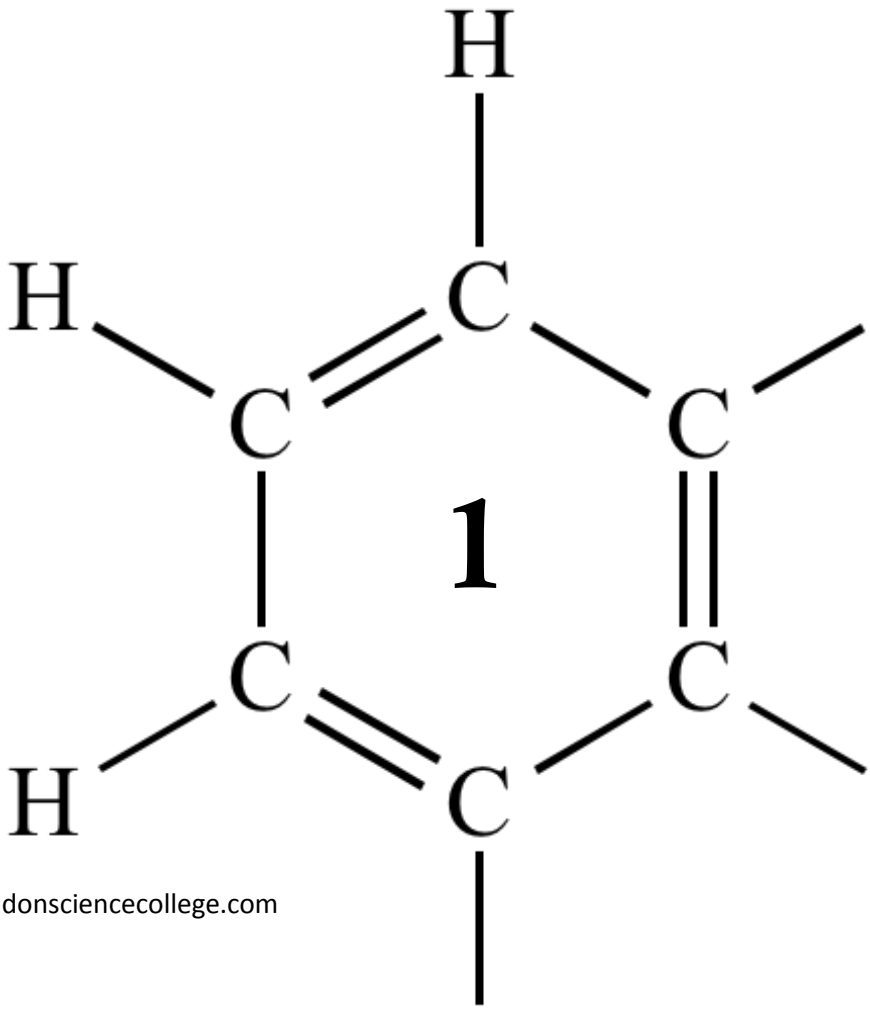
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

# KINETICS



**1** When an aqueous solution of ethanoic acid reacts with magnesium, the progress of reaction can be followed using the equipment shown in **Figure 1** to measure the volume of hydrogen produced.

**Figure 1**

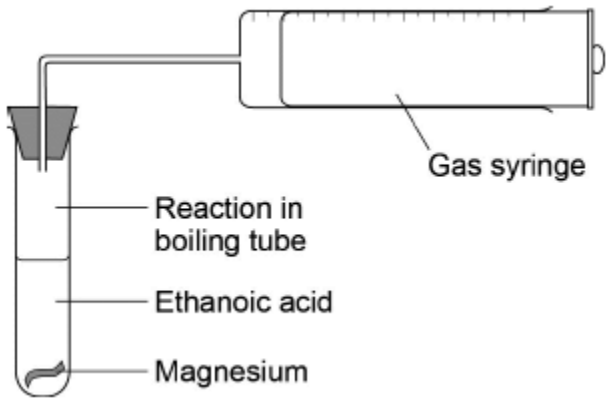
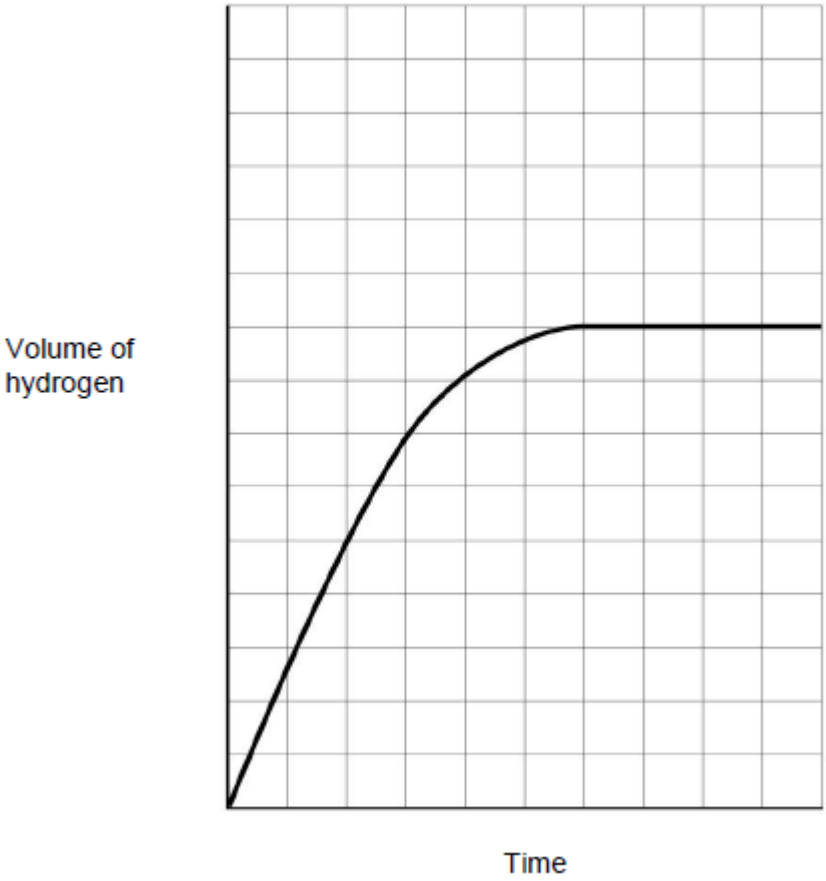



**Figure 2** shows how the volume of hydrogen produced varies with time when 396 mg of magnesium are added to 30.0 $cm^3$ of 0.600 mol $dm^{-3}$ ethanoic acid.

**Figure 2**



(a) The equation for the reaction between ethanoic acid and magnesium is shown.

$$2CH_3COOH(aq) + Mg(s) \longrightarrow (CH_3COO)_2Mg(aq) + H_2(g)$$

With the aid of calculations, show that the magnesium is in excess in this reaction.

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**(3)**

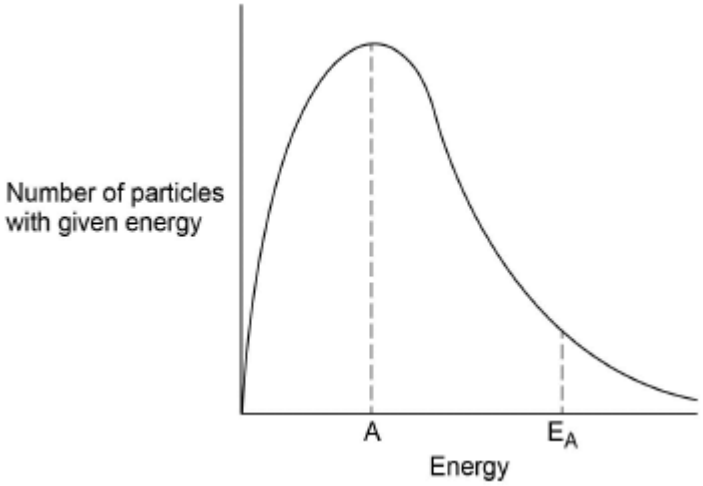
(b) The reaction was repeated using 20 $cm^3$ of 0.800 mol $dm^{-3}$ of ethanoic acid solution with all other conditions the same. The magnesium was still in excess.

Sketch a line on **Figure 2** to show how the volume of hydrogen produced varies with time in this second experiment.

Space for working.

**(2)**
**(Total 5 marks)**

**2** The graph below shows a typical energy distribution for particles of an ideal gas in a sealed container at a fixed temperature.




Which of the following statements is true?

**A** Position A represents the mean energy of a molecule in the container. ⬭

**B** Addition of a catalyst moves the position of $E_A$ to the right. ⬭

**C** The area under the curve to the right of $E_A$ represents the number of molecules with enough energy to react. ⬭

**D** The position of the peak of the curve at a higher temperature is further away from both axes. ⬭

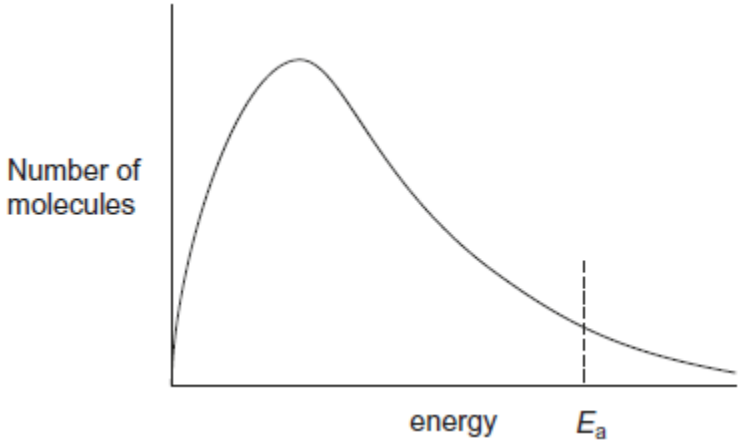
**(Total 1 mark)**

**3** Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically carried out at 300 °C and $3 \times 10^7$ Pa, in the presence of a catalyst.

(a) The graph shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 °C.




(i) Sketch a second curve on the graph to show the distribution of molecular energies in this mixture at a higher temperature.

**(1)**

(ii) Explain with reference to both curves on the graph how a small change in temperature leads to a large change in the rate of reaction.

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**(2)**

(b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

(i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

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**(3)**

(ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 °C rather than at a higher temperature.

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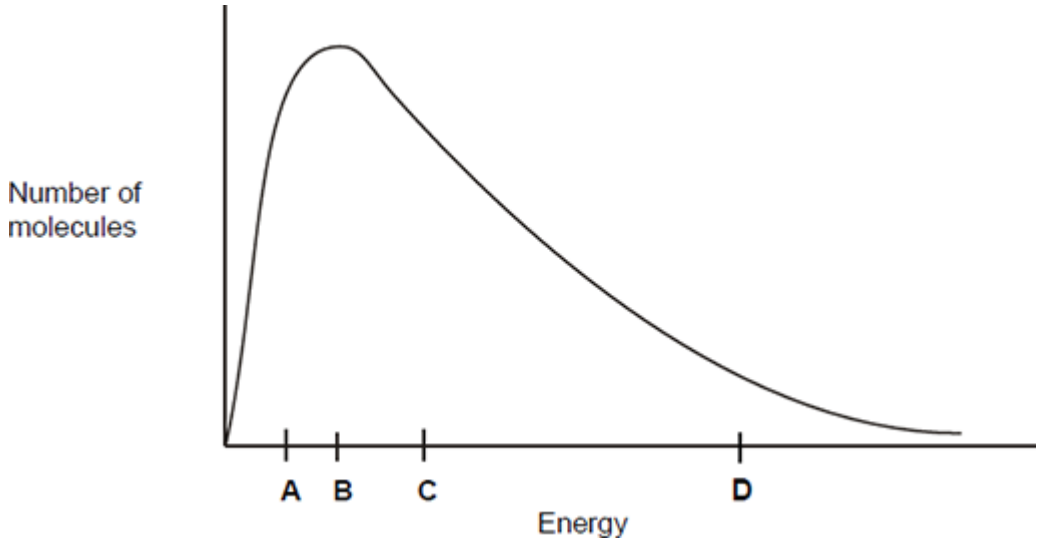
**(2)**
**(Total 8 marks)**

**4** This question is about the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas shown in the figure below.




Which letter best represents the mean energy of the molecules?

**A** ⬭

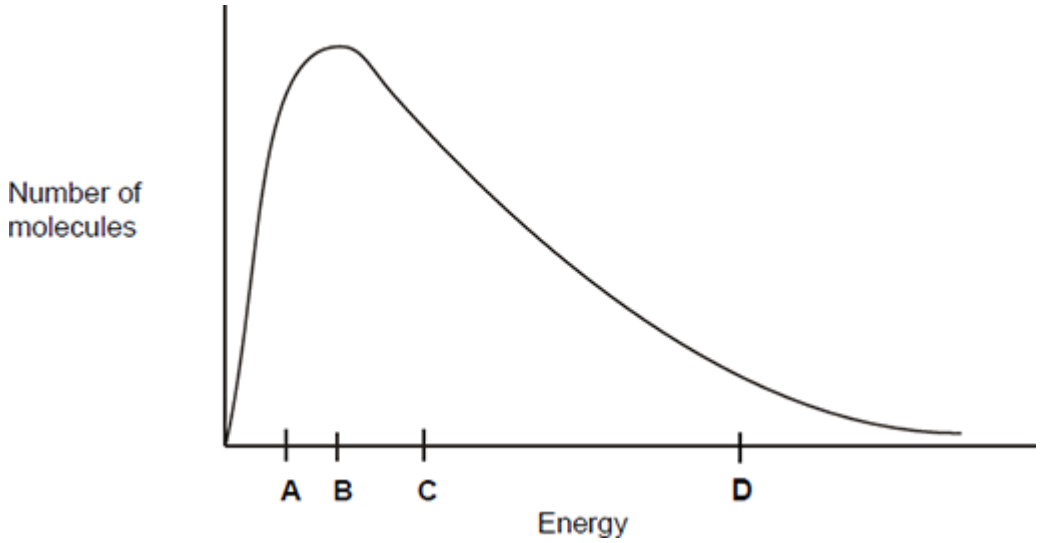
**B** ⬭

**C** ⬭

**D** ⬭

**(Total 1 mark)**

**5** This question is about the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas shown in the following figure.




What does the area under the curve represent?

**A** The total energy of the particles. ⬭

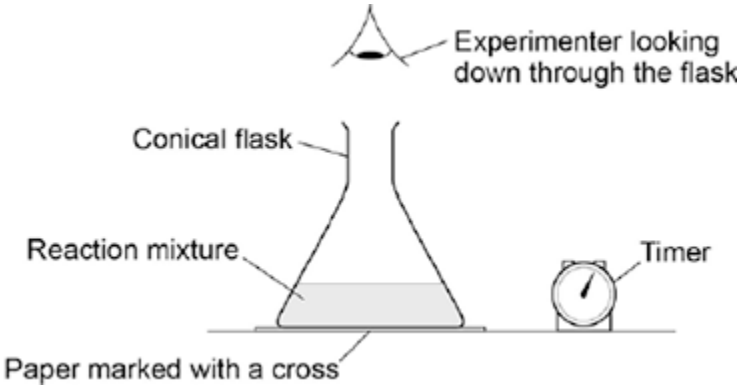
**B** The total number of particles. ⬭

**C** The number of particles that can react with each other. ⬭

**D** The total number of particles that have activation energy. ⬭

**(Total 1 mark)**

**6** The apparatus in the figure below was set up to measure the time taken for 20.0 $cm^3$ of sodium thiosulfate solution to react with 5.0 $cm^3$ of hydrochloric acid in a 100 $cm^3$ conical flask at 20 °C.
The timer was started when the sodium thiosulfate solution was added to the acid in the flask.
The timer was stopped when it was no longer possible to see the cross on the paper.




What is likely to decrease the accuracy of the experiment?

**A** Rinsing the flask with acid before each new experiment. ⬭

**B** Stirring the solution throughout each experiment. ⬭

**C** Using the same piece of paper for each experiment. ⬭

**D** Using different measuring cylinders to measure the volumes of acid and sodium thiosulfate. ⬭

**(Total 1 mark)**

**7** The experiment was repeated at 20 °C using a 250 $cm^3$ conical flask.

Which statement is correct about the time taken for the cross to disappear when using the larger conical flask?

**A** The time taken will **not** be affected by using the larger conical flask. ⬭

**B** The time taken will be decreased by using the larger conical flask. ⬭

**C** The time taken will be increased by using the larger conical flask. ⬭

**D** It is impossible to predict how the time taken will be affected by using the larger conical flask. ⬭

**(Total 1 mark)**

**8** Hydrogen is produced in industry from methane and steam in a two-stage process.

(a) In the first stage, carbon monoxide and hydrogen are formed.
The equation for this reaction is

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

(i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage.
Explain your answer.

Temperature .....

Explanation .....

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**(3)**

(ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

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(iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

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**(2)**

(b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -41$ kJ mol$^{-1}$

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

Effect .....

Explanation .....

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**(2)**
**(Total 9 marks)**

**9** Calamine lotion can contain a mixture of zinc carbonate and zinc oxide in suspension in water. A manufacturer of calamine lotion claims that a sample contains 15.00 g of zinc carbonate and 5.00 g of zinc oxide made up to 100 cm$^3$ with distilled water.

(a) A chemist wanted to check the manufacturer's claim. The chemist took a 20.0 cm $^3$ sample of the calamine lotion and added it to an excess of sulfuric acid.
The volume of carbon dioxide evolved was measured over time. The chemist's results are shown in the table.

| **Time / s** | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Volume / cm$^3$** | 0 | 135 | 270 | 380 | 470 | 530 | 560 | 570 | 570 | 570 |

(i) Plot a graph of the results in the table on the grid. The volume should be on the *y*-axis. Draw a best-fit curve through **all** the points.

**(3)**

(ii) Estimate the time taken for the reaction to be completed.

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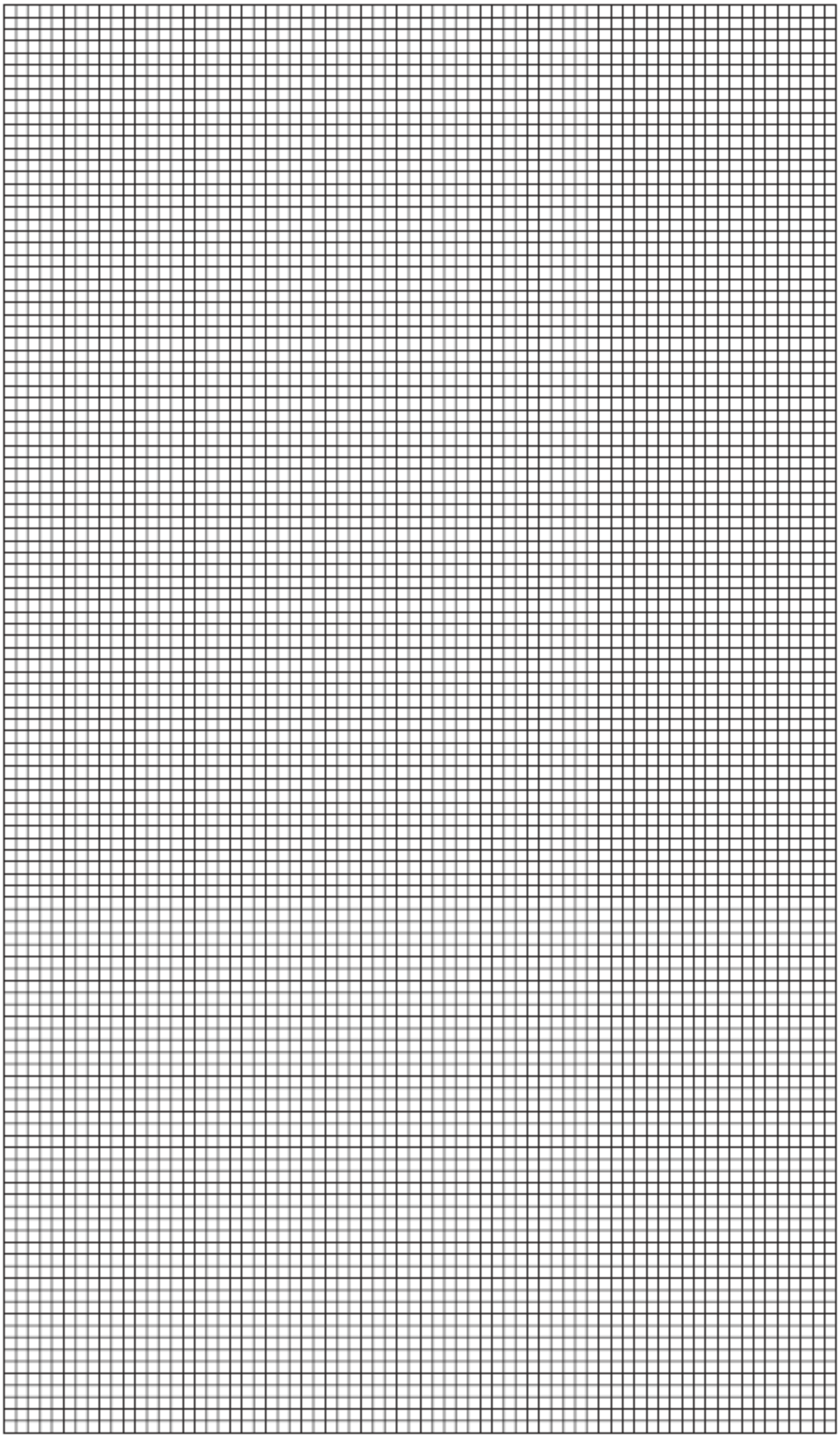
**(1)**



(b) (i) The volume of carbon dioxide in part (a) was measured at 293 K and at a pressure of 100 kPa.

Use information from your graph to calculate the maximum amount, in moles, of carbon dioxide evolved from the zinc carbonate in this 20.0 $cm^3$ sample.

The gas constant, $R$ = 8.31 J $K^{-1}$ $mol^{-1}$

Show your working.

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**(3)**

(ii) Use your answer to part (i) to calculate the mass of zinc carbonate in the 20.0 $cm^3$ sample of calamine lotion.

(If you were unable to complete part (i), you may assume that the amount of carbon dioxide evolved was 0.0225 mol. This is **not** the correct answer.)

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**(2)**

(iii) Calculate the difference between your answer to part (ii) and the manufacturer's claim that there are 15.00 g of zinc carbonate in 100 $cm^3$ of the calamine lotion.

Express this difference as a percentage of the manufacturer's claim.

(If you were unable to complete part (ii), you may assume that the mass of zinc carbonate in the 20 $cm^3$ sample of calamine lotion was 2.87 g. This is **not** the correct answer.)

Difference .....

Percentage .....

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**(2)**

(c) Draw a diagram of a suitable apparatus needed to perform the experiment outlined in part (a). Include in your diagram a method for collecting and measuring the carbon dioxide. The apparatus should be airtight.

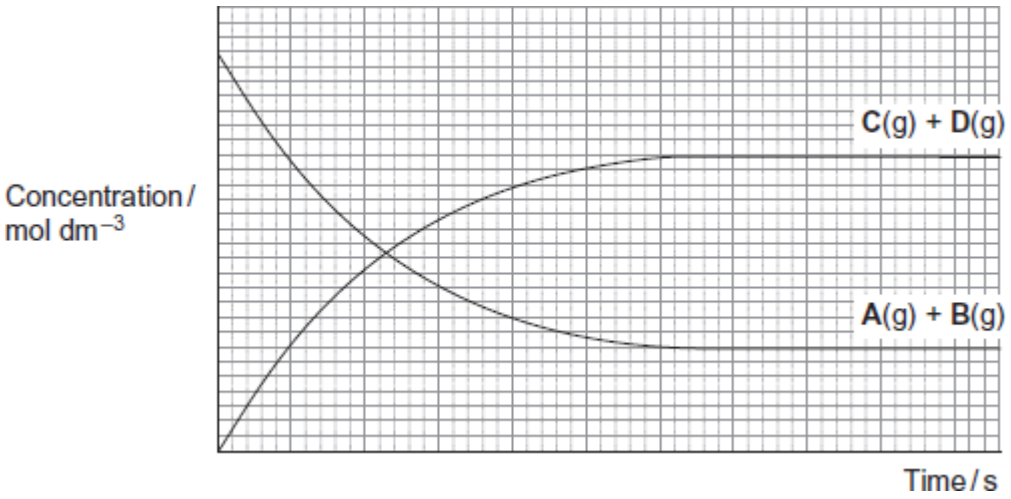
**(2)**

**(Total 13 marks)**

**10** A dynamic equilibrium is established when gas **A** is mixed with gas **B** at a given temperature.

$$\mathbf{A}(g) + \mathbf{B}(g) \rightleftharpoons \mathbf{C}(g) + \mathbf{D}(g)$$

The figure below shows how the concentrations of reactants and products change with time.




(a) (i) On the appropriate axis of the figure, place an **X** to show the time when equilibrium is first established.

**(1)**

(ii) State how the rate of the forward reaction and the rate of the reverse reaction are related to each other at equilibrium.

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**(1)**

(b) Give the meaning of the term **dynamic** in the context of a dynamic equilibrium.

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**(1)**

(c) The total pressure on the system is increased at constant temperature.

(i) State and explain the effect, if any, of this change on the position of this equilibrium.

Effect .....

Explanation .....

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**(2)**

(ii) State and explain the effect, if any, of this change on the time taken to reach this equilibrium.

Effect .....

Explanation .....

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**(3)**
**(Total 8 marks)**