carbon dioxide / a gas. • Potassium carbonate does not decompose at the temperature of the Bunsen burner or the Bunsen burner is not hot enough to decompose potassium carbonate. • When potassium carbonate decomposes a gas is not formed. 	1
		[11]

- 11** (a) (i) the higher the temperature, the greater the rate
or
 at 40 °C rate is faster than at 20 °C
accept the higher the temperature, the faster the reaction 1
- (ii) 40 °C curve is steeper
accept the 40 °C line becomes horizontal sooner
accept at higher temperatures the reaction finishes sooner
accept reaction finishes sooner at 40 °C
accept at higher temperatures the gas is produced faster
or
 correct comparison of data from the graph 1
- (iii) 2 1
- (b) (i) Concentration of acid
 Mass of marble chips 2
- (ii) increases rate
incorrect reference to energy = max 1 1
- (because of) more frequent collisions (between particles)
accept particles are more likely to collide
ignore more collisions
ignore more successful collisions 1
- (c) any **one** from:
 • increases rate of reaction
 • reduces energy required
 • lower temperature can be used
 • catalyst is not used up. 1
- [8]**
- 12** (a) sulfur / sulphur / S / S(s) 1
- (b) as the temperature increases, the rate of reaction increases
allow two correct values for rate quoted (from graph) at different temperatures 1
- the rate of increase increases **or** there is an exponential relationship
accept the rate of reaction increases slowly (from 20 °C to 50 °C)
then increases more rapidly for 2 marks
answer MUST be based on rate / speed of reaction 1

- (c) (i) any **two** from:
- temperature (of the reactants)
 - concentration of hydrochloric acid
 - volume of hydrochloric acid
 - volume of sodium thiosulfate
 - the (size / darkness / thickness of the) cross
 - total volume of solution.

if no other marks gained, allow 1 mark for:

rate of stirring

OR

amount of hydrochloric acid / sodium thiosulfate

OR

volume of solution

2

- (ii) (because as the concentration increases) the number of particles per unit volume increases **or** particles are closer together.

idea of more particles in a given space is required for the first mark.

ignore references to area.

1

(therefore) the frequency of (successful) collisions increases

allow increased chance / probability of collisions

number of collisions increases is insufficient here.

must mention per unit time or frequency.

ignore speed of collisions.

if reference to space and time missing from M1 and M2 but they are otherwise correct, then award 1 mark.

1

so the number of particles (per unit volume) doubles **or** (the frequency of) collisions doubles.

students can score 2 marks for a qualitative explanation; the third mark is for a quantitative explanation.

1

[8]

13

- (a) cotton wool

1

- (b) all points correct

± ½ small square

2

allow 1 mark if 5 or 6 of the points are correct

best fit line

must not deviate towards anomalous point

1

- (c) (mass)
2.1 (g)
allow ecf from drawn best fit line 1
- (time)
100 (s) 1
- (d) a gas is produced 1
which escapes from the flask 1
- (e) $\frac{9.85}{150} = 0.0656$ 1
0.07 (g / s)
allow ecf answer correctly calculated to 2 decimal places 1
- (f) collect the gas in a gas syringe 1
measured the volume of gas
allow carbon dioxide for gas 1
allow for 1 mark
collected gas
or
counted bubbles
- (g) The particles have more energy 1
The particles move faster 1
- 14** (a) $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$ 2
allow 1 mark for correct formulae
- (b) sensible scales, using at least half the grid for the points 1
all points correct
 $\pm \frac{1}{2}$ small square
allow 1 mark if 8 or 9 of the points are correct 2
best fit line 1

[14]

- (c) steeper line to left of original 1
- line finishes at same overall volume of gas collected 1
- (d) acid particles used up 1
- allow marble / reactant used up*
- so concentration decreases 1
- allow surface area of marble decreases*
- so less frequent collisions / fewer collisions per second 1
- do **not** accept fewer collisions unqualified*
- so rate decreases / reaction slows down 1
- (e) mass lost of 2.2 (g) 1
- time taken of
270 s
- allow values in range 265 – 270* 1
- $$\frac{2.2}{270} = 0.00814814$$
- allow ecf for values given for mass and time* 1
- 0.00815 (g / s)
- or**
- 8.15×10^{-3}
- allow 1 mark for correct calculation of value to 3 sig figs*
- accept 0.00815 or 8.15×10^{-3} with no working shown for 4 marks* 1
- (f) correct tangent 1
- eg 0.35 / 50 1
- 0.007 1
- allow values in range of 0.0065 – 0.0075*
- 7×10^{-3} 1

accept 7×10^{-3} with no working shown for 4 marks

[20]

15

(a) because sulfur / S (forms)

1

(which) is solid / insoluble / a precipitate / a suspension

1

(b) any **two** from:

- volume of sodium thiosulfate
ignore amount of sodium thiosulfate
- volume of (hydrochloric) acid
ignore amount of (hydrochloric) acid
- concentration of sodium thiosulfate
- concentration of (hydrochloric) acid

*if no other mark, allow 1 mark for same cross **or** same flask **or** unspecified volume **or** unspecified concentration*

ignore same person

*do **not** accept references to temperature*

2

(c) rate increases

1

because particles move faster

accept particles have more energy

1

so frequency of collisions increases

*accept particles are more likely to collide **or** more chance of collisions*

ignore more collisions

1

more particles / collisions have energy greater than (or equal to) the activation energy

1

(d) cool

*accept refrigerate **or** method to decrease temperature*

or

decrease the temperature (of the solutions)

1

[9]