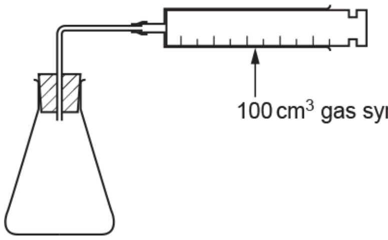
Reaction Rates

1(a). Zinc reacts with hydrochloric acid, HC*l*(aq), as shown in the following equation.

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

A student investigates the rate of this reaction.

The student uses the apparatus in the diagram.



The student's method is outlined below:

- Pour 50.0 cm^3 of 0.100 mol dm^{-3} HC*l* into the conical flask.
- Add 0.200 g of zinc (an excess), and quickly attach the delivery tube and gas syringe.
- Measure the volume of gas collected every 20 seconds until the reaction stops.

The student obtains the results shown in **Table 4.1**.

Time / s	0	20	40	60	80	100	120	160	200
Volume of gas / cm^3	0	16	27	37	39	50	53	58	58

Table 4.1

(i) On the graph paper in **Fig. 4.1**, label the x axis **and** plot the results in **Table 4.1.** **[1]**

(ii) Circle any anomalous results present in the graph you have drawn in **Fig. 4.1.** **[1]**

(iii) Draw a best-fit smooth curve on the graph you have drawn in **Fig. 4.1.** **[1]**

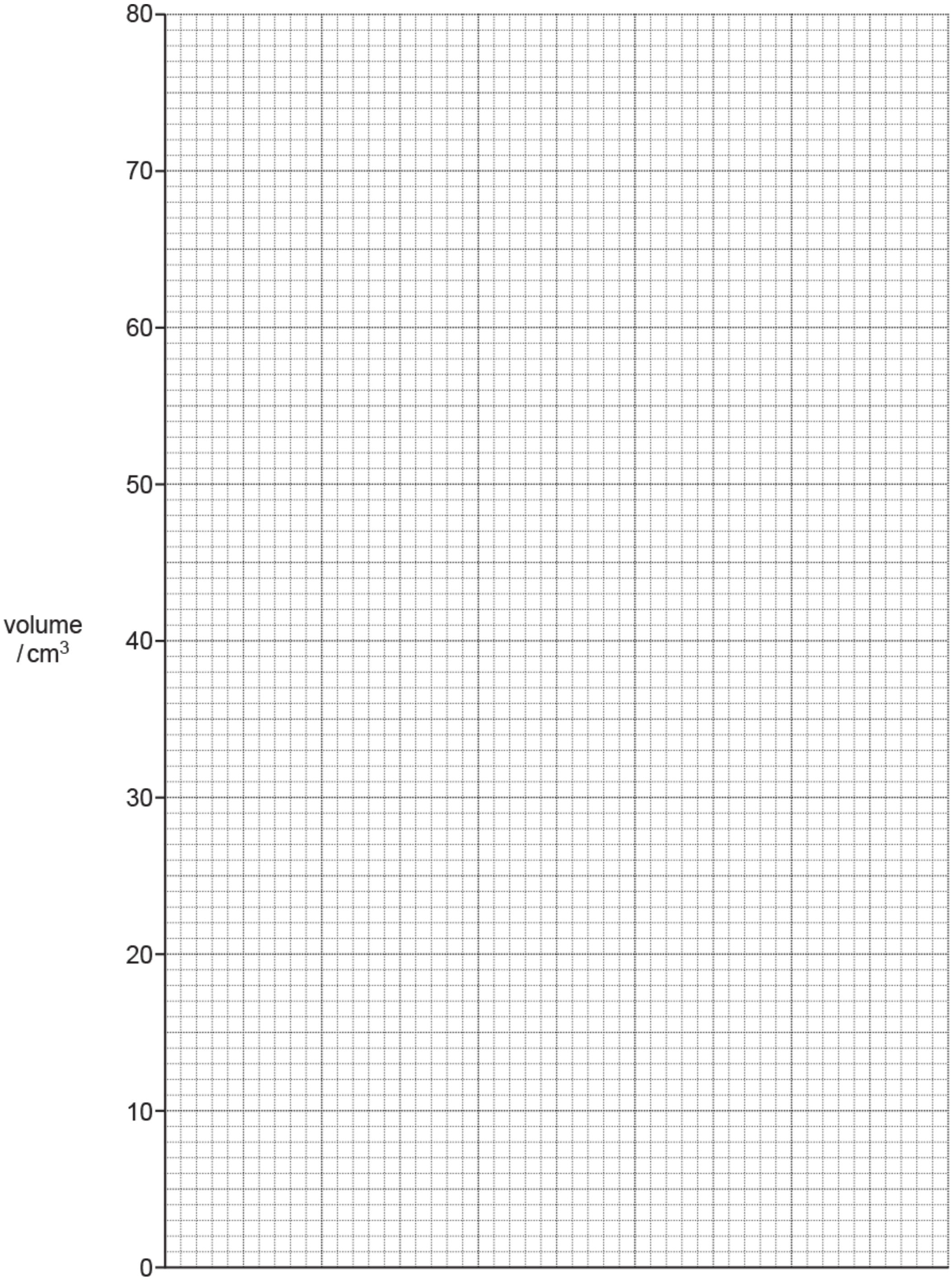


Fig. 4.1

(b). The student repeats the experiment using:

- zinc with the same mass (0.200 g) and same surface area
- the same temperature and pressure
- 40.0 cm^3 of 0.125 mol dm^{-3} HC*l*, instead of 50.0 cm^3 of 0.100 mol dm^{-3} HC*l*.

On your graph in **Fig. 4.1** sketch the curve you would expect in this experiment. **[2]**

(c). The graph shows that rate of reaction decreases over time.

Explain why, in terms of collision theory.

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____ **[2]**

(d). i. The rate of the reaction between zinc and hydrochloric acid can be increased using a solution of copper(II) sulfate as a catalyst.

Explain how a catalyst increases the rate of reaction.

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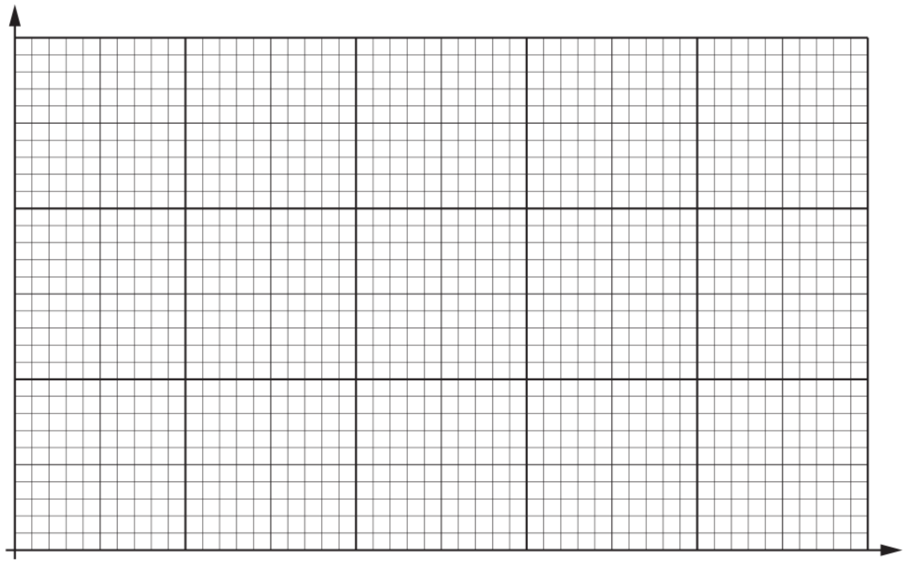
____ **[2]**

ii. Why is it difficult to classify the solution of copper(II) sulfate as a homogeneous or heterogeneous catalyst in this reaction?

[1]

2. Using the Boltzmann distribution model, explain how the rate of a reaction is affected by temperature.

You are provided with the axes below, which should be labelled.



[4]

3. Nitrogen can be reacted with hydrogen in the presence of a catalyst to make ammonia in the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

Describe and explain the effect of increasing the pressure on the rate of this reaction.

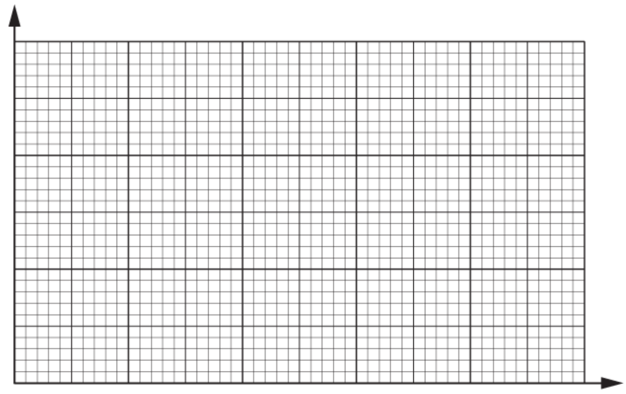
[2]

4(a). Methanol can be prepared industrially by reacting carbon monoxide with hydrogen in the presence of a copper catalyst. This is a reversible reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH\ (g)$$

Using the Boltzmann distribution model, explain why the rate of a reaction increases in the presence of a catalyst.

You are provided with the axes below, which should be labelled.



[4]

(b). The reaction for the production of methanol in the presence of the copper catalyst is carried out at 200–300 °C.

Explain why use of the catalyst reduces energy demand and benefits the environment.

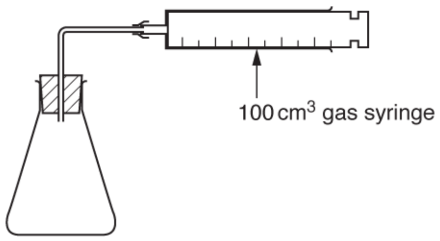
[2]

5. A student was asked to carry out an experiment to determine the initial rate of reaction of zinc and hydrochloric acid.

The student plans to collect a total of about 72 cm^3 of hydrogen at RTP and to use an excess of zinc.

The student selects the following apparatus:

- the apparatus shown in the diagram
- 100 cm^3measuring cylinder
- stop clock
- 2 decimal place balance



Outline how the student could carry out the experiment and explain how the results could be processed graphically.
Show all working in your calculations.

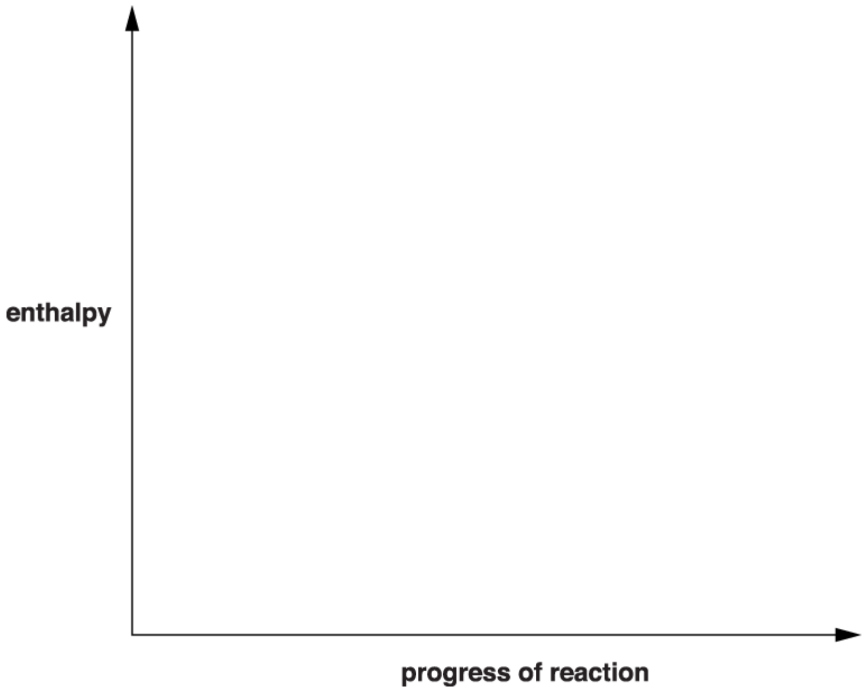
--- **[6]**

6(a). Catalysts can be used to change the rate of some chemical reactions.

i. Zinc and sulfuric acid react together to form a solution of zinc sulfate, $ZnSO_4$, and hydrogen gas. The reaction is exothermic.

The rate of the reaction increases when a catalyst is added.

- Complete the enthalpy profile diagram for this reaction using the formulae of the reactants and products.
- Label activation energies, $\boldsymbol{E_a}$ (without catalyst) and $\boldsymbol{E_c}$ (with catalyst).
- Label the enthalpy change of reaction, $\boldsymbol{\Delta H}$.

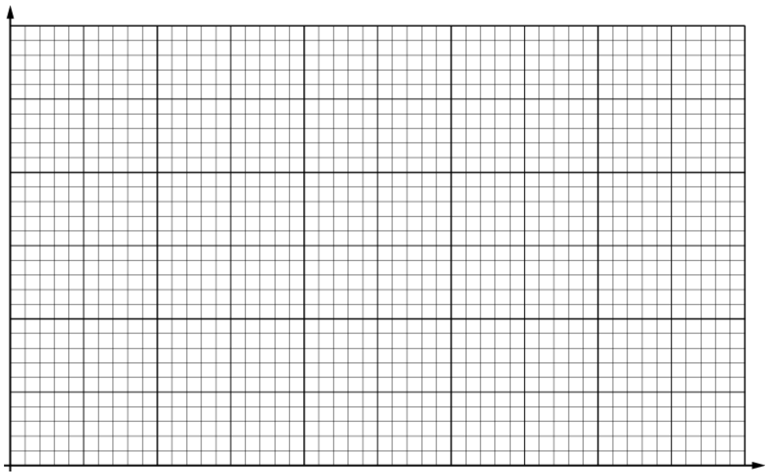


[3]

ii. Using a Boltzmann distribution, explain how a catalyst increases the rate of a chemical reaction.

Include a labelled sketch of your Boltzmann distribution on the grid below. Label the axes and any other important features.

Your answer needs to be clear and well organised using the correct terminology.



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____ **[4]**

(b) The chemical industry uses catalysts for many of its reactions.

i. State an example of a catalyst used by the chemical industry and write the equation for the reaction that is catalysed.

catalyst: ....

equation: ....

[1]

ii. State **two** ways that the use of catalysts helps chemical companies to make their processes more sustainable and less harmful to the environment.

--- **[2]**

7(a). A student investigates the reaction between strontium carbonate and dilute nitric acid.

$$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + CO_2 + H_2O$$

The rate of reaction is determined from the loss in mass over a period of time.

i. Explain why there is a loss in mass during the reaction.

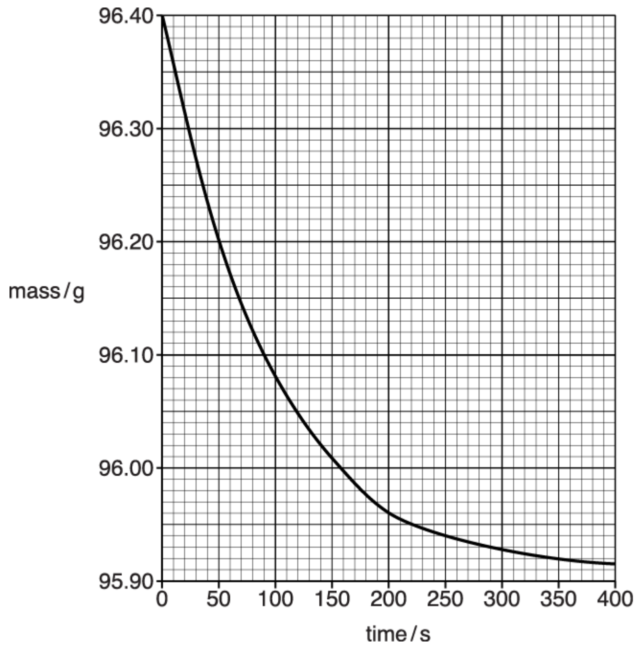
--- **[1]**

ii. An excess of strontium carbonate, $SrCO_3$, is mixed with 20.0 cm^3 of 1.25 mol dm^{-3} nitric acid, HNO_3.

Calculate the mass of $SrCO_3$ that reacts with the HNO_3.

mass = ... g **[3]**

(b). The student plots a graph of total mass (reagents + container) against time.



i. Describe and explain the change in the rate of the reaction during the first 200 seconds of the experiment.

--- **[2]**

ii. Using the graph, calculate the rate of reaction, in g s^{-1}, at 200 seconds.

Show your working on the graph.

rate of reaction = ... g s^{-1} **[2]**

(c). Outline a method that could be used to obtain the results that are plotted on the graph.

Your answer should include the apparatus required and the procedure for the experiment.

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____ **[3]**

8(a). Methanol, CH_3OH, is an important feedstock for the chemical industry.

In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49\ \text{kJ mol}^{-1}$$

Describe and explain the effect of increasing the pressure on the reaction **rate**.

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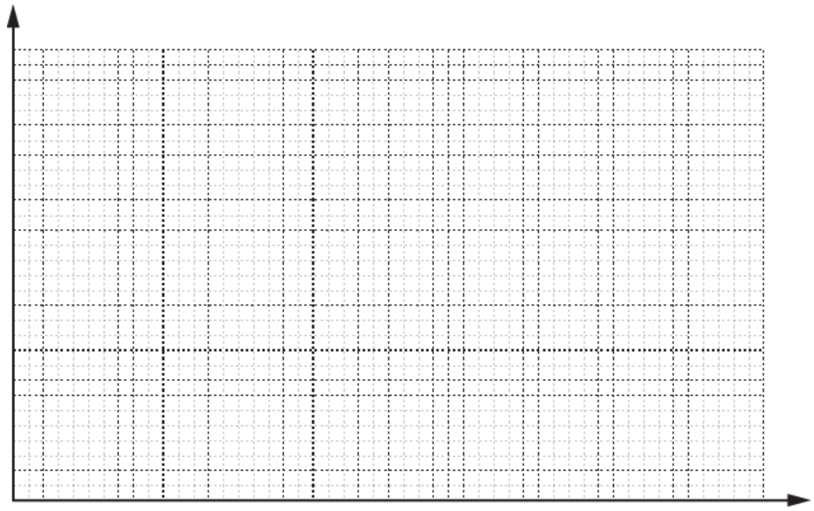
____ **[2]**

(b). The manufacture of methanol uses a catalyst.

- Sketch a labelled diagram of the Boltzmann distribution on the grid provided.
- Label your axes.
- Using your Boltzmann distribution, explain how the catalyst increases the rate of reaction.



--- **[4]**

(c). Explain why the use of a catalyst can reduce the demand for energy.

--- **[1]**

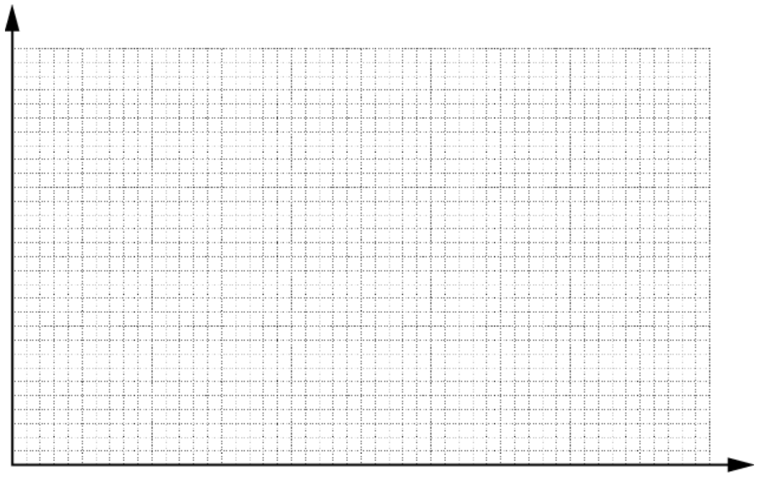
9. Reaction rates can be increased or decreased by changing conditions of temperature and pressure.

i. Explain how increasing the temperature increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution, on the grid below.

Label the axes.

Your answer needs to be clear and well organised using the correct terminology.



[4]

ii. Describe and explain the effect of decreasing the pressure on the rate of a reaction.

[2]

10(a). An experiment is carried out to find the rate of this reaction:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The results of the experiment are given in the table below:

Time / s	0	50	100	150	200	250	300	350
Concentration of SO_3 / mol dm^{-3}	0	0.024	0.034	0.038	0.039	0.040	0.041	0.041

i. Plot a graph from the data provided.
Include a line of best fit.

[3]

ii. Use the graph to determine the **initial** rate of this reaction.
Show your working below and on the graph.

initial rate = ... mol dm^{-3} s^{-1} **[2]**

iii. This experiment is repeated in the presence of a catalyst.
Draw and label a line **on the graph** to show the results of the catalysed experiment over the same time period.

[1]

(b). A solid catalyst, vanadium(V) oxide, V_2O_5, is used in industry to increase the rate of the production of sulfur trioxide, SO_3, in this reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -196 \text{ kJ mol}^{-1}$$

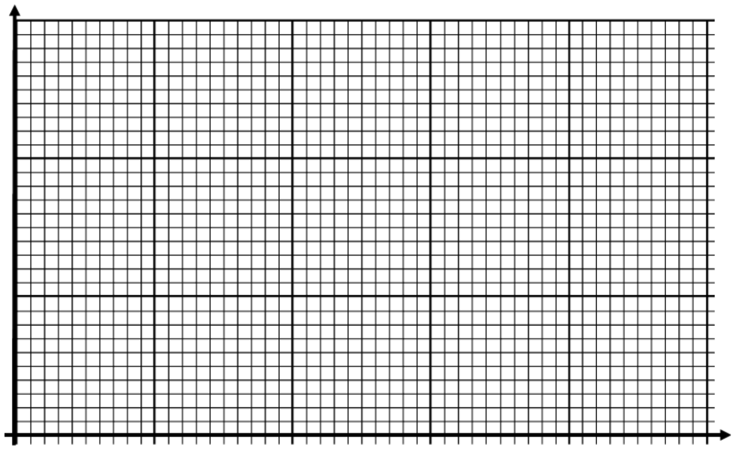
i. Explain, with a reason, whether V_2O_5 is a homogeneous or heterogeneous catalyst.

[1]

ii. The use of catalysts in industrial processes can be beneficial to the environment.
State **one** reason for this.

[1]

iii. Using a fully labelled Boltzmann distribution on the grid below, explain why adding a catalyst increases the rate of a reaction.

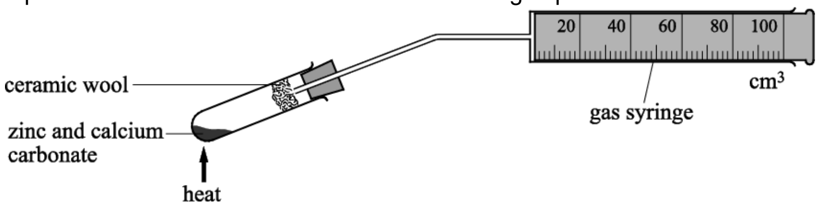


[4]

11. Carbon monoxide can be made in the laboratory by heating a mixture of zinc metal and calcium carbonate. An equation for this reaction is shown below.

$$Zn(s) + CaCO_3(s) \rightarrow ZnO(s) + CaO(s) + CO(g)$$

A student carried out the reaction of zinc (Zn) and calcium carbonate ($CaCO_3$) in a fume cupboard. The student measured the volume of gas produced.



A mixture containing 0.27 g of powdered zinc and 0.38 g of powdered $CaCO_3$ was heated strongly for two minutes. The volume of gas collected in the 100 cm^3 syringe was then measured. The experiment was then repeated.

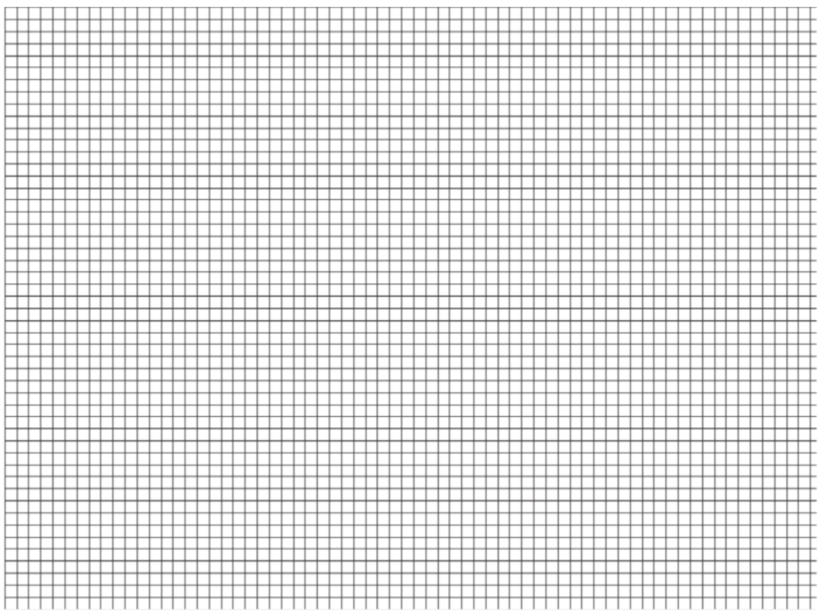
The student repeated the experiment in **(c)** using different quantities of zinc and calcium carbonate.

The student measured the total volume of gas collected over time.

The student's results are shown below.

Time / s	**Total volume of gas collected / cm³**
0	0
20	13
40	42
60	56
80	65
100	72
120	72

i. Plot a graph from the data provided.
Include a line of best fit.



[3]

ii. Using the graph, determine the rate of reaction, in $cm^3\ s^{-1}$, after 50 s.

Show your working on your graph.

rate after 50 s = ... $cm^3\ s^{-1}$ **[2]**

END OF QUESTION PAPER