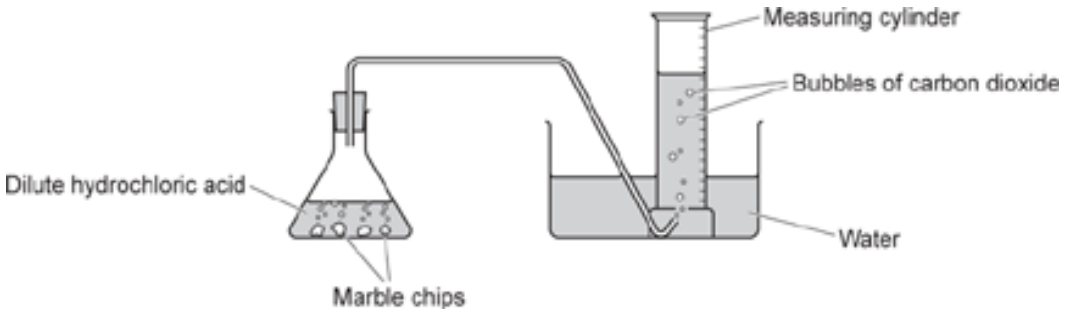
1(a). A student investigates the reaction between marble chips and dilute hydrochloric acid.

The diagram shows their experiment.



The student measures the volume of carbon dioxide gas collected in the measuring cylinder every 30 seconds.

i. Suggest another piece of equipment that could be used to measure the volume of carbon dioxide gas.

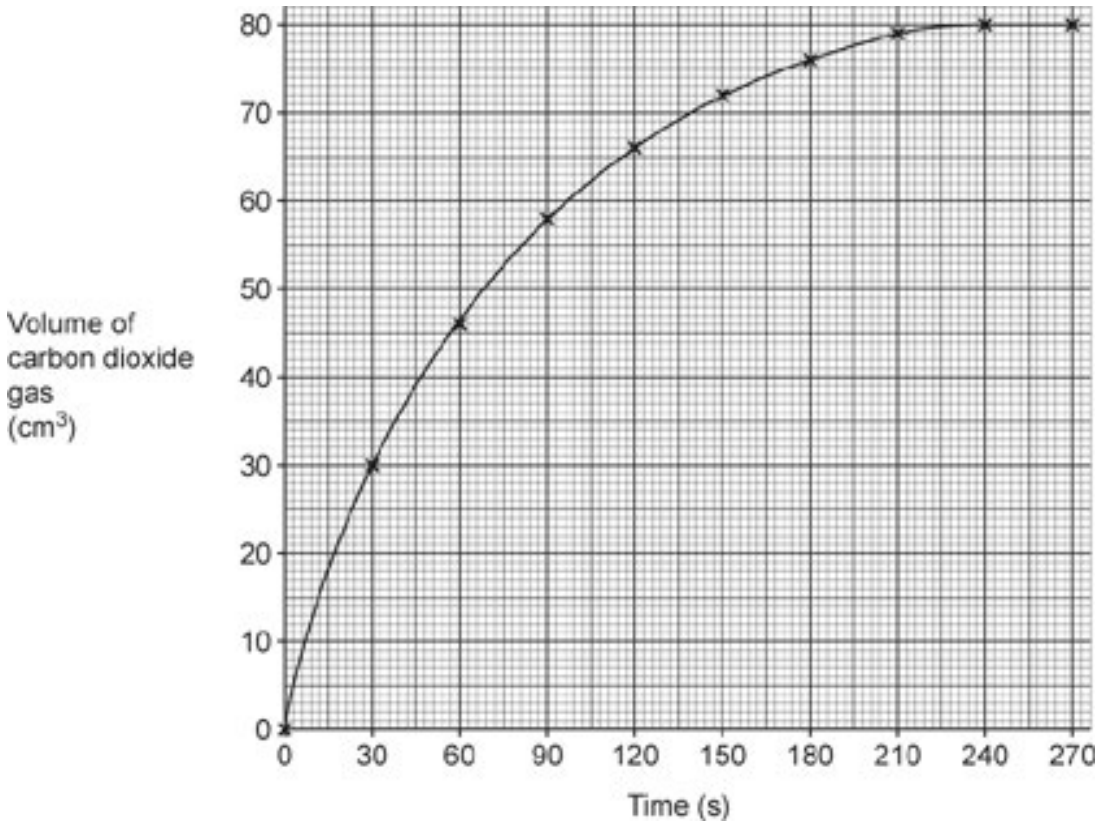
_____ **[1]**

ii. Explain how the student could tell that the dilute hydrochloric acid is the limiting reactant in this reaction.

_____

_____ **[1]**

(b). The student plots their results on a graph.



Use the graph and a tangent line to calculate the rate of the reaction at 60 seconds.

Rate of reaction at 60 seconds = ... cm^3 / s **[3]**

(c). The rate of the reaction can be changed by adding a catalyst.

i. What happens to the final volume of carbon dioxide when a catalyst is added?

---

[1]

ii. How does the mass of the catalyst change during the experiment?

---

[1]

(d). A student reacts dilute hydrochloric acid with magnesium.

The student does two experiments.

In each experiment they use the **same**

- concentration of dilute hydrochloric acid
- mass of magnesium.

The table shows their results.

	Experiment 1	**Experiment 2**
Magnesium	large pieces	small pieces
Temperature of dilute hydrochloric acid (°C)	20	42
Rate of reaction (/s)	0.0044	0.04

Evaluate the student's results, explaining the difference in the rate of reaction.

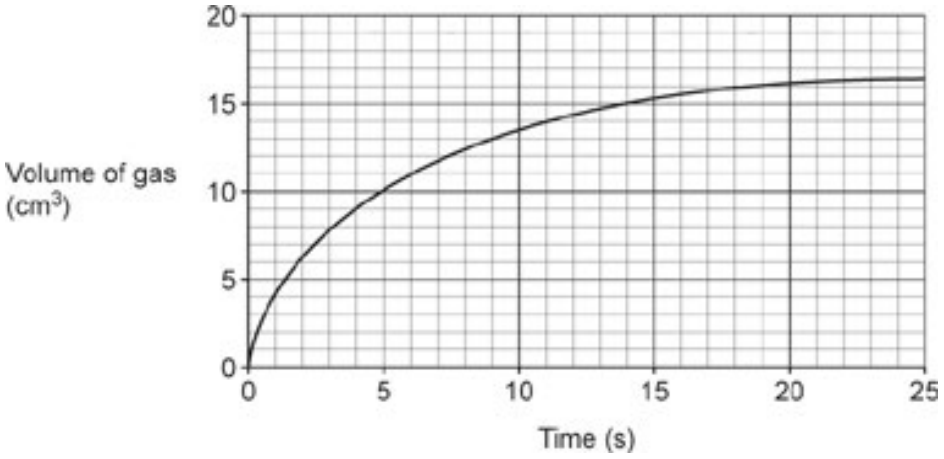
Use the reacting particle model.

State how the student's experiment could be improved.

---

[6]

2. What is the average rate of this reaction, in cm^3 / s, during the first 5 seconds?



A 0.5 cm^3 / s
B 2.0 cm^3 / s
C 5.0 cm^3 / s
D 50.0 cm^3 / s

Your answer ☐ **[1]**

3. Which statement about activation energy is correct?

A Activation energy is increased by the addition of a catalyst.
B Activation energy is lowered when the temperature is increased.
C Activation energy is the minimum amount of energy for a reaction to occur.
D The greater the activation energy, the greater the rate of reaction.

Your answer ☐ **[1]**

4. Methanol, CH_3OH, is made in industry by reacting carbon monoxide with hydrogen.

This is the equation for the reaction.

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

The forward reaction is exothermic.

A temperature of 250 °C and a pressure of 100 atmospheres is used for the reaction.

i. Describe and explain the effect on the yield of methanol from using a pressure of 15 atmospheres.

[3]

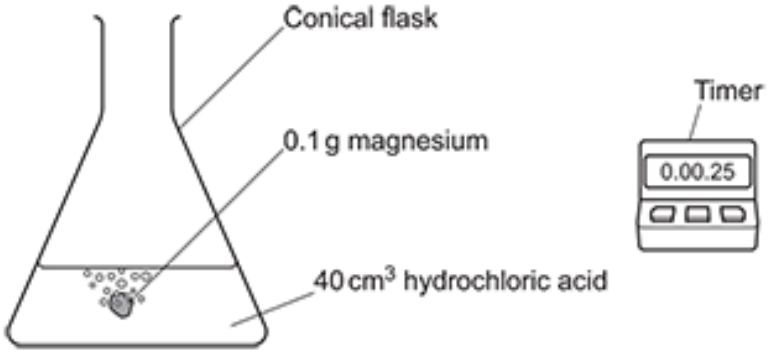
ii. The yield of methanol is greater when a temperature of 150 °C is used instead of 250 °C.

Suggest why a temperature of 150 °C is **not** used in industry.

[1]

5(a). A teacher investigates the reaction between hydrochloric acid and magnesium.

The diagram shows the teacher's experiment.



The teacher uses five different concentrations of hydrochloric acid. Each time they react the hydrochloric acid with 0.1 g of magnesium powder.

The table shows the teacher's results.

Concentration of hydrochloric acid (mol / dm^3)	Time for magnesium powder to react(s)
0.5	117
1.0	82
1.5	48
2.0	24
2.5	16

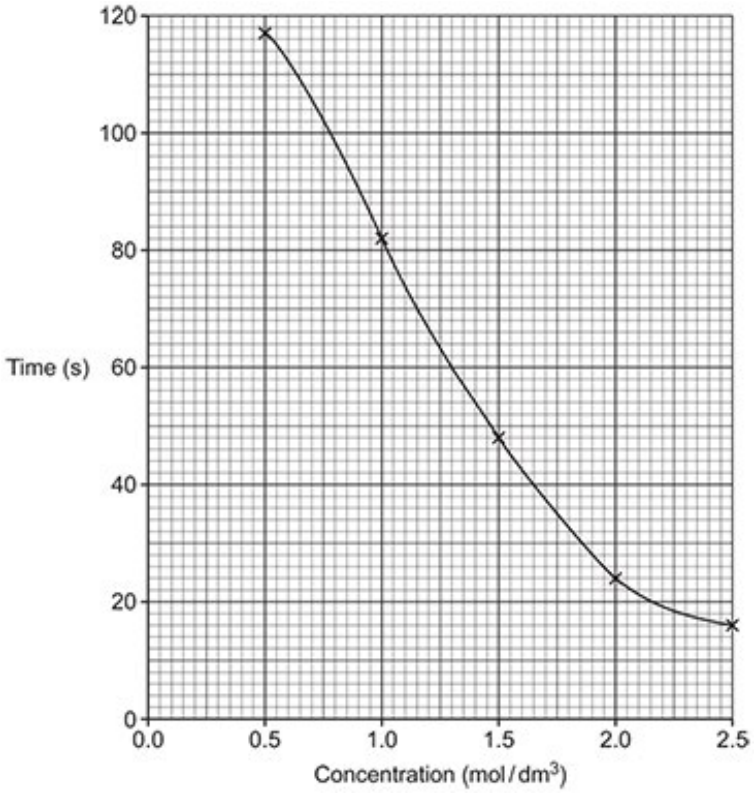
The teacher says, 'The reaction is faster the more concentrated the hydrochloric acid'.

Use the results to explain why the teacher is **correct**.

---

[1]

(b). The graph shows the teacher's results.



i. Use the graph to deduce the time for magnesium powder to react if 1.3 mol / dm^3 hydrochloric acid is used.

Time = ... s **[1]**

ii. The teacher repeats the experiment with 0.1 g of magnesium **ribbon**.

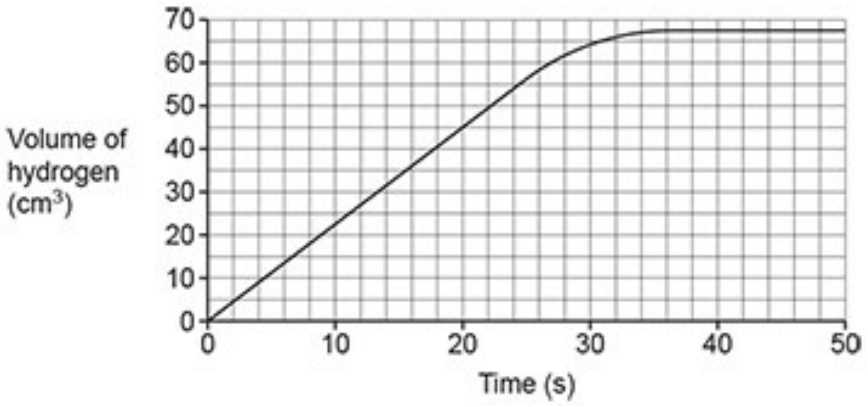
Draw a line on the graph to show the results you would expect the teacher to get.

[2]

(c). Write the **balanced symbol** equation for the reaction between hydrochloric acid, HC*l*, and magnesium.

_____ **[2]**

6. The graph shows the volume of hydrogen gas made in an experiment.



What is the rate of reaction when the time is 20 s?

A 0.44 cm^3/s
B 2.25 cm^3/s
C 25 cm^3/s
D 900 cm^3/s

Your answer ☐ **[1]**

END OF QUESTION PAPER