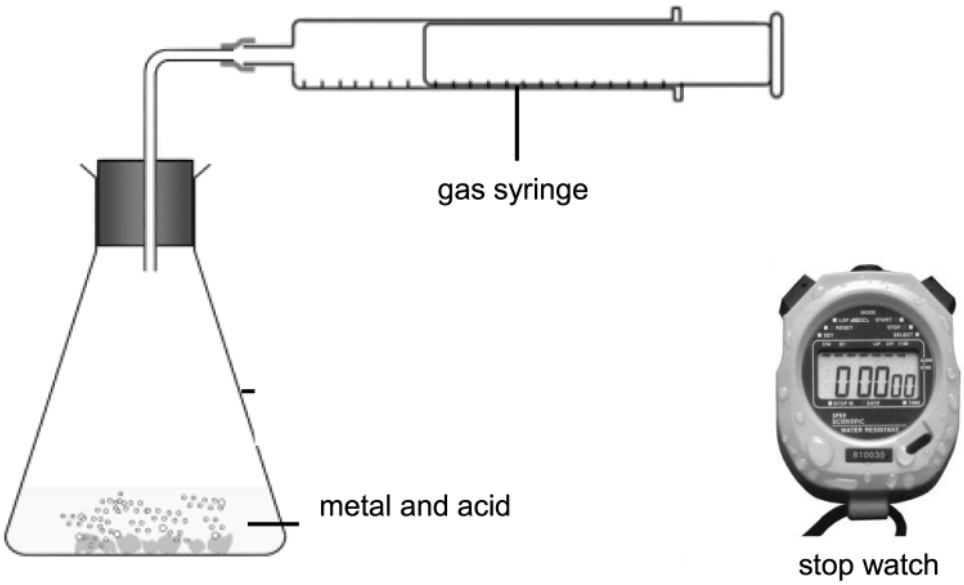
1(a). Joe investigates the rate of reaction between a metal and an acid.

He uses this apparatus.



Joe investigates how changing the concentration of the acid affects the volume of gas collected in 10 s.

What factors should Joe control to make sure that his results are repeatable?

Justify your answer.

---

[5]

(b). Joe repeats his experiment three times for four different concentrations of acid.

The table shows his results.

Concentration of acid (mol/dm^3)	Volume of gas collected after 10 seconds (cm^3)			Mean volume of gas (cm^3)
	Repeat 1	Repeat 2	Repeat 3	
0.50	3	2	4	3
1.00	4	5	4	4
1.50	5	6	6	
2.00	6	7	6	

Joe makes this comment on his results.

If I show the mean volumes for the last two concentrations to one significant figure, they are the same .

I need to show the mean volumes to at least two significant figures to see a difference.

(i) Use calculations to show that Joe is right.

[3]

(ii) *Evaluate Joe's results and explain how he could change his method to improve the quality of his data.

---

[6]

2. Scientists are working on a new process to produce hydrogen.

The new process splits water to make hydrogen. A catalyst is used in the process.

$$2H_2O \quad ? \quad 2H_2 \quad + \quad O_2$$

(i) What is the name of the by-product of this reaction?

---

[1]

(ii) Using a catalyst reduces the energy needed to break up the water.

How does the catalyst work?

Put ticks (?) in the boxes next to the **two** correct answers.

The catalyst increases the time taken for the reaction. ☐

The catalyst lowers the activation energy. ☐

The catalyst provides a different route for the reaction ☐

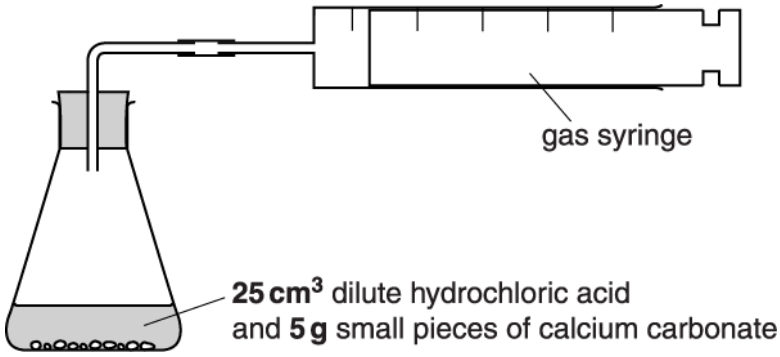
The catalyst is used up instead of the water. ☐

[2]

3(a). Alex reacts small pieces of calcium carbonate with dilute hydrochloric acid.

He measures the time taken for the reaction to make 20 cm^3 of gas.

He uses this equipment.



Results

Mass of calcium carbonate	Time taken to make 20 cm^3 gas
5 g small pieces	50 s

Alex predicts that the reaction will be **slower** if he uses **large lumps** of **calcium carbonate**.

Alex does another experiment to find out if his prediction is right.

Write a plan for his experiment.

Your answer should include:

- the quantities he should use
- how he can make it a fair test
- how he will know if his prediction is right.

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

[6]

(b). What other conditions could be changed to give a slower reaction?

Put ticks (✓) in the boxes next to the **two** correct answers.

use a more concentrated acid	☐
use a catalyst	☐
shake the flask	☐
use a lower temperature	☐
add water to the acid	☐

[2]

4(a). A catalyst is used to turn the fats and oils into biodiesel.
The usual catalyst is hot concentrated sodium hydroxide.

Scientists are investigating a new catalyst. The new catalyst is called an enzyme.

Here is some information about both catalysts.

Features of enzyme	Features of hot concentrated sodium hydroxide
needs gentle heating	needs strong heating
easy to remove from the reaction mixture	dissolves in reaction mixture
speeds up this reaction only	speeds up other reactions which produce waste material
expensive	very cheap

Identify the **advantages** and **disadvantages** of using the enzyme, and explain which catalyst is best.

---

[6]

(b). Scientists draw energy level diagrams for the reactions .

Diagram **A** – using enzyme catalyst

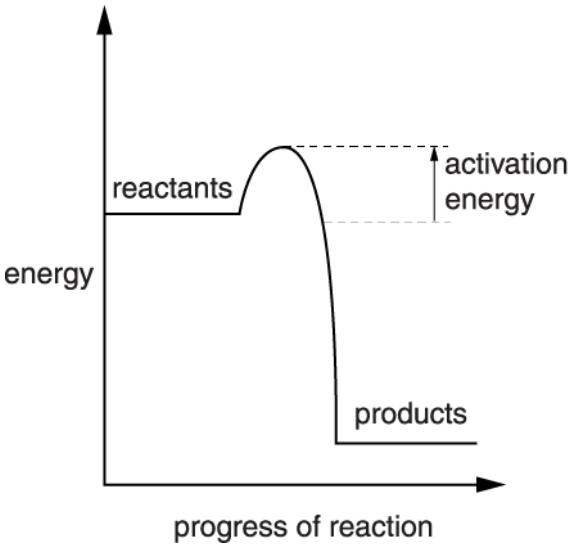
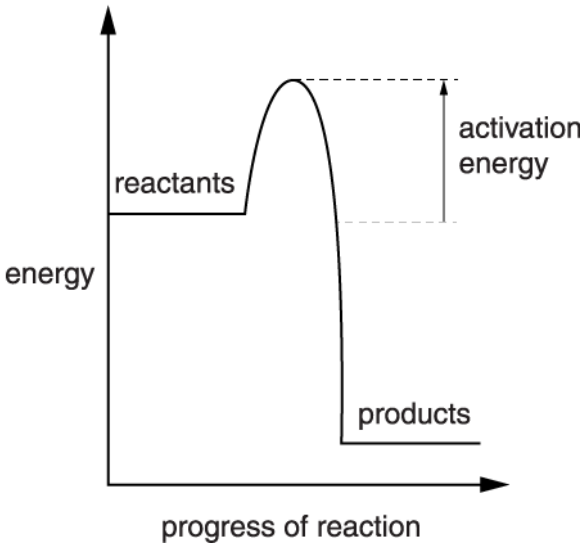


Diagram **B** – using sodium hydroxide catalyst



Give **one** similarity and **one** difference between the changes shown in these diagrams.

--- [2]

5(a). Joe does some experiments to investigate the rate of a reaction.

He measures the time taken for the reaction to finish at different temperatures.

Temperature in °C	Time taken for reaction to finish in s
20	45
30	25
40	15
50	8

Explain what the results show about the rate of reaction.

---

[2]

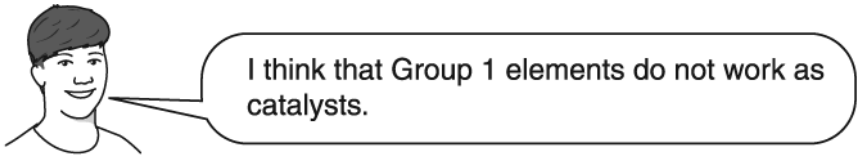
(b). Joe investigates the effect of some catalysts on the reaction.

He writes down which metal ion is in each catalyst.

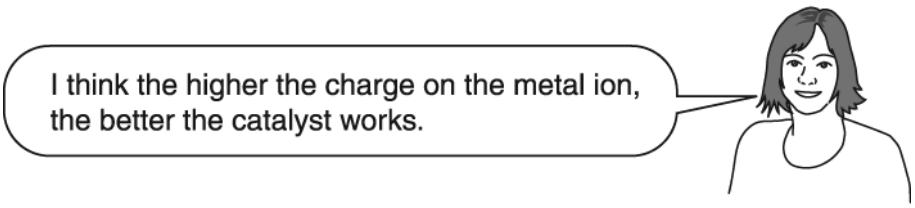
He measures the time taken for the reaction to finish when each catalyst is used.

	Experiment	Metal ion in catalyst	Formula	Time taken for reaction to finish in s
	1	no catalyst		45
Group 1 elements	2	sodium	Na^+	45
	3	potassium	K^+	45
Other elements	4	cobalt	Co^{2+}	15
	5	iron	Fe^{3+}	22

Joe talks about his results with Eve.



Joe



Eve

Do the results in the table support the ideas of Joe and Eve? Explain your answer.

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

---

[6]

6. Calcium hydroxide is dropped into a lake from a helicopter to neutralise the water.

The calcium hydroxide is a fine powder and not large pieces.

What effect does using a fine powder rather than large pieces have on the rate of the reaction?

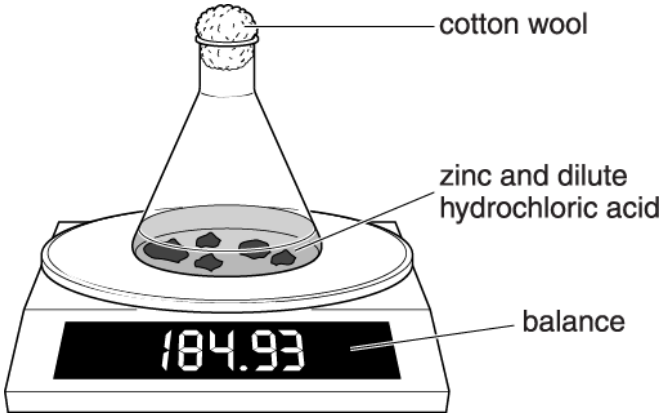
Explain your answer.

---

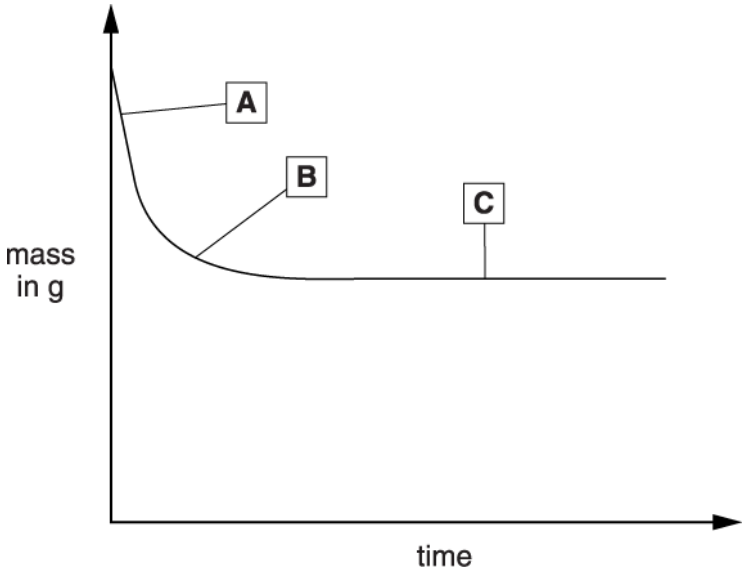
[2]

7(a). Liz does an experiment to investigate the rate of reaction between zinc and dilute hydrochloric acid.

She measures the mass of the flask during the reaction.



Liz plots her results on the graph below.



Draw straight lines to connect each **point on the graph** to what is happening to the **rate of reaction**.

point on the graph	rate of reaction
	reaction has stopped
A	
	rate has speeded up
B	
	rate has slowed down
C	
	rate is at its fastest

[2]

(b). Liz reads an article on the internet which says that copper acts as a catalyst for this reaction.

She does an investigation to find out if this is true.

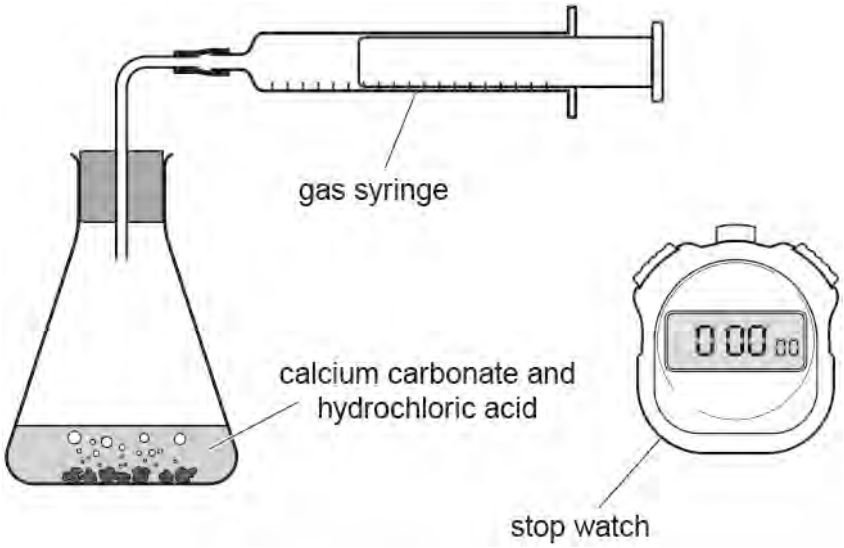
How should she do the investigation, and what results should she expect?

---

[3]

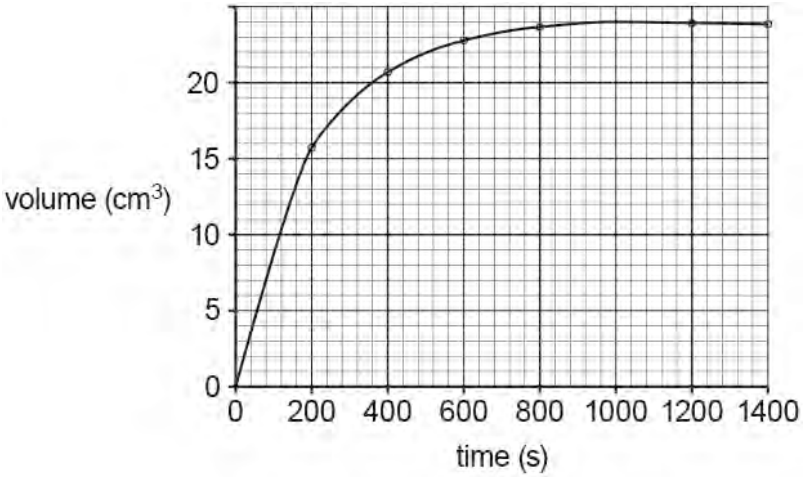
8(a). Calcium carbonate reacts with excess hydrochloric acid to make carbon dioxide.

Here is the apparatus Jack uses to investigate the reaction.



Jack records the volume of carbon dioxide made every 200 seconds.

Here is a graph of his results.



Use the graph to calculate the rate of reaction over the first 100 s.

Rate = _____ cm^3 / s **[2]**

(b). Amaya wants to repeat Jack's experiment.

She uses the same mass of calcium carbonate.

She uses the same volume and concentration of hydrochloric acid.

Which **two** other factors does she need to keep the same?

1 ----------

2 ----------

[2]

(c). Jack repeats his experiment with more concentrated hydrochloric acid.

He keeps **all** other factors the same. The rate of reaction is faster.

Explain why.

Write about particles in your answer.

---

[2]

9(a). Eve measures the volume of gas given off when solid calcium carbonate reacts with a dilute acid.

Fig. 7.1 shows a graph of her results.

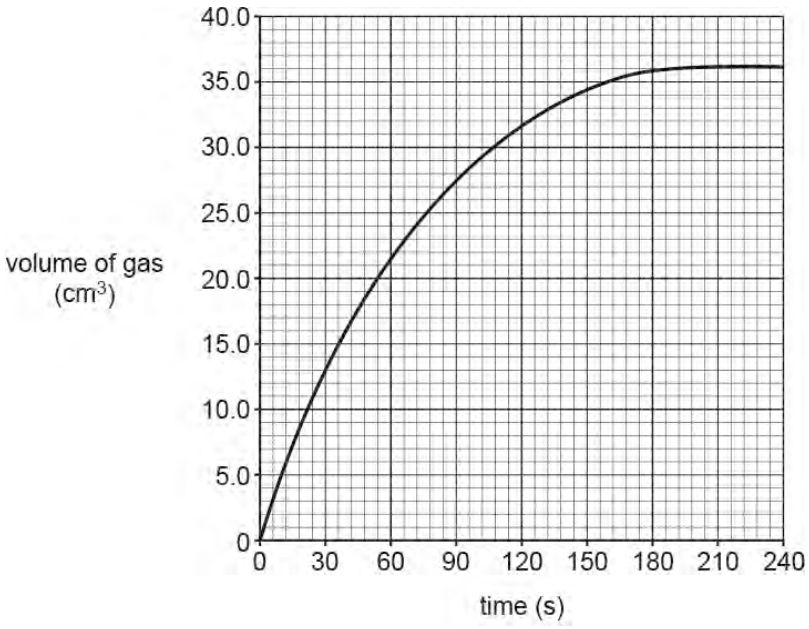


Fig. 7.1

(i) What volume of gas is given off during the first minute of the reaction?

Volume =_____ cm^3 **[1]**

(ii) What volume of gas is given off during the second minute of the reaction?

Volume =_____ cm^3 **[2]**

(b). Look at the graph in **Fig. 7.1**.

Describe what happens to the rate of the reaction during the experiment.

---**[2]**

(c). Eve does some more experiments.

She measures the rate of reaction when she uses different concentrations of acid.

Table 7.1 shows her results.

Concentration of acid (mol / dm^3)	Rate of reaction (cm^3 / s)
0.2	1.4
0.4	2.8
0.6	4.2
0.8	5.6
1.0	7.0

Table 7.1

(i) Predict the rate of reaction when acid of concentration 0.5 mol/dm^3 is used.

Rate of reaction =_____ cm^3 / s **[2]**

(ii) Eve says that the data shows that rate of reaction is proportional to the concentration.

How does the data show that Eve is right?

---

[2]

(iii) Eve writes an expression to show that rate of reaction is proportional to concentration.

Which expression shows that rate of reaction is proportional to concentration?

Tick (✓) **one** box.

rate of reaction	⇋	concentration	☐
rate of reaction	→	concentration	☐
rate of reaction	α	concentration	☐
rate of reaction	~	concentration	☐

[1]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a		volume of acid✓ temperature of acid ✓ mass of magnesium✓ surface area of magnesium ✓ Correct link between increase in rate of reaction and factor (e.g. if surface area is greater, rate increase) ✓	5	
	b	i	(1.50) 5 + 6 + 6 / 3 = 5.7(to two sig figs) ✓ (2.00) 6 + 7 + 6 / 3 = 6.3 (to two sig figs) ✓ both values round to 6 (to one sig fig) ✓	3	ALLOW 5.67 etc if correctly rounded (last number must be 7)
		ii	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** *Correctly evaluates the quality of the data as being poor with valid reasons.* **And** *Makes several correct suggestions for the development of the method with correct explanation of how the data will be improved.* *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated* **Level 2 (3–4 marks)** *Correctly evaluates the quality of the data as being poor with valid reasons.* **And** *Makes several correct suggestions for the development of the method or makes one suggestion with a correct explanation of how the data will be improved.* *There is a line of reasoning presented with some structure. The information presented*	6	**Indicative scientific points may include** **AO3.1b evaluation of the quality of Joe's results.** For example • no spread of data • results too close together • volumes measured very small **AO3.3a suggestions for the development of Joe's method** For example • Increase time before volume measured • Increased volume of acid • Increased surface area of magnesium • more magnesium **AO3.3b explanation of how the data will be improved** For example • Volume of gas will be greater • more precise measurement of volume • Larger spread of data • Less overlap of ranges

Question			Answer/Indicative content	Marks	Guidance
			is relevant and supported by some evidence. **Level 1 (1–2 marks)** *Correctly evaluates the quality of the data as being poor with a valid reason.* **And** *makes one suggestion for the development of the method with no explanation.* *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		
			Total	**14**	
2		i	oxygen (1)	1	Ignore O_2 **Examiner's Comments** The word 'by-product' did not seem to be well known. Less than half correctly identified oxygen as the by-product from the equation.
		ii	….lowers the activation energy (box 2); (1) … provides a different route (box 3); (1)	2	**Examiner's Comments** Most gained a single mark for identifying one or other of the two correct statements about catalysts.
			Total	**3**	

Question			Answer/Indicative content	Marks	Guidance
3	a		**Level 3 (5–6 marks)** Describes a logical sequence for the experiment which includes some details of fair testing, a quantity used and links this to Alex's prediction. Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** Identifies aspects of a method / fair test **and** a quantity used. Quality of written communication partially impedes communication of the science at this level. **Level 1 (1–2 marks)** Identifies an aspect of a method / fair test **or** a quantity used. Quality of written communication impedes communication of the science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted at grades up to E Indicative scientific points include: Quantities used • $25cm^3$ of acid • 5g of calcium carbonate • Collect 20 cm3 gas Method/fair test • Larger lumps are used • same volume / amount of acid • same mass / amount of calcium carbonate • Same temperature (of acid) • Same concentration of acid • Same volume of gas collected • Repeat to identify outliers / check reliability • Measurement of time (to collect gas) How he will know the prediction is right • It would take more time for larger chips OWTTE • Same volume of gas collected in a longer time Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments For this question responses were mixed. The best candidates who achieved Level 3 gave a sequence for the experiment where they had clearly given correct volumes and masses, and stated how they would keep the experiment fair. Mistakes were often made by candidates stating they would complete a fair test, but then gave the incorrect values for mass and volume of acid. Some did not achieve higher level responses because they merely stated “I will do everything the same” but not being specific about amounts or method. A few candidates did not understand the concept

Question			Answer/Indicative content	Marks	Guidance
					of fair testing or gave a description of a different investigation than the one suggested in the question.
	b		use a more concentrated acid: use a catalyst: shake the flask: use a lower temperature: ✓ add water to the acid: ✓	2	**Examiner's Comments** Most candidates achieved a mark here; usually for “use a lower temperature”. Some candidates appeared to have misread the question and chose the top two distracters, which would have made reaction faster.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
4	a		**Level 3** Gives advantages and a disadvantage of using the enzyme, reaches a conclusion and makes a comparison between the two catalysts. *Quality of written communication does not impede communication of the science at this level*. (5 ? 6 marks) **Level 2** Gives advantages and a disadvantage of using the enzyme. *Quality of written communication partly impedes communication of the science at this level*. (3 ? 4 marks) **Level 1** Makes correct statements from the table. *Quality of written 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 D** No marks for the conclusion itself **Indicative scientific points may include:** **Level 3:** • links heating to energy costs • NaOH produces waste / enzyme does not produce waste • NaOH dissolves in the reaction mixture / need to separate idea **Level 1 and level 2:** **Advantages of the enzyme** • gentle heating • easy to remove / purification of product / re-use of Catalyst **ignore** speeds up this reaction only **Disadvantage** • expensive **Allow** other advantages / disadvantages which are not on the table e.g. enzymes are specific / work in narrow temperature bands / NaOH is very corrosive / alkaline **Use the L1, L2, L3 annotations in Scoris; do not use ticks.** **Examiner's Comments** This level of response question was targeted up to grade D. A table of information was given and candidates were asked to identify the advantages and disadvantages of the enzyme and to say which catalyst is best. Some excellent answers were seen with a relatively high proportion of candidates gaining level 3. Best answers clearly classified the points about the enzyme into advantages and disadvantages and explained which catalyst was best by referring to the shortcomings of the other catalyst. In this type of question it is important that

Question			Answer/Indicative content	Marks	Guidance
					candidates consider carefully what they are asked to do. Common reasons for lower scores included not clearly identifying advantages and disadvantages. Merely copying out the information in the table does not show an understanding of which features are positive or negative. Candidates also need to make sure that they say which catalyst is best.
	b		similarity [1] reactants / products have the same energy (on both diagrams) / both reactions need an activation energy / both reactions are exothermic / energy level decreases / products have less energy than reactants difference [1] activation energy [of enzyme / diagram A] lower	2	**Accept** 'different' **Do not allow** produces / gives out activation energy **Examiner's Comments** Most candidates correctly identified that A has a lower activation energy than B. However, the second mark was much less frequently scored. This was usually either because the candidate did not go on to make a second point or because the candidate thought that both reactions were endothermic. A common misconception seems to be that if products have less energy than reactants the reaction is endothermic.
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
5	a		Any two from: Shorter times mean faster reaction; at higher temperatures times are shorter; at higher temperature reaction is faster;	2	Examiner's Comments Most responses to this question correctly described the effect of temperature on rate of reaction. How this was shown by the results was seen less often.

Question			Answer/Indicative content	Marks	Guidance
	b		[Level 3] Makes correct judgements for Joe and Eve **AND** justifies these using appropriate evidence from the data for both judgements Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Makes correct judgements for Joe and Eve **OR** justifies a correct judgement using appropriate evidence from the data. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Makes a correct judgement for Joe or Eve but may not link this clearly to data OR shows how data links to rate. Quality of written 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 E Indicative scientific points may include: Joe • Joe is correct • Group 1 times same as one with no catalyst • Group 1 and no catalyst times are all 45s • Na^+ / K^+ times are the same as no catalyst Eve • Eve is not correct • Fe^{3+} is not fastest / takes longer than Co^{2+} • Evidence: Mentions data for ions with +1, +2 and +3 charges. How data links to rate • Times are lower if rate is faster • Same times = same rate Use the L1, L2, L3 annotations in Scoris; do not use ticks. <u>Examiner's Comments</u> There were some very good attempts at this level of response question, with candidates using the data to conclude that the Group 1 ions do not act as catalysts and that the effectiveness of the catalyst is not determined by the charge on the ions used. Some responses had less detail in, for example, comparing the Group 1 ions with each other only rather than with the uncatalysed reaction or comparing the +1 ions with the +2/+3 ions rather than the higher charged ions with each other.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
6			faster reaction / rate increases / decreases time for reaction; (1) due to increased surface area; (1)	2	**Ignore** speed of dissolving / spreading / diffusing Examiner's Comments There were some good responses to this question where candidates linked the fine powder with an increased rate that was caused by an increase in surface area. Some explained the rate increased due to the time needed to break up the lumps and others focussed on the idea of dispersion rather than rate of reaction. There was also some confusion between dissolving and reacting.
			Total	2	
7	a		A ? …. fastest B ? …. slowed down C ? ….. stopped	2	all 3 correct = 2 any 2 correct = 1 1 correct = 0 Examiner's Comments Candidates showed a good understanding of the graph and could correctly identify what was happening at each point on the graph. A few confused speeding up with slowing down and others inappropriately drew multiple lines.
	b		Repeat (same) experiment; add copper / catalyst; look for a faster reaction / higher rate;	3	**Allow** 'do it again' **Allow** shorter time Examiner's Comments Most candidates were able to suggest an appropriate investigation, usually either the addition of copper or the expectation that a faster reaction would occur. Many chose to use the catalyst instead of the zinc and others omitted to say what the expected result would be.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
8	a		FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.08 ± 1 (cm^3 / s) award 2 marks Change in volume = 8 ± 1 (cm^3) ✓ rate = 8 / 100 = 0.08 (cm^3 / s) ✓	2 (AO 2.2 × 2)	ALLOW use of any number 7- 9 anywhere in calculation (1) ALLOW ECF for 2nd mark: rate = change in volume / 100 ALLOW 0.07 – 0.09 (2) Examiner's Comments Question 12 is targeted at standard demand and is an overlap question with the higher tier paper. The majority of candidates gained the first mark by reading off a suitable value from the graph, and the higher ability candidates went on to calculate the rate.
	b		"Particle size" of carbonate / AW ✓ Temperature ✓	2 (AO 3.3a × 2)	ALLOW take readings every 200s or less/ same time interval IGNORE 'the same time' Examiner's Comments Candidates encountered surprising levels of difficulty with this question. Answers were often very general and focused on the equipment, "keep the apparatus the same" and "keep the syringe the same". The other main suggestion was "keep the timing the same", which again lacked sufficient detail to be awarded credit.

Question			Answer/Indicative content	Marks	Guidance
	c		Particles closer/have less space / more particles in same volume / more (densely) packed ✓ Collide more frequently / higher rate of collisions / more collisions per unit time/per second ✓	2 (AO 2.1 × 2)	ALLOW molecules for particles ALLOW more chance of collisions IGNORE more particles / more collisions / faster collisions / energy arguments / more successful collisions / <u>Examiner's Comments</u> Almost all candidates attempted a basic explanation. Higher ability candidates took their explanations beyond discussing 'more particles' and 'more collisions' by discussing the space between the particles and the collision frequency rather than number, and so gained credit.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
9	a	i	21 – 22 (cm^3) ✓	1 (AO 2.2)	<u>Examiner's Comments</u> For (i) most candidates read off the correct volume at 60 seconds. However for part (ii), most candidates then answered with the volume at 120 seconds (and not the amount given off <u>during</u> the second minute).
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer = 9 – 11 (cm^3) award 2 marks Uses 31 – 32 in answer ✓ 31.5 – 21.5 = 10 ± 1.0 (cm^3) ✓	2 (AO 2 × 2.2)	ALLOW ECF from (i)
	b		slows down ✓ then stops ✓	2 (AO 2 × 3.1a)	IGNORE starts fast IGNORE reference to volume rather than rate <u>Examiner's Comments</u> Almost all candidates described the volume directly (increasing to a constant value) rather than the rate of the reaction (which decreases to zero) shown by the slope of the line.

Question			Answer/Indicative content	Marks	Guidance
	c	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 3.5 (cm^3/s) award 2 marks Uses 2.8 and 4.2 in working ✓ = 3.5 (cm^3/s) ✓	2 (AO 2 × 2.2)	Examiner's Comments Many higher ability candidates gave the right answer here. A few candidates gave answers which were close but not quite correct. If they had not attempted to show their working, their answers did not gain any credit.  AfL It is important to stress to candidates that they should always show their working in calculation questions so if they get the answer wrong they may still gain credit for their method. Key  AfL Guidance to offer for future teaching and learning practice.
		ii	rate increases as concentration increases ✓ when concentration doubles rate doubles ✓	2 (AO 2× 3.1a)	ALLOW positive correlation ✓ 'when concentration doubles rate doubles' earns 2 marks (second marking point subsumes first) Examiner's Comments It was commonly understood that an increase in concentration gave an increase in the rate of reaction, but the fact that direct proportion involves the two terms changing by the same percentage (e.g. both doubling) was often missing from the answer.
		iii	rate of reaction α concentration ✓	1 (AO 1.1)	Examiner's Comments This was not well known. The symbol for proportionality is given in the assessable maths skills, Appendix 5e, skill M3, in the specification.
			Total	10	