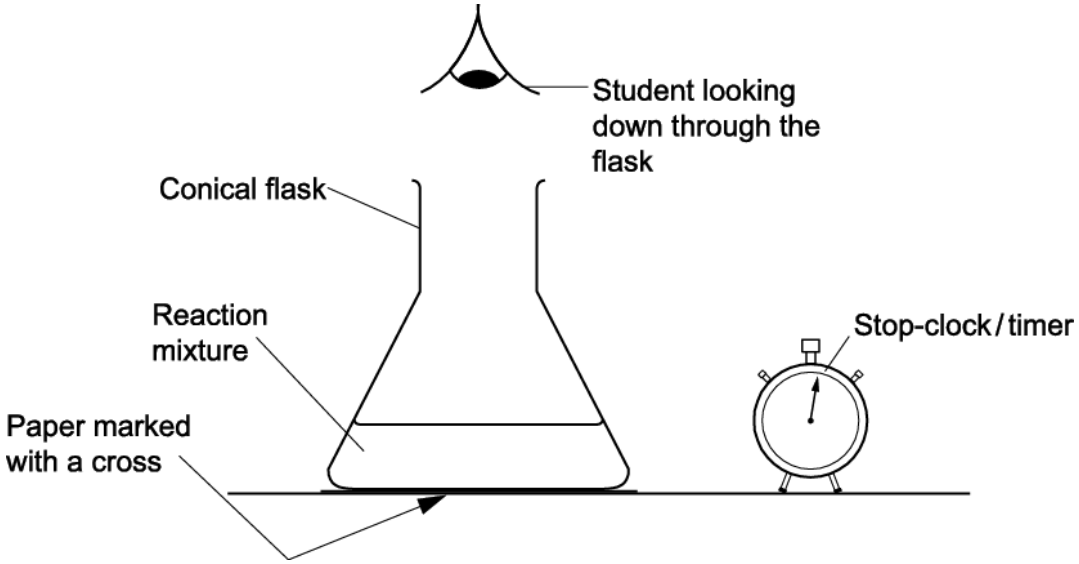
Answer **all** the questions.

1. A student investigates the reaction between sodium thiosulfate and hydrochloric acid.
Look at the diagram below. It shows the apparatus he uses.



After a time he cannot see the cross because the liquid in the beaker goes cloudy. The student measures the time taken until the cross cannot be seen.

He does the experiment four times, each with a different concentration of sodium thiosulfate solution.

Which of the following must **not** be changed to do a fair test?

A concentration of sodium thiosulfate used
B stop-clock or timer
C total volume of the reaction mixture
D volume of sodium thiosulfate added

Your answer ☐

[1]

2. A student investigates the reaction between sodium carbonate and dilute nitric acid.

She measures the reaction time with four different concentrations of acid.

She does all the experiments using the

- same temperature
- same mass of sodium carbonate
- same volume of acid.

Look at her results.

Concentration	Reaction time in seconds
A	41
B	74
C	135
D	67

Which concentration of nitric acid gave the **fastest** reaction?

Your answer ☐

[1]

3(a). Zinc and dilute sulfuric acid react to make hydrogen.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Inga measures the rate of this reaction by measuring the **loss in mass** of the reaction mixture.

She finds that the change in mass is very small and difficult to measure.

Draw a labelled diagram to show a **better way** of measuring the rate of this reaction.

[3]

(b). The reaction between zinc and dilute sulfuric acid is slow.

Inga decides to try and find a catalyst for this reaction.

She tests four possible substances.

Each time she adds 0.5 g of the substance to 1.0 g of zinc and 25 cm^3 of dilute sulfuric acid.

Look at her table of results.

Substance	Colour of substance at start	Colour of substance at end	Relative rate of reaction
no substance			1
calcium sulfate powder	white	white	1
copper powder	pink	pink	10
copper(II) sulfate powder	blue	pink	30
manganese(IV) oxide powder	black	black	1

(i) It is important to do the reaction with **only** zinc and dilute sulfuric acid.

Explain why.

---

[1]

(ii) It is important to do all of the reactions with the same concentration of acid.

Explain why.

---

[1]

(iii) Which of the substances could be a catalyst for the reaction between zinc and dilute sulfuric acid?

Explain your answer.

---

[2]

(iv) There is not enough evidence to confirm which substance is a catalyst.

Suggest an extra piece of experimental evidence that could be collected to confirm which substance is a catalyst.

---

[1]

(v) Inga does the experiment with copper, zinc and dilute sulfuric acid again.

This time she uses a lump of copper rather than copper powder.

Predict, with reasons, the relative rate of reaction.

---

[2]

4. The Contact Process is used to manufacture sulfuric acid.

The Contact Process involves the reaction between sulfur dioxide and oxygen.

The conditions used are 450°C and about 10 atmospheres pressure.

(i) If the temperature is increased to 500°C the rate of reaction changes.

Describe and explain this change in rate of reaction.

---

[2]

(ii) If the pressure is reduced to 5 atmospheres the rate of reaction changes.

Describe and explain this change in rate of reaction.

---

[2]

5. Zinc and dilute sulfuric acid react to make hydrogen.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Inga measures the rate of this reaction by measuring the **loss in mass** of the reaction mixture.

She finds that the change in mass is very small and difficult to measure.

Draw a labelled diagram to show a **better way** of measuring the rate of this reaction.

[3]

6. A student investigates the reaction between 1.0 g of calcium carbonate and 20 cm^3 of 1.0 mol/dm^3 hydrochloric acid at 25°C.

The student does two experiments. He uses different sized pieces of calcium carbonate for each experiment.

The rate of reaction is greater in the first experiment.

Which is the best explanation for this?

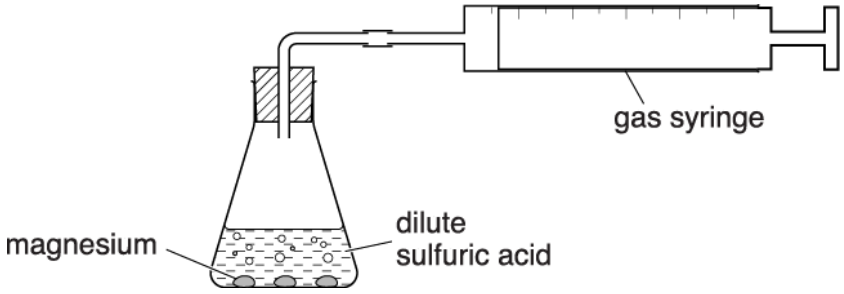
A Small pieces of calcium carbonate have a larger surface area resulting in less frequentcollisions.
B Large pieces of calcium carbonate have a larger surface area resulting in less frequentcollisions.
C Large pieces of calcium carbonate have a smaller surface area resulting in morefrequent collisions.
D Small pieces of calcium carbonate have a larger surface area resulting in morefrequent collisions.

Your answer ☐

[1]

7. Hayley and Andy investigate the reaction between magnesium and sulfuric acid.

Look at the diagram. It shows the apparatus they use.

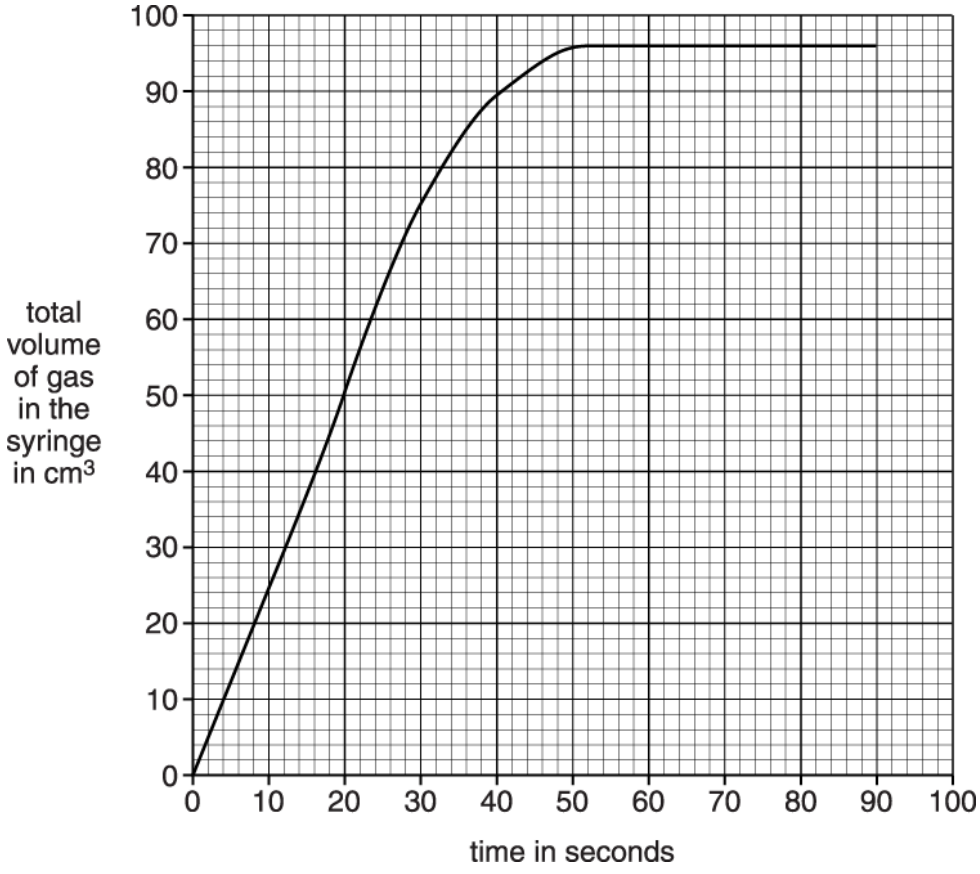


They add 0.1 g of magnesium to 50 cm^3 of sulfuric acid.

They measure the total volume of gas in the syringe every 10 seconds.

All the magnesium is used up at the end of the reaction.

Look at the graph of their results.



(i) What is the total volume of gas in the syringe after 30 seconds?

answer _____ cm^3 **[1]**

(ii) How long does it take for the reaction to stop?

answer _____ seconds **[1]**

(iii) Hayley and Andy do the experiment again.

They use the same volume and concentration of sulfuric acid.

This time they only use 0.05 g of magnesium.

On the grid, sketch the graph they should get. **[2]**

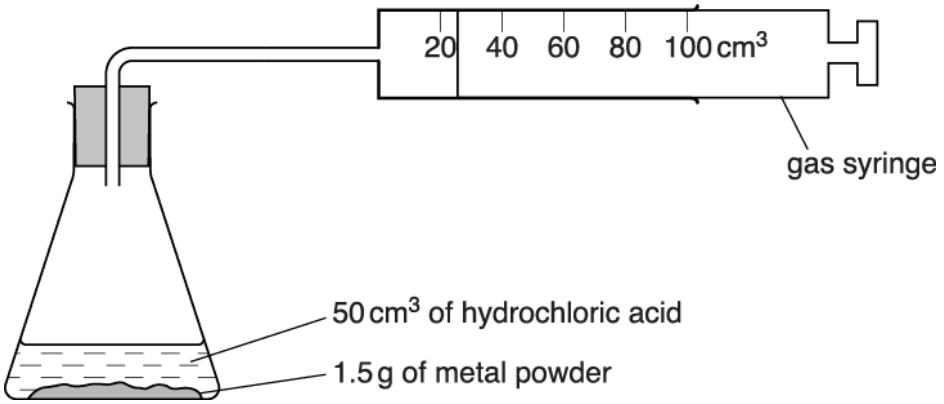
8. Zinc reacts with hydrochloric acid.

Hydrogen gas and zinc chloride are made.

Fatimah and Sam investigate the reaction between acid and metals.

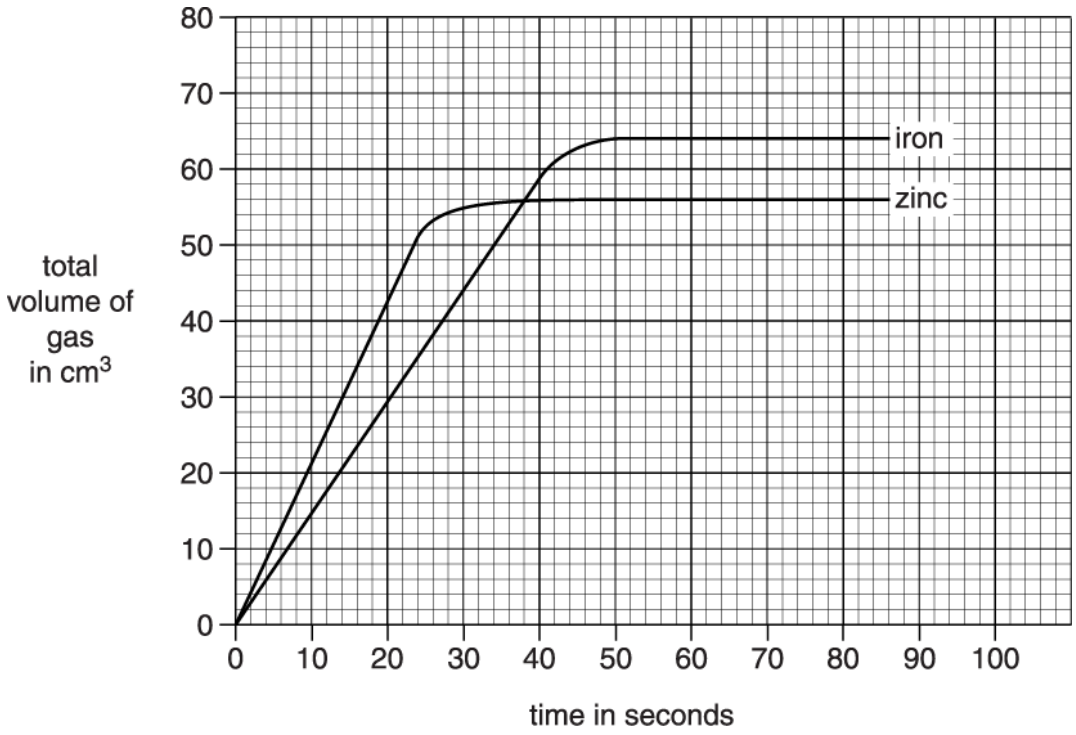
They react dilute hydrochloric acid with zinc powder and then with iron powder.

Look at the apparatus they use.



Every 10 seconds they measure the volume of gas in the gas syringe.

Look at the graph of the results.



(i) The graph for the reaction of **zinc** is different from the graph for **iron**.

Write about **two** differences in these graphs.

---**[2]**

(ii) Iron powder reacts faster than a lump of iron of the same mass.

Explain why.

---**[1]**

(iii) Fatimah and Sam want to make the reaction between iron powder and dilute hydrochloric acid **faster**.

They do not want to change the mass of the iron powder or the volume of acid.

Write about **three** ways they can make the reaction faster.

---**[3]**

9. Nitrogen molecules and oxygen molecules react extremely slowly, even at 200 °C.

Write about the **different ways** in which the reaction between nitrogen and oxygen can be made faster and explain, using the reacting particle model, how one of these ways works.

The quality of written communication will be assessed in your answer to this question.

---

[6]

10. Nitrogen molecules react with oxygen molecules.

Nitrogen monoxide molecules are made.

$$N_2 + O_2 \text{ ? } 2NO$$

The reaction is endothermic.

Nitrogen molecules and oxygen molecules react extremely slowly, even at 200 °C.

The reaction between nitrogen and oxygen becomes faster as both the temperature and the pressure increase.

Explain why, using the reacting particle model.

The quality of written communication will be assessed in your answer to this question.

[6]

11(a). Zinc, Zn, reacts with hydrochloric acid, HCl.

Hydrogen gas, H_2, and zinc chloride, $ZnCl_2$, are made.

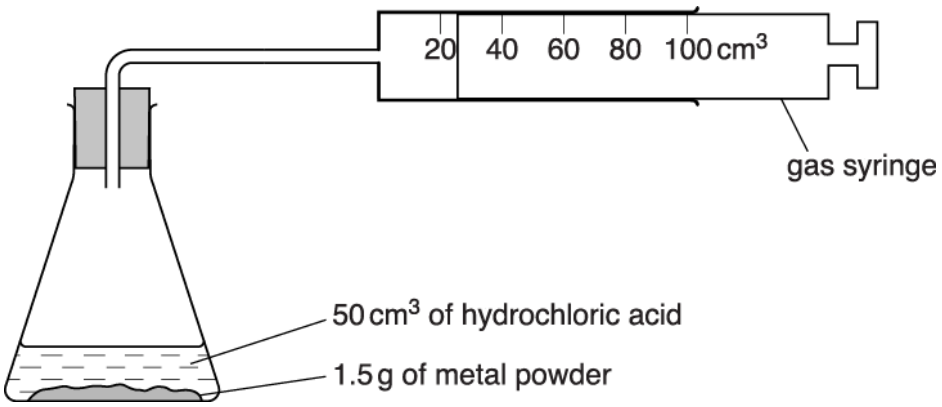
Construct the **balanced symbol** equation for this reaction.

[1]

(b). Fatimah and Sam investigate the reaction between acid and metals.

They react dilute hydrochloric acid with zinc powder and with iron powder.

Look at the apparatus they use.

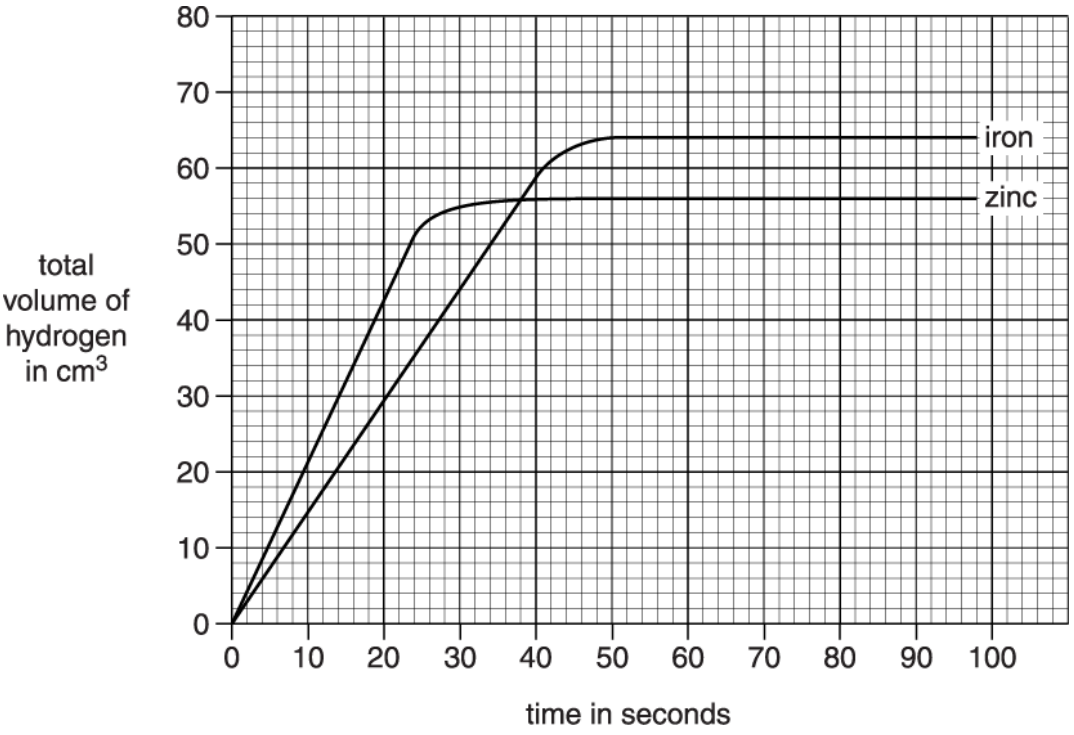


Every 10 seconds they measure the volume of gas in the gas syringe.

Fatimah and Sam do three different experiments.

- 50 cm^3 hydrochloric acid and 0.15 g of zinc
- 50 cm^3 hydrochloric acid and 0.15 g of iron
- 50 cm^3 hydrochloric acid and 0.075 g of iron mixed with 0.075 g of zinc.

Look at the graph of the results for the first two experiments.



(i) Calculate the rate of reaction of **iron** during the **first 30 seconds**.

---

rate of reaction = _____ cm^3 / s

[1]

(ii) Predict the total volume of hydrogen formed when the **mixture** of zinc and iron powder is used.

_____ cm^3

[1]

(c). Increasing the concentration of a reactant in solution will increase the rate of reaction.

Use the reacting particle model to explain why.

---

[2]

12(a). Fatimah investigates the reaction between sodium hydrogencarbonate and dilute hydrochloric acid.

Fatimah does two investigations.

She always adds 0.5 g of sodium hydrogencarbonate to 20 cm^3 of dilute hydrochloric acid.

She measures the time it takes for the reaction mixture to stop bubbling.

This is called the **reaction time**.

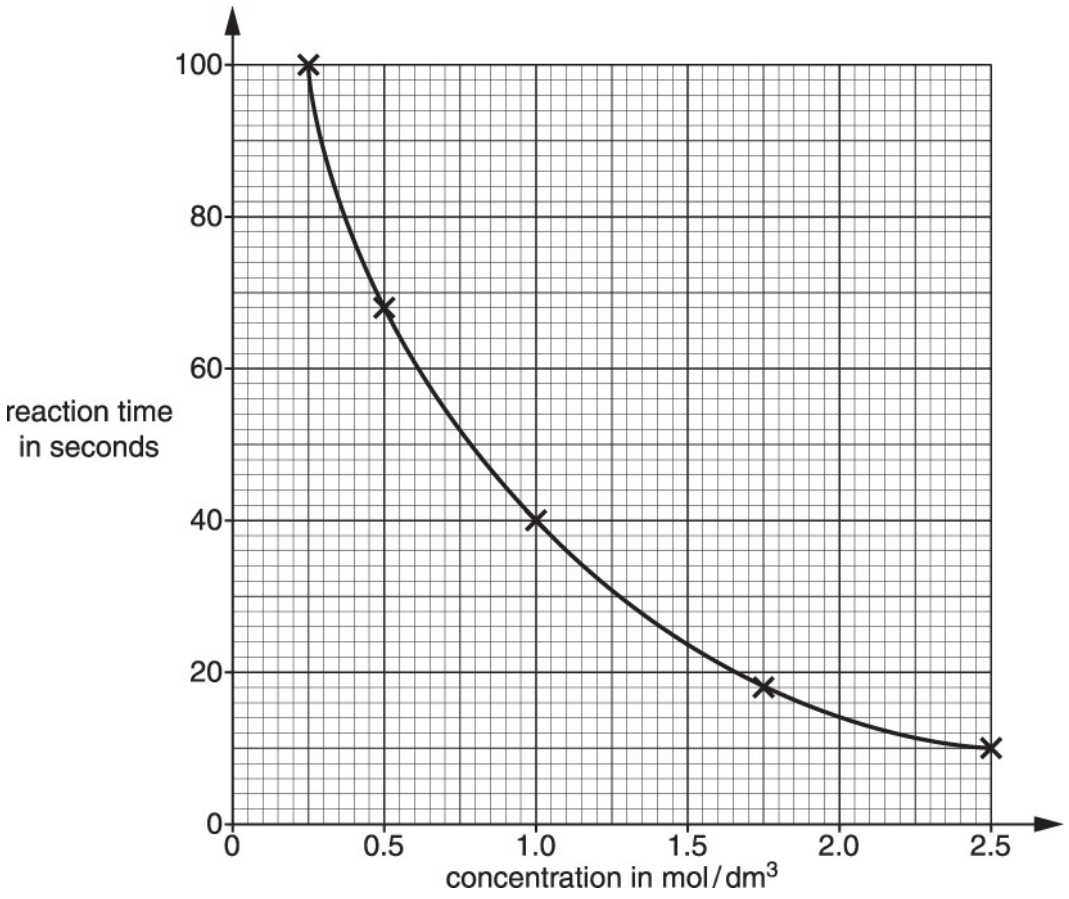
Investigation One

She does five different experiments.

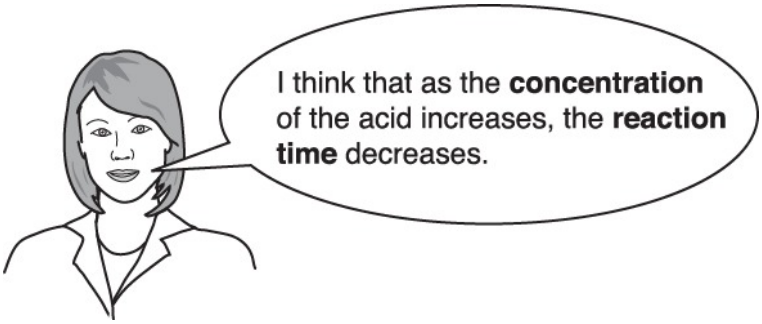
She keeps the temperature the same.

Each experiment uses a **different concentration** of acid.

Look at a graph of her results.



Fatimah makes a conclusion.



Do the results in **Investigation one** support Fatimah's conclusion?

Explain your answer.

Use the reacting particle model to explain Fatimah's results.

The quality of written communication will be assessed in your answer to this question.

[6]

(b). **Investigation Two**

Fatimah does five experiments.

She keeps the concentration of the acid the same.

She uses acid at **different temperatures**.

Look at her results.

Temperature of acid in °C	Reaction time in seconds
20	68
30	34
40	17
50	9
60	5

(i) What conclusion can you make about the effect of **temperature** on the **reaction time**?

---

[1]

(ii) Fatimah does an experiment with acid at a temperature of 10°C.

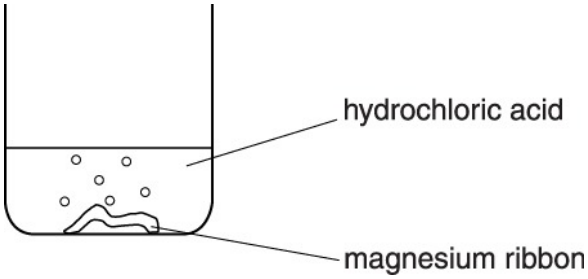
Predict the reaction time, in seconds.

_____ seconds

[1]

13(a). Rachel investigates the reaction between magnesium and hydrochloric acid.

She adds a piece of magnesium ribbon to hydrochloric acid in a beaker.

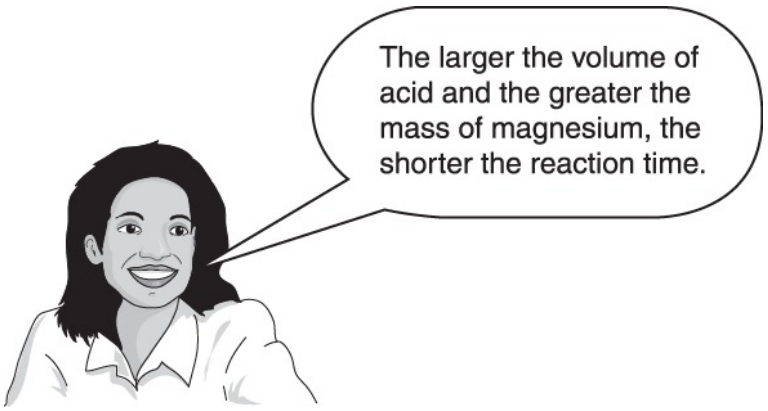


Rachel measures the time it takes for all the magnesium ribbon to react.

This is the reaction time.

She does five different experiments.

Look at Rachel's prediction.



Look at Rachel's results.

Experiment number	Mass of magnesium used in g	Volume of acid used in cm^3	Concentration of acid in mol/dm^3	Reaction time in seconds
1	0.05	25	1.0	30
2	0.10	25	1.0	30
3	0.05	50	1.0	30
4	0.05	50	2.0	15

5	0.10	50	2.0	15

Explain if Rachel's results support her prediction. Use the reacting particle model to explain the difference between the reaction time in experiments **3** and **4**.

The quality of written communication will be assessed in your answer to this question.

[6]

(b). Rachel repeats experiment **1**. This time she uses acid at a **higher** temperature.

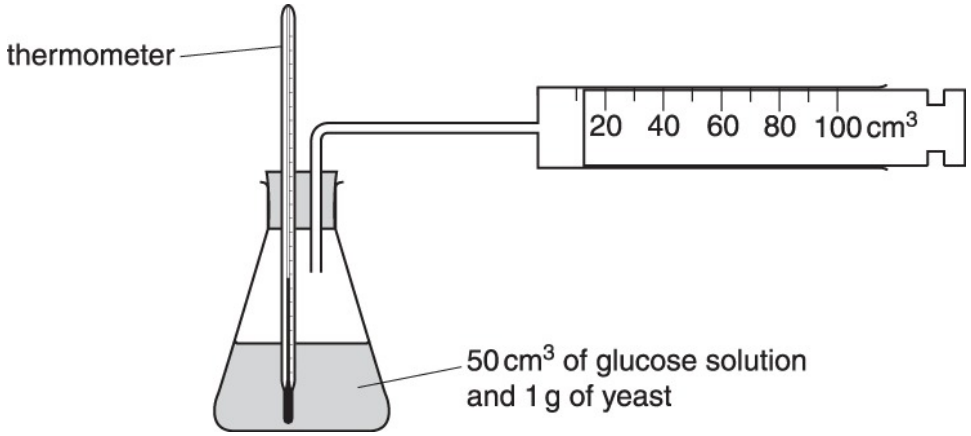
Explain, using the reacting particle model, what happens to the rate of reaction.

[2]

14. Ethanol can be made by the fermentation of glucose.

Tina and Tommy investigate the fermentation of glucose.

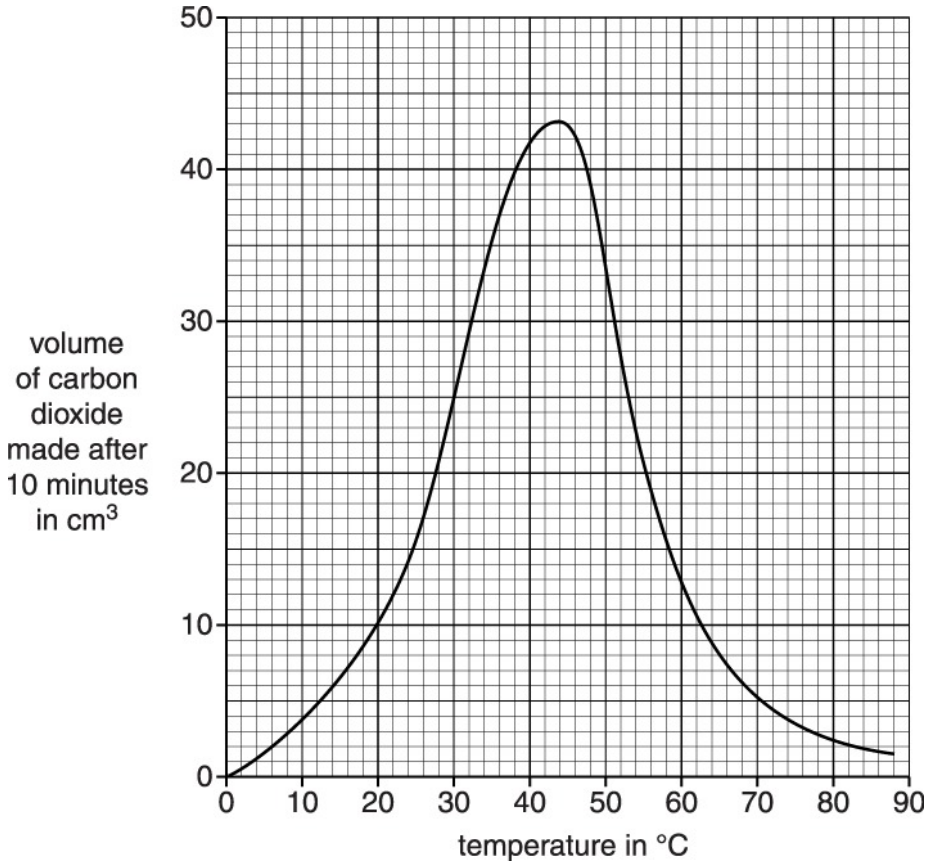
Look at the diagram. It shows the apparatus they use.



Tina and Tommy measure the volume of carbon dioxide made after 10 minutes.

They do the experiment at different temperatures.

Look at the graph. It shows their results.



(i) What is the volume of carbon dioxide made at **70 °C**?

answer _ _ _ _ _ _ _ _ _ _ _ cm^3

[1]

(ii) At what temperature is the reaction fastest?

answer _ _ _ _ _ _ _ _ _ _ _ °C

Explain your answer.

---

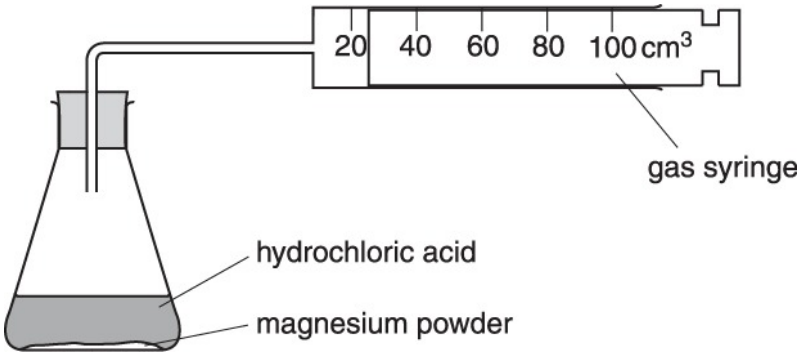
[2]

15(a). Hilary investigates the reaction between magnesium and hydrochloric acid.

Magnesium chloride and hydrogen are made.

Look at the diagram.

It shows the apparatus she uses.



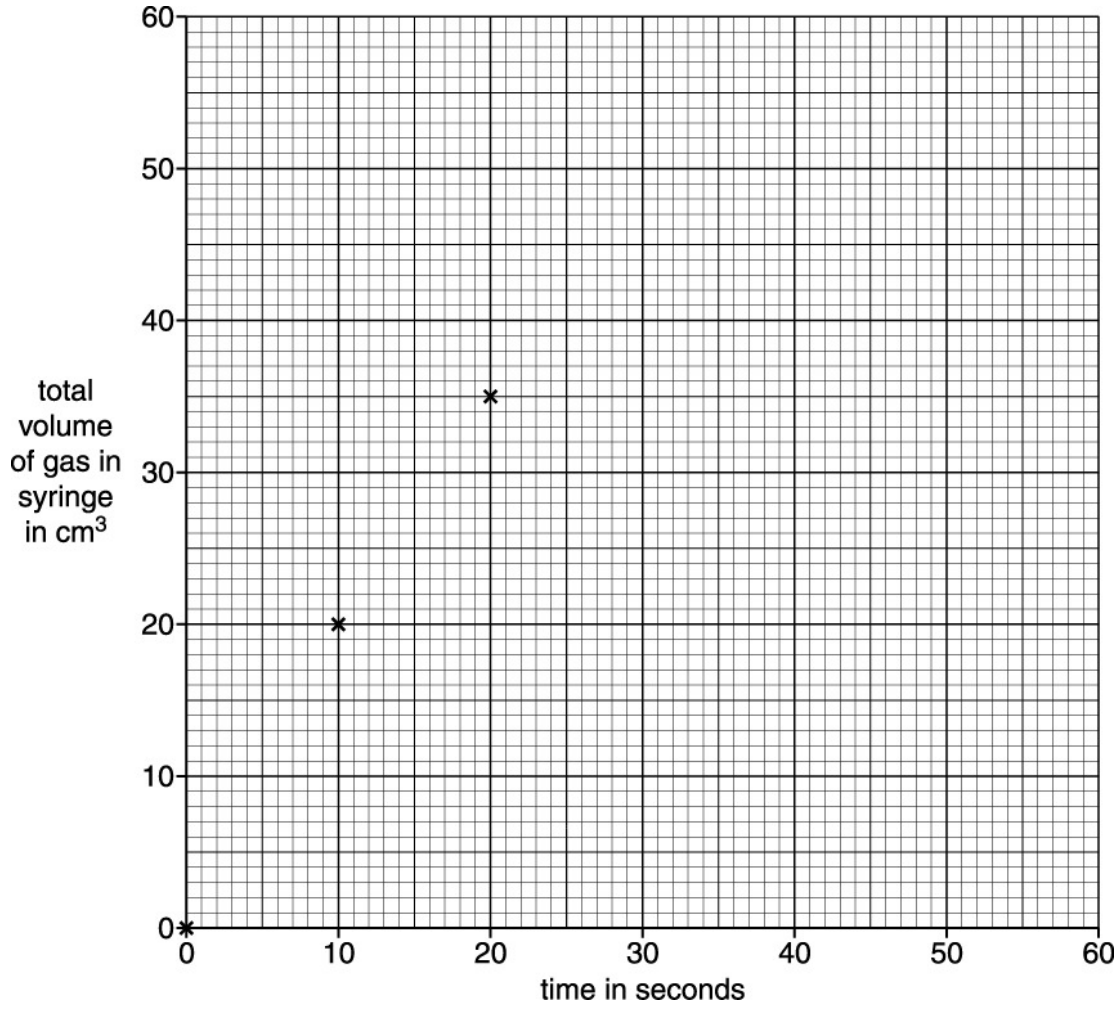
Hilary measures the total volume of gas in the syringe every 10 seconds.

Look at Hilary's results.

Time in seconds	Total volume of gas in syringe in cm^3
0	0
10	20
20	35
30	45
40	49
50	50
60	50

(i) **Plot** these results on the graph and draw the best line through the points.

The first three points have been plotted for you.



[2]

(ii) Look at the results.

The reaction stops after **50 seconds**. No more gas is given off.

Explain why.

---

[1]

(b). Hilary repeats the experiment.

This time she uses **lumps** of magnesium.

The reaction is **slower**.

Explain, using the reacting particle model, why the reaction is slower.

---

[2]

16. Fatimah investigates the reaction between sodium hydrogencarbonate and dilute hydrochloric acid.

She always adds 0.5 g of sodium hydrogencarbonate to 20 cm^3 of dilute hydrochloric acid.

She measures the time it takes for the reaction mixture to stop bubbling.

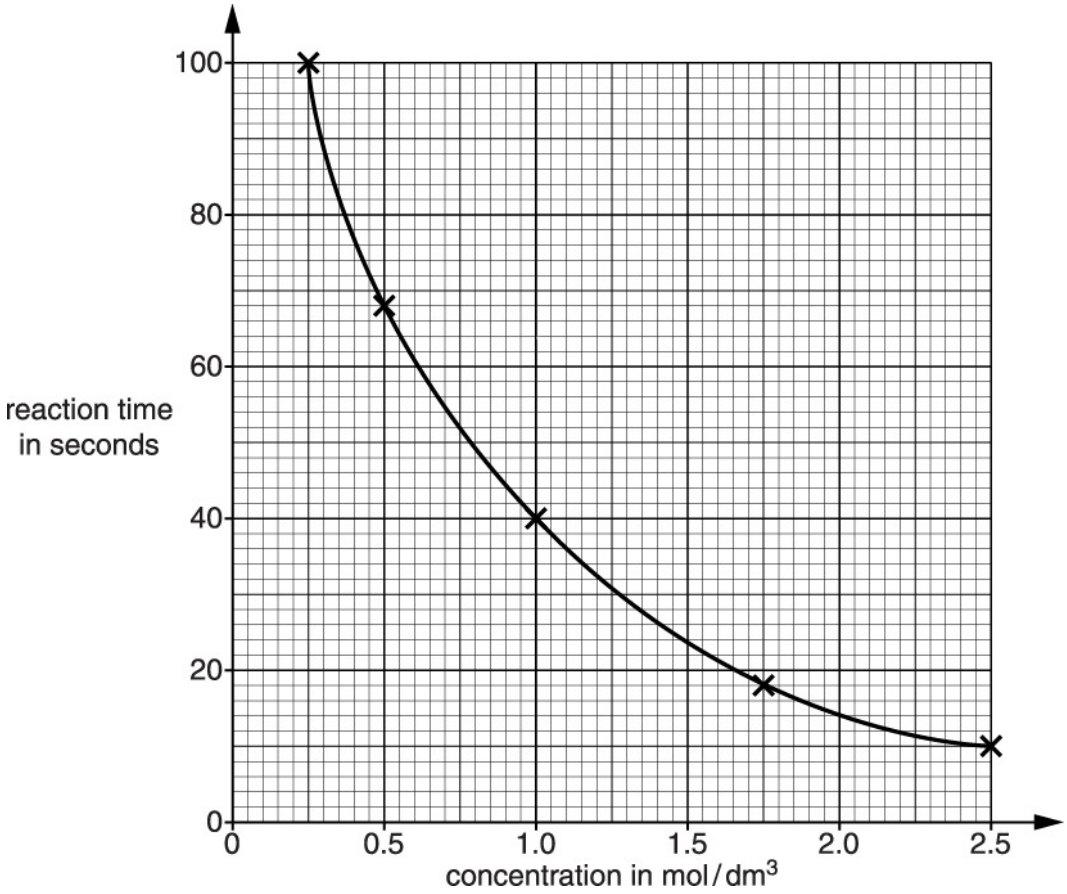
This is called the **reaction time**.

She does five different experiments.

She keeps the temperature the same.

Each experiment uses a **different concentration** of acid.

Look at a graph of her results.



Fatimah concludes that as the concentration of acid increases, the rate of reaction increases.

Explain, with a reason, whether the results support Fatimah's conclusion.

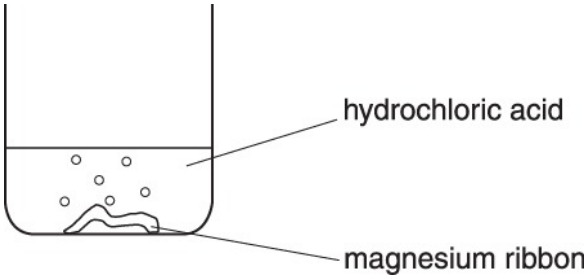
Use the reacting particle model to explain Fatimah's results.

The quality of written communication will be assessed in your answer to this question.

[6]

17. Rachel investigates the reaction between magnesium and hydrochloric acid.

She adds a piece of magnesium ribbon to hydrochloric acid in a beaker.

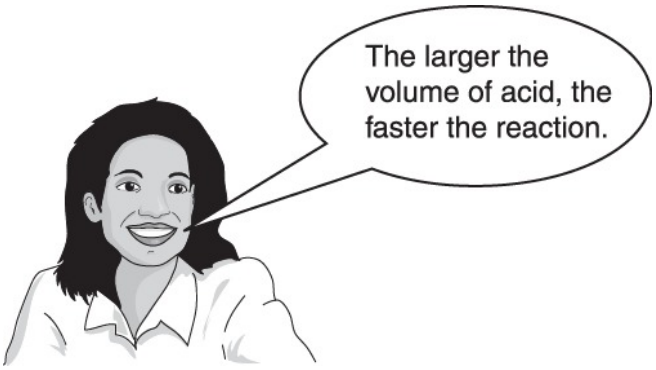


Rachel measures the time it takes for all the magnesium ribbon to react.

This is the reaction time.

She does four different experiments.

Look at Rachel's prediction.



Look at Rachel's results.

Experiment number	Mass of magnesium used in g	Volume of acid used in cm^3	Concentration of acid in mol/dm^3	Reaction time in seconds
1	0.05	25	1.0	30
2	0.10	25	1.0	30
3	0.05	50	1.0	30

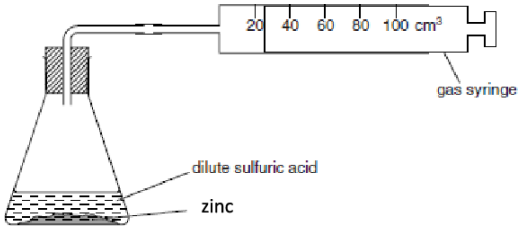
4	0.05	50	2.0	15

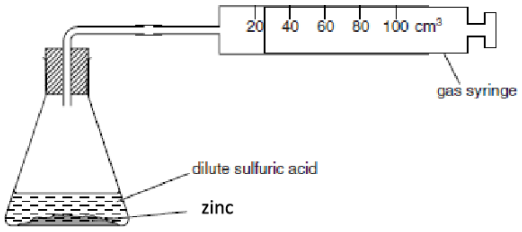
Explain if Rachel's results support her prediction. Use the reacting particle model to explain the difference between the reaction time in experiments **3** and **4**.

The quality of written communication will be assessed in your answer to this question.

[6]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			A	1	
			Total	**1**	
3	a		Suitable container for the reactants e.g. flask, boiling tube or test tube (1) Use of a gas syringe / upturned burette with water in trough of water / upturned measuring cylinder with water in trough of water (1) The method actually works (1)	3	
	b	i	To allow a comparison between with and without the added substance (1)	1	
		ii	Idea that the rate of reaction will change if concentration is changed (1)	1	It is a fair test is not sufficient **ALLOW** if concentration is increased the rate of reaction is increased **ALLOW** to ensure there are the same number of acid particles present / same number of acid particles per unit volume
		iii	Copper Because the reaction is faster (1) There is no change in appearance (1)	2	**No** marks for copper on its own If substance other than copper given then 0 marks for the question
		iv	Measure mass of catalyst before and after (1)	1	
		v	(Relative rate) between above 1 and below 10 because of smaller surface area / less exposed particles / less collisions (2)	2	**No** marks for the prediction on its own **No** marks for whole question if prediction incorrect
			Total	**10**	

Question			Answer/Indicative content	Marks	Guidance
4		i	Rate increases More particles have energy above that of activation energy (1) More successful collisions (per second) (1)	2	**No** mark for rate increases but must be there to award two marks. Rate decreases give 0 marks for the question
		ii	Rate decreases Less particles per unit volume (1) Fewer collisions per second / decreased collision frequency (1)	2	**No** mark for rate decreases but must be there to award two marks. Rate increases give 0 marks for the question **ALLOW** less crowded particles **ALLOW** collisions less often
			Total	**4**	
5			Suitable container for the reactants, e.g. flask, boiling tube or test tube (1) Use of a gas syringe / upturned burette with water in trough of water / upturned measuring cylinder with water in trough of water (1) The method actually works (1)	3	
			Total	**3**	
6			D	1	
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
7		i	75 (cm^3) (1)	1	**allow** any value between 74 – 76 cm^3 **Examiner's Comments** This question assessed aspects of quantitative chemistry in the context of the reaction between magnesium and sulfuric acid. Most candidates could interpret the graphs. A significant proportion of the candidates did not answer
		ii	any value between 50 and 52 (seconds) (1)	1	**Examiner's Comments** This question assessed aspects of quantitative chemistry in the context of the reaction between magnesium and sulfuric acid. Most candidates could interpret the graphs. A significant proportion of the candidates did not answer
		iii	line remains on or below original line and levels off at a lower volume (1) **BUT** line remains on or below original line and levels off at 48 ± 2 cm^3 (2)	2	line with a steeper gradient = 0 marks for the question **Examiner's Comments** This question assessed aspects of quantitative chemistry in the context of the reaction between magnesium and sulfuric acid. Those that did rarely obtained both marks. A common misconception was to give a volume just below the original. Candidates need to make certain that they draw sketch graphs carefully so that the line does not ‘ wobble’ too much.
			Total	**4**	

Question			Answer/Indicative content	Marks	Guidance
8		i	zinc has a greater gradient / iron has a smaller gradient (1) less gas is made with zinc / more gas is made with iron (1)	2	**allow** reaction with zinc is faster / reaction with iron is slower / takes less time to react **Examiner's Comments** This question was about the reactions of zinc and iron with hydrochloric acid. Candidates in (i) had little difficulty interpreting the two graphs and could describe two differences focusing on the difference in the rate of reaction and the total volume of gas being made at the end of the reaction.
		ii	Powder has more surface area / more collisions (per second) / more exposed particles (1)	1	assume answers refer to powder unless lump is specified **allow** or a lump has less surface area / less collisions (per second) / less exposed particles **Examiner's Comments** This question was about the reactions of zinc and iron with hydrochloric acid. The idea that a powder has a larger surface area was well understood in (ii) and some candidates also referred to more collisions.
		iii	**any three from:** higher temperature / heat (1) greater concentration (1) add a catalyst (1) use a finer powder (1) shake or stir (1)	3	**ignore** increase pressure **Examiner's Comments** This question was about the reactions of zinc and iron with hydrochloric acid. In (iii) candidates often gave at least two ways of speeding up the reaction. The most common answers were adding a catalyst or having a higher temperature. Candidates sometimes explained the factor but there were no marks available in the mark scheme for explanations.
			Total	**6**	

Question			Answer/Indicative content	Marks	Guidance
9			**Level 3 (5–6 marks)** Identification of at least three ways of making the reaction go faster **AND** applies reacting particle model correctly, including mention of collisions, to explain one way. Quality of written communication does not impede communication of science at this level. **Level 2 (3–4 marks)** Identification of at least two ways of making the reaction go faster **AND** makes an attempt to apply reacting particle theory to one of the ways (theory only partly correct). Quality of written communication partly impedes communication of science at this level. **Level 1 (1–2 marks)** Identification of two ways of making the reaction go faster. Quality of written communication impedes communication of science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science such as repeating the question. Answer not worthy of credit.	6	**This question is targeted at grades up to C.** **Relevant points include:** **Reacting particle theory** • increasing concentration or pressure gives more crowded nitrogen and oxygen molecules / molecules are closer together / more nitrogen and oxygen molecules in the same volume so there is an increased number of collisions (per second) / more collisions • increasing temperature has nitrogen or oxygen molecules moving faster / molecules have more energy so more (successful) collisions (per second) • adding a catalyst means there are more successful collisions (per second). **allow** one correct way of making the reaction go faster and a complete explanation level 2 (4 marks) **Ways of making reaction faster** • increase temperature • increase pressure • increase concentration • add a catalyst. **Examiner's Comments** This level of response question differentiated well. At the simplest level a candidate who gave two correct ways to speed up this reaction, with no attempt to use the reacting particle model, scored Level 1. Use of a catalyst and heating the gases were common correct responses. To gain Level 2, an incomplete explanation was required in addition to the ways of speeding up the reaction. To gain Level 3, a full and correct particle level explanation and a range of methods of speeding up the reaction were required. Just over 10% of

Question			Answer/Indicative content	Marks	Guidance
					candidates omitted the question.
			Total	**6**	
10			**[Level 3]** Applies reacting particle model, including mention of collisions frequency and / or successful collisions, to explain the effect of temperature **AND** pressure on the rate of reaction. Quality of written communication does not impede communication of science at this level. **(5–6 marks)** **[Level 2]** Applies reacting particle theory, including mention of collisions, to explain the effect of temperature **OR** pressure on the rate of reaction. Quality of written communication partly impedes communication of science at this level. **(3–4 marks)** **[Level 1]** Applies reacting particle theory to explain the effect of temperature **OR** pressure on the rate of reaction. Quality of written communication impedes communication of science at this level. **(1–2 marks)** **[Level 0]** Insufficient or irrelevant science such as repeating the question. Answer not worthy of credit. **(0 marks)**	6	**This question is targeted at grades up to A.** **Indicative scientific points may include:** • Increasing pressure gives more crowded nitrogen and oxygen molecules / molecules are closer together / more nitrogen and oxygen molecules in the same volume so there is an increased number of collisions per second / collisions more often • Increasing temperature has nitrogen or oxygen molecules moving faster / molecules have more energy so more successful collisions per second / more energetic collisions. **Use the L1, L2, L3 annotations in scoris. Do not use ticks.** **Examiner's Comments** Many candidates gave detailed answers and gave answers in terms of either more frequent collisions for Level 3 or more collisions for Level 2. A common misconception was that pressure increases the speed of the nitrogen and oxygen molecules.
			Total	**6**	

Question			Answer/Indicative content	Marks	Guidance
11	a		Zn + 2HC*l* ? Zn$C l_2$ + H_2 (1)	1	**allow** correct multiples **allow** = or ? instead of ?. **not** 'and' or & instead of + **all** subscripts and case **must** be correct **Examiner's Comments** This question focused on rates of reaction. Most candidates correctly constructed the balanced symbol equation.
	b	i	1.47 (1)	1	**allow** 1.46 / 1.5 (1) **unit not needed** **Examiner's Comments** This question focused on rates of reaction. Many candidates correctly calculated the rate of reaction in part (i). 30 ÷ 44 was a common error, as was misreading the volume of hydrogen as 42 cm_3.
		ii	60 (1)	1	**unit not needed** **Examiner's Comments** This question focused on rates of reaction. In part (ii) the most common incorrect response was 120 cm_3.

Question			Answer/Indicative content	Marks	Guidance
	c		particles more crowded / particles closer together / more particles in the same volume / more particles per unit volume (1) more collisions (1)	2	**allow** particles more concentrated / more particles in the same area **not** just more particles **not** particles have more energy / move faster / more energetic collisions **allow** higher level answers e.g. more frequent collisions / more collisions per second / collisions more often / more chance of collisions (1) **Examiner's Comments** This question focused on rates of reaction. Good responses explained the increase in the rate of reaction in terms of particles being more crowded / more particles in the same volume, hence more collisions. Candidates who did not score both marks often simply stated that there were more particles, but failed to describe within the same volume.
			Total	**5**	

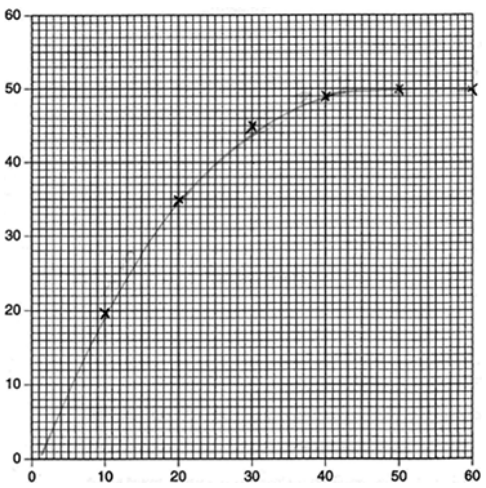
Question			Answer/Indicative content	Marks	Guidance
12	a		**Level 3** **Complete evaluation including some use of data from graph** **AND** **Explanation using reacting-particle model that must mention the idea of collisions** Quality of communication does not impede communication of science at this level. (5–6 marks) **Level 2** **EITHER** **Partial evaluation including some use of data from graph AND partial explanation using reacting particle model** **OR** **Explanation using reacting-particle model that must mention the idea of collisions** **OR** **Complete evaluation including some use of data from graph** Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **Level 1** **EITHER** **Partial evaluation including some use of data from graph** **OR** **Partial explanation using reacting-particle model** Quality of communication impedes communication of the science at this level. (1 – 2 marks) **Level 0** Insufficient or irrelevant science. Answer not worthy of credit.	6	**This question is targeted at grades up to C** **Indicative scientific points may include:** **Evaluation** • results support the conclusion • a reference to the data in the graph to justify the answer e.g. at low concentration high reaction time which is smaller as you go the right of the graph, or the graph has a negative slope **Reacting particle model** • idea that as reaction time decreases the rate of reaction increases • idea that the rate of reaction increases with concentration • as acid is more concentrated particles (of acid) are more crowded • as acid is more concentrated particles (of acid) are closer together • as acid is more concentrated there are more collisions (per second) **allow** ora i.e. as the concentration gets lower **Use the L1, L2, L3 annotations in Scoris, do not use** ticks **<u>Examiner's Comments</u>** This question focused on the rate of reaction between sodium hydrogencarbonate and hydrochloric acid. This question assessed both quality of written communication and evaluation. Almost all candidates realised that the data supported the conclusion made, however a smaller proportion of candidates quoted data from the graph to support their

Question			Answer/Indicative content	Marks	Guidance
			(0 marks)		answer. The most common data quoted were reaction times from two different acid concentrations. Candidates rarely explained their answers in terms of collision theory.
	b	i	As temperature increases the reaction time decreases.	1	**allow** ORA **allow** reaction time is shorter as reaction gets hotter **not** faster, quicker or slower times **Examiner's Comments** Candidates often appreciated that the rate of reaction increased as the temperature of acid got higher but this did not address the question set which referred to reaction time. The best answers were that the reaction time decreases as the temperature increases. A common misconception was to refer to the reaction time being faster or quicker.
		ii	Any time between 100 and 160 seconds	1	**Examiner's Comments** Some candidates could make a correct prediction the most common answer being 136 seconds.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
13	a		**[Level 3]** **Explanation that the results (in relation to both volume of acid & mass of magnesium) do not support the prediction with reference to experimental data** **AND** **an explanation *using collision frequency* that reaction in experiment 4 is faster, or has a shorter reaction time, than experiment 3.** Quality of communication does not impede communication of science at this level. (5–6 marks) **[Level 2]** **Explanation that the results (in relation to both volume of acid & mass of magnesium) do not support the prediction with reference to experimental data** **AND** **an explanation that the reaction in experiment 4 is faster, or has a shorter reaction time, than experiment 3 using idea of more collisions rather than collision frequency** **OR** **an explanation *using collision frequency* that reaction in experiment 4 is faster or has a shorter reaction time than experiment 3.** Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **[Level 1]** **Explanation that the results (in relation to either volume of acid or mass of magnesium) do not support the prediction with reference to experimental data** **OR** **an explanation that the reaction in experiment 4 is faster or has a shorter reaction time than experiment 3 *using idea of more collisions rather than***	6	**This question is targeted at grades up to A*** **Indicative scientific points for explanation may include:** • results show as volume increases reaction time does not change • results show that as mass increases reaction time does not change **Indicative scientific points for experiments 3 and 4 may include:** • concentration is higher in experiment **4** • acid particles are more crowded in experiment **4** / acid particles are closer together / more acid particles per unit volume / more acid particles per cm^3 / more acid particles in the same space • more (successful) collisions per second / collisions more often / increased collision frequency / more chance of a collision **Use the L1, L2, L3 annotations in Scoris; do not use ticks** **Examiner's Comments** This 6 mark question was targeted up to grade A* and required candidates to draw conclusions based on evidence and to explain a scientific process using the reacting particle model. Candidates who gave good responses supported their answers with clear reference to the experimental data and could explain why experiment 4 was faster than experiment 3 using ideas about collision frequency. When candidates did not gain credit it was usually because they did not refer to experimental evidence. Some candidates compared experiments 2 and 3, where both the mass of magnesium and volume of acid changed.

Question			Answer/Indicative content	Marks	Guidance
			***collision frequency*.** Quality of communication impedes communication of the science at this level (1–2 marks) **[Level 0]** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)		
	b		(acid) particles have more energy / (acid) particles are moving faster / more collisions per second (1) more successful collisions / more energetic collisions / more collisions above the activation energy / more effective collisions (1)	2	**ignore** particles vibrate more or vibrate faster **ignore** particles move more **allow** more successful collisions per second / more frequent energetic collisions for two marks **ignore** harder collisions / faster collisions **allow** more collisions (1), if no other mark awarded **allow** rate increases / reaction is faster (1), if no other mark awarded **Examiner's Comments** Most candidates scored 1 mark for explaining that at higher temperature the particles would have more energy or move faster. Good responses also explained that this resulted in more *successful* collisions.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
14		i	5 (cm^3)(1)	1	**allow** any value between 5 and 6 **Examiner's Comments** The vast majority of candidates could correctly read 5cm3 off the graph in part (i).
		ii	44^oC (1) idea of highest point on the curve / where most carbon dioxide is made (1)	2	**allow** 42-45 (^oC) (1) **second mark is dependent on the correct temperature** **allow** optimum temperature (1) **Examiner's Comments** About half of candidates scored 2 marks in part (ii) for correctly identifying 44^oC and stating that this temperature produces the greatest volume of carbon dioxide after 10 minutes. A common misconception was to identify the steepest part of the curve i.e. around 30^oC
			Total	**3**	

Question			Answer/Indicative content	Marks	Guidance
15	a	i	 all points plotted correctly (1) correct best fit line (1)	2	**allow** error of half a square **allow** curve half a square either side of points **not** dot to dot instead of curve **Examiner's Comments** The points were well plotted but many candidates tried to draw a best fit straight through the points rather than a curve.
		ii	**any one from:** magnesium used up (1) hydrochloric acid used up (1) reactant(s) used up (1)	1	no more gas given off on its own scores 0
	b		smaller surface area of magnesium (1) less collisions between acid and magnesium (1)	2	**allow** higher level answers less frequent / less often / less chance of collision **Examiner's Comments** Many candidates assumed a reaction had finished because no more gas is given off, rather than one or other of the reactants had been used up.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
16			**Level 3** **Complete evaluation including some information from the graph** **AND** **explanation using reacting particle model that must mention the idea of collision frequency** Quality of communication does not impede communication of science at this level. (5 – 6 marks) **Level 2** **Complete evaluation including some information from the graph AND explanation using reacting particle model that must mention the idea of collisions** **OR** **explanation using reacting particle model that must mention the idea of collision frequency** Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **Level 1** **Complete evaluation including some information from the graph** **OR** **explanation using reacting particle model that must mention the idea of collisions** Quality of communication impedes communication of the science at this level. (1 – 2 marks) **Level 0** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	**This question is targeted at grades up to A** **Indicative scientific points may include:** **Evaluation** • results support the analysis • idea that as concentration increases reaction time decreases and the rate of reaction increases **Reacting particle model** • as acid is more concentrated particles (of acid) are more crowded • as acid is more concentrated particles (of acid) are closer together • as acid is more concentrated more particles (of acid) per unit volume • as acid is more concentrated there are more collisions • as acid is more concentrated there are more collisions per second **allow** collisions more often, more chance of collision, increases collision frequency for more collisions per second **allow** reverse argument with as acid gets less concentrated **Use the L1, L2, L3 annotations in Scoris. Do not use ticks.** **Examiner's Comments** This 6 mark question was targeted up to grade A and required candidates to draw conclusions based on evidence and to explain a scientific process using the reacting particle model. Candidates who gave good responses supported their answers with clear reference to the experimental results and could explain why the results supported Fatimah's conclusion using ideas about collision frequency. Answers that did not refer to experimental evidence or only mentioned the idea of

Question			Answer/Indicative content	Marks	Guidance
					collisions, rather than collision frequency, did not gain credit beyond Level 2.
			Total	**6**	

Question			Answer/Indicative content	Marks	Guidance
17			**[Level 3]** **Explanation that the results do not support the prediction with reference to experimental data AND** **an explanation using reacting particle model that reaction in experiment 4 is faster or the reaction time is shorter than experiment 3.** Quality of communication does not impede communication of science at this level. (5–6 marks) **[Level 2]** **Explanation that the results do not support the prediction with reference to experimental data** **AND** **an explanation that the reaction in experiment 4 is faster or the reaction time is shorter than experiment 3 because acid is more concentrated** **OR** **an explanation using reacting particle model that reaction in experiment 4 is faster or the reaction time is shorter than experiment 3.** Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **[Level 1]** **Explanation that the results do not support the prediction with reference to experimental data** **OR** **An explanation that the reaction in experiment 4 is faster or reaction time is shorter than experiment 3 because the acid is more concentrated.** Quality of communication impedes communication of the science at this level (1–2 marks) **[Level O]** Insufficient or irrelevant science. Answer	6	**This question is targeted at grades up to C** **Indicative scientific points for evaluation could include:** • identification that experiments **1** and **3** must be compared • results show as volume increases reaction time does not change **Indicative scientific points for experiments 3 and 4 could include:** • concentration is higher in experiment **4** • acid particles are more crowded in experiment **4** / acid particles are closer together / more acid particles per unit volume / more acid particles per cm^3 / more acid particles in the same space • more (successful) collisions (per second) **Use the L1, L2, L3 annotations in Scoris, do not use ticks** **Examiner's Comments** This question assessed quality of written communication, evaluation and the ability to apply collision theory. Although candidates often appreciated that the conclusion was not supported by the results they did not refer to the experiment numbers to help their explanation. The best answers referred to experiments 1 and 3 where the volume changed but the reaction time did not. Candidates often appreciated that the difference in reaction times in experiments 3 and 4 was because the concentration of the acid had been changed. Only the best answers related this to collision theory and described an increased collision frequency or more crowded particles in the more concentrated acid.

Question			Answer/Indicative content	Marks	Guidance
			not worthy of credit. (0 marks)		
			Total	**6**	