

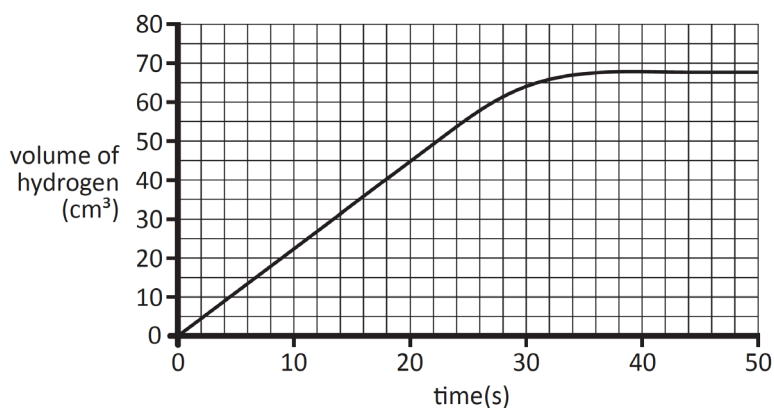
Rates of Reaction

Mark Scheme



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- The rate of a chemical reaction is the measure of how quickly a reactant is used up or a product is formed. Circle the letter of the correct answer for each of the following questions.
 - The graph below shows the volume of hydrogen gas made in an experiment. Calculate the mean rate of reaction over the first 20 seconds.

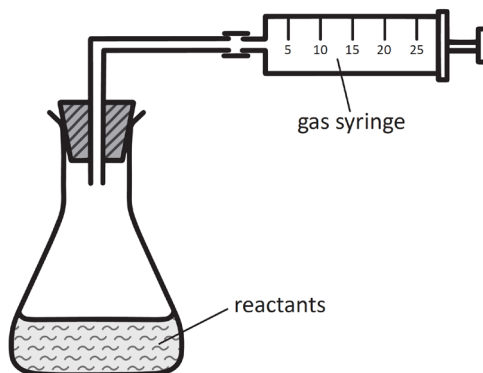


B – is the only correct answer.

1 mark

Total: 1 mark

- The apparatus in the diagram below is used to determine the rate of a chemical reaction.



Which equation represents a reaction where the speed can be measured using this apparatus?

A – is the only correct answer.

1 mark

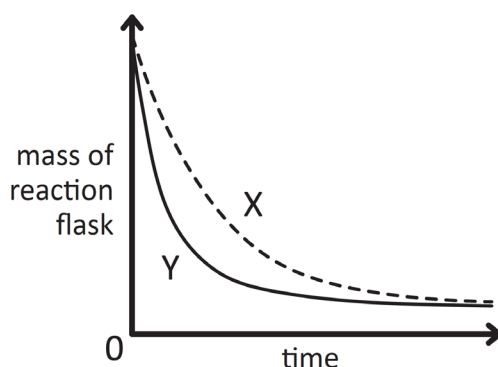
Total: 1 mark

- c. Why does increasing the concentration of a reactant in a solution increase the rate of reaction?

C – is the only correct answer.	1 mark
	Total: 1 mark

- d. The reaction between calcium carbonate and hydrochloric acid produces carbon dioxide gas.

To measure the reaction rate, the mass of the unsealed flask and its contents was recorded over time. The graph shows the total mass lost for two separate experiments, X and Y.



Which change explains the difference between X and Y?

D – is the only correct answer.	1 mark
	Total: 1 mark

- e. A catalyst is a substance that can be used to increase the rate of a chemical reaction.

Which of the following graphs show the mass of a catalyst as a chemical reaction takes place?

C – is the only correct answer.	1 mark
	Total: 1 mark

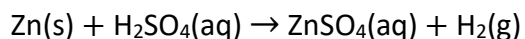
- f. Reactions can be exothermic and endothermic.

Which of the following describes a reaction that is endothermic?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

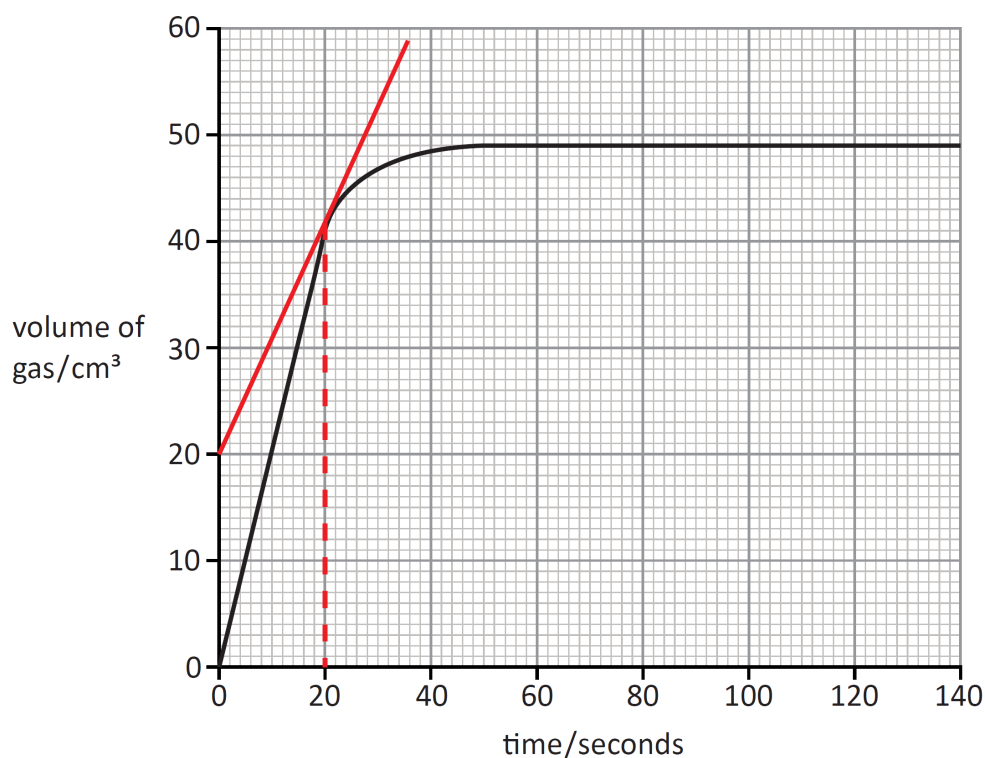
2. A student investigated the reaction of zinc metal with dilute sulfuric acid.
The equation below shows the balanced equation for the reaction.



- a. Complete the diagram to show how the student would collect and measure the volume of gas produced.

Award 1 mark for the bung or stopper in the neck of the flask.	1 mark
Award 1 mark for the delivery tube connecting the flask to the collection method.	1 mark
Award 1 mark for a measuring cylinder.	1 mark
Accept a gas syringe if that is used instead.	
	Total: 3 marks

- b. The student carried out the reaction at 30 °C using magnesium ribbon.



- i. How long does it take for the reaction to stop?

Accept an answer between 44 and 50 seconds.	1 mark
	Total: 1 mark

- ii. What is the volume of hydrogen made after 20 seconds?

Accept an answer between 42 and 45 (cm ³)	1 mark
	Total: 1 mark

- iii. Use the graph to calculate the rate of reaction at 20 seconds.
You **must** show your working on the graph by drawing a tangent. State the units in your final answer.

Tangent: tangent drawn correctly at t = 20	1 mark
Calculation: correct calculation of gradient. Gradient = $24 \div 20$ Gradient = 1.2 (Accept answers in range 1.1 – 1.4)	1 mark
Rate of reaction = 1.2	1 mark
Units = cm ³ /s	1 mark
	Total: 4 marks

- iv. Explain why the rate of reaction at 40 seconds is slower than the rate at 20 seconds.
Use ideas about collision theory in your answer.

An explanation to include the following: Award 1 mark for each.	
- Concentration of acid decreases. - Fewer particles per unit volume. - Lower frequency of collisions / Fewer collisions per second.	
	Total: 3 marks

(Total for Question 2 is 12 marks)

3. Nitrogen and hydrogen are reacted together to make ammonia.
A catalyst can be added to speed the reaction up without being used up itself.
- a. Explain, in terms of activation energy, how this catalyst increases the speed of the reaction.

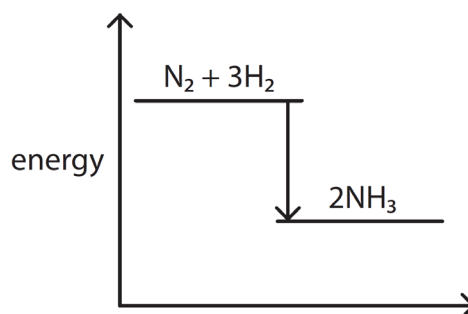
The minimum amount of energy.	1 mark
that particles must have to react (upon collision).	1 mark
	Total: 2 marks

- b. The reaction to produce ammonia reaction is **reversible**.

- i. Complete the equation below by adding the sign for a reversible reaction.

$\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$	1 mark
Award 1 mark for the correct symbol.	
	Total: 1 mark

- ii. The energy level diagram for this reaction is shown.
Is this reaction exothermic or endothermic? Give a reason for your answer.



Type: Exothermic.	1 mark
Reason: The energy level of the products is lower than the energy level of the reactants / Energy is released to surroundings.	1 mark
	Total: 2 marks

- c. The student wanted to do a test to prove that the substance produced was ammonia.
Describe a test for ammonia.

A description that includes:	
Damp or moist red litmus paper	1 mark
turns blue.	1 mark
	Total: 2 marks

(Total for Question 3 is 6 marks)

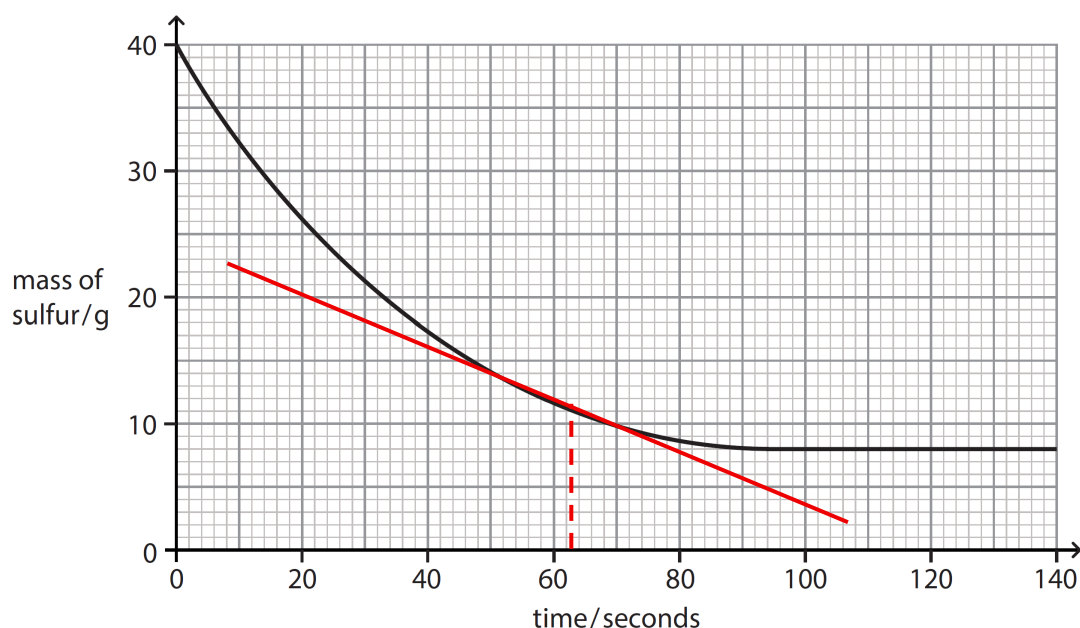
4. Sulfur dioxide (SO₂) is a toxic, colourless gas with a sharp, pungent odour, it primarily comes from the burning fossil fuels that contain sulfur.

Large pieces of solid sulfur burn in **excess** oxygen to produce sulfur dioxide gas.

- a. Write the balanced symbol equation for this reaction. You must include state symbols.

$S(s) + O_2(g) \rightarrow SO_2(g)$	3 marks
Award 1 mark for the correct formulae.	
Award 1 mark for the correct balancing.	
Award 1 mark for the correct state symbols	
	Total: 3 marks

- b. The figure below shows how the mass of sulfur changes as the combustion of sulfur occurs.



- i. How long did it take for the combustion of sulfur to be completed.

90 (seconds)	1 mark
	Total: 1 mark

- ii. The combustion was repeated using **powdered** sulfur.

Describe the effect on the rate of reaction of using powdered sulfur rather than large pieces of sulfur.

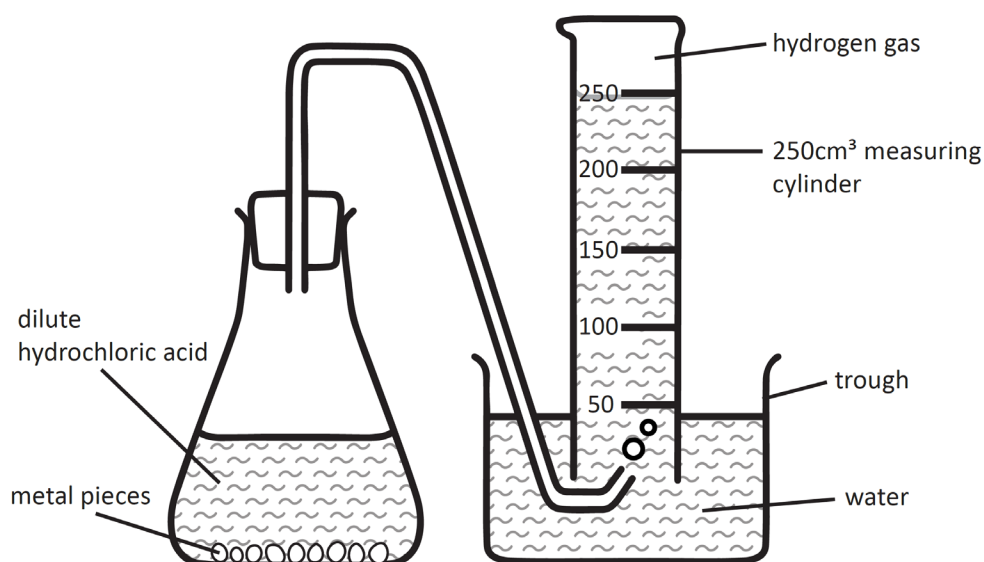
Rate increases / Reaction is faster.	1 mark
Powder has a larger surface area (to volume ratio).	1 mark
	Total: 2 marks

- iii. Use the graph to calculate the rate of reaction at 40 seconds.

Tangent: Drawn at t = 40 (see graph above).	1 mark
Gradient: Calculation using values from tangent.	1 mark
Answer: Range 0.25 – 0.35.	1 mark
Units: g/s	1 mark
	Total: 4 marks

(Total for Question 4 is 10 marks)

5. To investigate reaction speed, a student added zinc pieces to a flask of dilute hydrochloric acid.



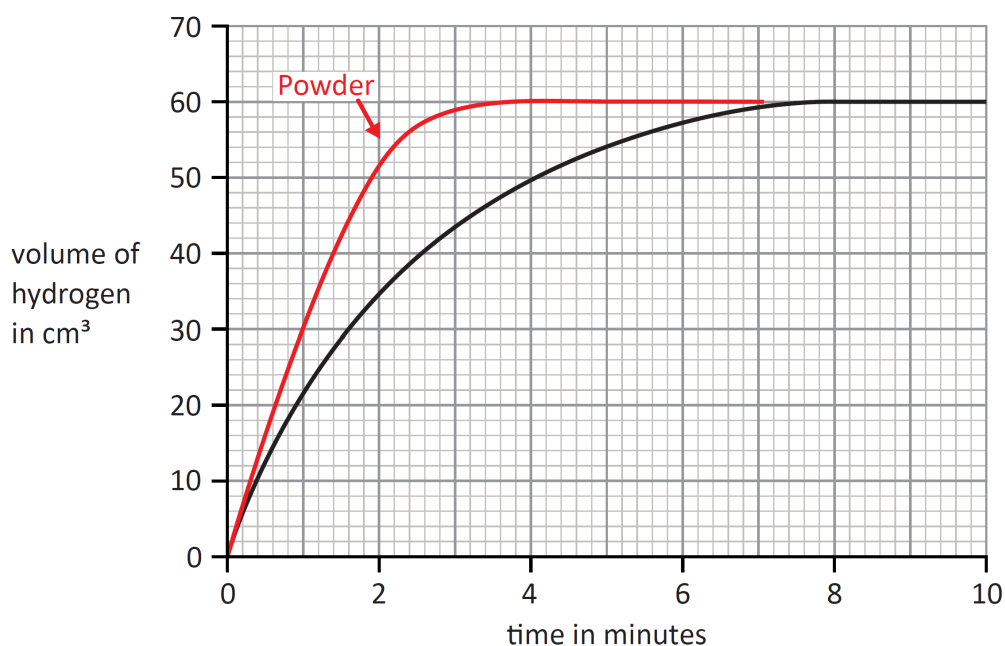
- a. Using the apparatus shown, how would the student know when the reaction has **finished**?

Accept any one of the following:	
- No more bubbles. - Gas production stops. - Volume of gas remains constant.	
	Total: 1 mark

- b. The student repeats the experiment using the same mass of zinc, but this time as a fine powder instead of pieces. The volume and concentration of the hydrochloric acid are kept the same.

On the axes below, sketch the curve you would expect for this second experiment.

Label this curve 'Powder'. The curve for the original experiment with zinc pieces is shown for comparison.



Shape: Curve starts steeper (left of original).	1 mark
End point: Levels off at the same final volume (60 cm³).	1 mark
	Total: 2 marks

- c. Calculate the mean rate of production of hydrogen over the first 240 seconds, in cm^3 per second.

Read: Volume at 4 mins (240s) = 48 cm^3	1 mark
Calculation: $48 \div 240$	1 mark
Answer: $0.2 \text{ (cm}^3/\text{s)}$	1 mark
	Total: 3 marks

- d. Explain, using collision theory, why the curve for zinc powder is a different shape from the curve for zinc pieces.

An explanation to include the following:	
Powder has larger surface area.	1 mark
Allow: More collisions per second.	
More frequent collisions (between zinc and acid particles).	1 mark
Different shape but same height because same mass of Zinc used (limiting reactant).	1 mark
Allow: The reaction finishes sooner / in less time.	
	Total: 3 marks

- e. The student carried out two additional experiments using zinc.

The same mass of zinc and the same sized pieces of zinc were used in each experiment.
The results are shown in the table below.

	Dilute hydrochloric acid (mol/dm^3)	Temperature ($^{\circ}\text{C}$)	Rate of reaction
Experiment 1	0.75	15	Slow
Experiment 2	2.00	30	Fast

Evaluate these results, explaining the reasons **why** the rate of reaction in experiment 2 is faster than the rate of reaction in experiment 1.

In your answer you should refer to the frequency and energy of collisions between particles.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about temperature or concentration increasing the rate, without fully explaining the underlying particle theory.
Level 2	3 - 4	An explanation is provided that covers both factors (temperature and concentration) but may lack depth on one aspect of collision theory (e.g., explains frequency but misses activation energy for temperature).
Level 3	5 - 6	A detailed and coherent explanation is provided. The student links both temperature and concentration to the rate of reaction using collision theory (referencing both collision frequency and energy).

Indicative content:	
Factor 1: Concentration - Experiment 2 has a higher concentration of sulfuric acid (2.00 mol/dm^3) compared to Experiment 1 (0.75 mol/dm^3). - This means there are more acid particles per unit volume. - Consequently, there is an increased frequency of collisions (more collisions per second) between the zinc and acid particles. Factor 2: Temperature - Experiment 2 is carried out at a higher temperature (30°C) compared to Experiment 1 (15°C). - At higher temperatures, particles have more kinetic energy and move faster. - This leads to an increased frequency of collisions. - Crucially, more particles have energy greater than or equal to the activation energy (E_a). - This results in a higher proportion of successful collisions. Conclusion: The combination of higher concentration and higher temperature significantly increases the rate of reaction in Experiment 2.	
	Total: 6 marks

(Total for Question 5 is 15 marks)

6. A teacher is demonstrating the classic 'iodine clock reaction' to a class. In this type of reaction, a noticeable change, like a colour appearing or disappearing, happens after a measurable period of time.
- The teacher mixes solution A and solution B, which immediately form a deep purple mixture. The class is told to watch as this purple colour will slowly fade until the solution becomes completely colourless.
- a. To begin the demonstration, the teacher measures out 25 cm³ of solution A and 25 cm³ of solution B. For speed, the teacher uses a beaker for this.

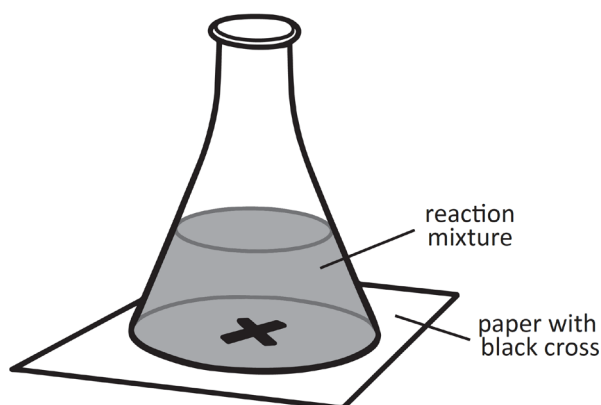
Suggest a piece of apparatus the teacher **should** have used to measure the 25 cm³ volumes more precisely, and **explain** why it is an improvement over a beaker.

Apparatus: volumetric pipette / burette.	1 mark
Allow: measuring cylinder (if reasoning is about graduations compared to beaker).	
Reason: It measures variable volumes / small volumes more precisely/accurately than a beaker.	1 mark
	Total: 2 marks

The teacher investigates this reaction using the apparatus shown in the figure below.

The teacher measures the time taken for the cross to become visible.

The experiment is repeated at different temperatures.



The experiment was repeated at several different temperatures. The results are shown in the table below.

Temperature in °C	Time in s
20	45
30	28
40	19
50	14
60	10
70	6

- b. For the investigation to be a fair test, variables that could affect the rate of reaction must be controlled.

Other than the concentration of the solutions, identify **one** variable that must be kept the same in each experiment.

Accept any one of the following:	
• Total volume of solution • Depth of solution in the flask.	
	Total: 1 mark

- c. State, and explain in terms of the energy of particles, how the time taken for the cross to become visible would change if a temperature of 90 °C had been investigated.

State: Time decreases / becomes visible faster.	1 mark
Explain: Particles have more kinetic energy.	1 mark
Resulting in more frequent and successful collisions.	1 mark
	Total: 3 marks

The teacher repeats the experiment at 30 °C, with the addition of a catalyst.

- d. State the function of a catalyst and **explain** how the addition of a catalyst will affect the rate of reaction.

Function: it changes / increases the rate of reaction.	1 mark
Allow: speeds up the reaction.	
Explanation: it provides an alternative reaction pathway (or route).	1 mark
Allow lowers the energy needed for particles to reaction.	
Which has a lower activation energy.	1 mark
The catalyst remains unchanged (chemically) at the end / is not used up.	1 mark
Allow mass of catalyst is the same at the start and end.	
	Total: 4 marks

- e. The concentration of solution A is 0.40 mol/dm³.
The relative formula mass (Mr) of solid A is 67.

Calculate the mass of solid A present in 25 cm³ of the solution.

You will need to use these **two** formulae:

$$\text{moles} = \text{concentration (mol dm}^3\text{)} \times \text{volume (dm}^3\text{)}$$

$$\text{mass (g)} = \text{moles} \times \text{Mr}$$

Moles = $0.40 \times (25 \div 1000) = 0.01$	1 mark
Mass = 0.01×67	1 mark
Mass = 0.67 (g)	1 mark
	Total: 3 marks

(Total for Question 6 is 13 marks)

7. The reaction between calcium carbonate and hydrochloric acid produces carbon dioxide gas.



Time /s	Volume of carbon dioxide in cm ³	Average reaction rate in cm ³ /s
0	0	
30	45	1.5
60	75	1.0
90	96	
120	105	0.3
150	105	0.0

- a. Explain how the average reaction rate, 1.5 cm³/s, was calculated for the first 30 seconds.

An explanation <u>linking</u> the following:	
The volume of gas produced (45cm ³)	1 mark
divided by the time taken (30s).	1 mark
	Total: 2 marks

- b. Complete the table by calculating the average reaction rate between 60 and 90 seconds.

Change in y: 96 – 75 = 21	
96 – 75 = 21	
Rate:	
21 ÷ 30 = 0.7 (cm ³ /s)	1 mark
	Total: 1 mark

- c. Explain why the average reaction rate decreases with time.

Reactant (acid) particles are used up.	1 mark
Allow: fewer collisions per second.	
Concentration decreases.	1 mark
Frequency of collisions decreases.	1 mark
	Total: 2 marks

- d. The experiment was repeated using 2.0 g of powdered calcium carbonate instead of small chips.
What effect, if any, would this have on the reaction rate and on the final volume of carbon dioxide?
Give a reason for each answer.

Effect on rate: increases.	1 mark
Reason: powder has <u>larger surface area</u> , so <u>more frequent collisions</u> .	2 marks
	Total: 3 marks

Effect on final volume: remains the same.	1 mark
Reason: the mass/amount of calcium carbonate (limiting reactant) is the same, so same amount of product formed.	2 marks
	Total: 3 marks

(Total for Question 7 is 11 marks)