# WJEC Chemistry A-level

## PI3: Chemical Kinetics

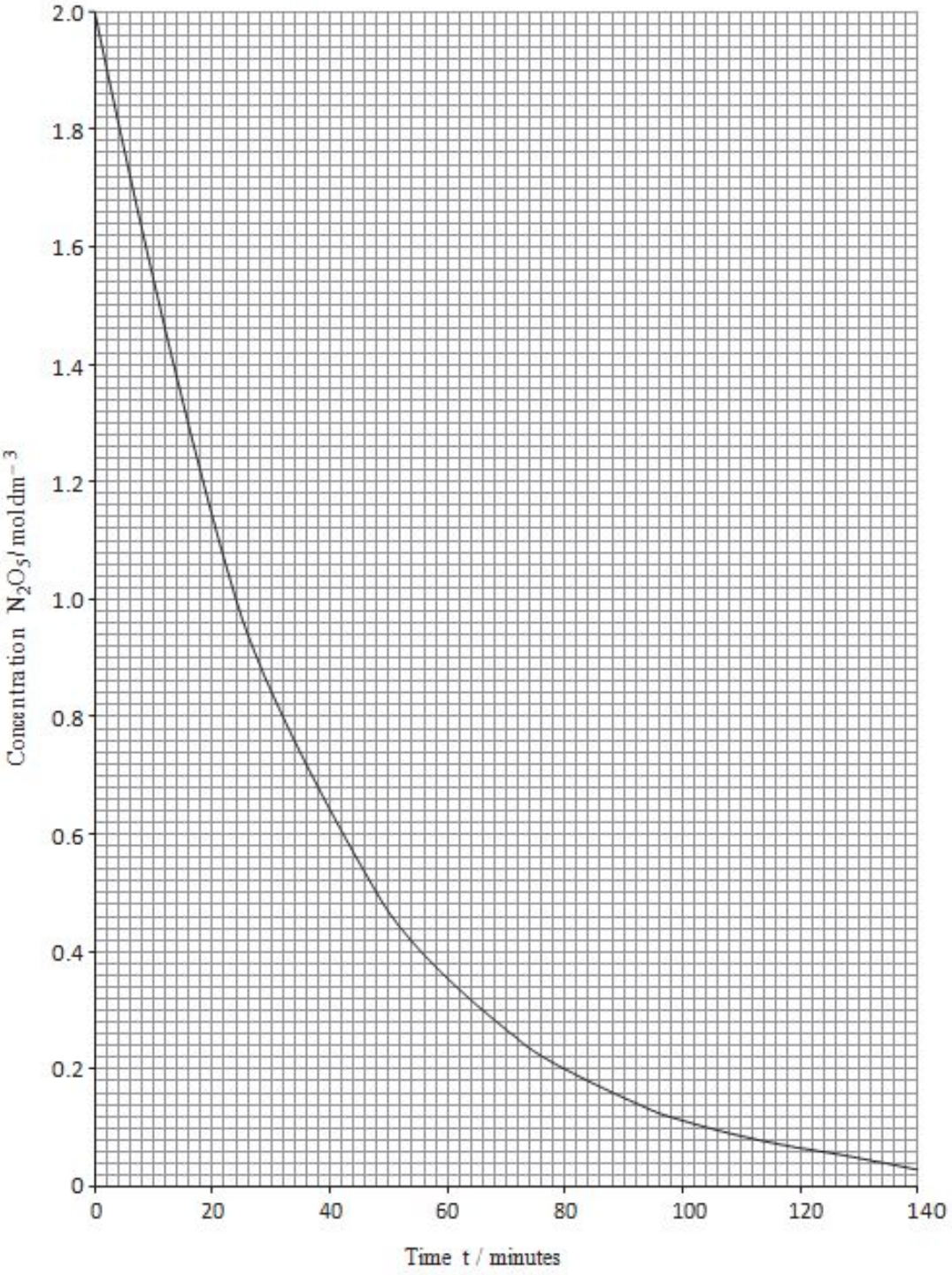
### Practice Questions

England Specification

1. Nitrogen forms a variety of oxides including dinitrogen pentoxide, $N_2O_5$, which can decompose as shown in the equation.

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$

The rate at which this decomposition occurs can be followed by measuring the change in concentration of $N_2O_5$. A graph of the results of this decomposition is shown below.



*(a)* (i) Use the graph to determine the rate of reaction, in $mol\,dm^{-3}\,min^{-1}$, after 40 minutes. Show clearly on the graph, how you determined your answer. [2]

*Rate after 40 minutes* = ..... $mol\,dm^{-3}\,min^{-1}$

(ii) Explain why the rate of reaction is lower at t = 60 minutes than it was at t = 40 minutes. [1]

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*(b)* (i) Use the graph to show that the reaction is first order with respect to $N_2O_5$. Explain how you reached your conclusion. [2]

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(ii) Write the rate equation for the reaction. [1]

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(iii) Find the value of k in the rate equation and state its units. [2]

*Value of k* = .....

*Units* = .....

(iv) Two students suggested possible mechanisms for the decomposition of $N_2O_5$.

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$

**StudentA**

$$N_2O_5 \xrightarrow{\text{slow}} NO_2 + NO + O_2$$

$$NO + O_2 \xrightarrow{\text{fast}} NO_2 + \tfrac{1}{2}\,O_2$$

**StudentB**

$$2N_2O_5 \xrightarrow{\text{slow}} 4NO + 3O_2$$

$$4NO + 2O_2 \xrightarrow{\text{fast}} 4NO_2$$

State, with a reason, which student's suggested mechanism is more likely to be correct. [1]

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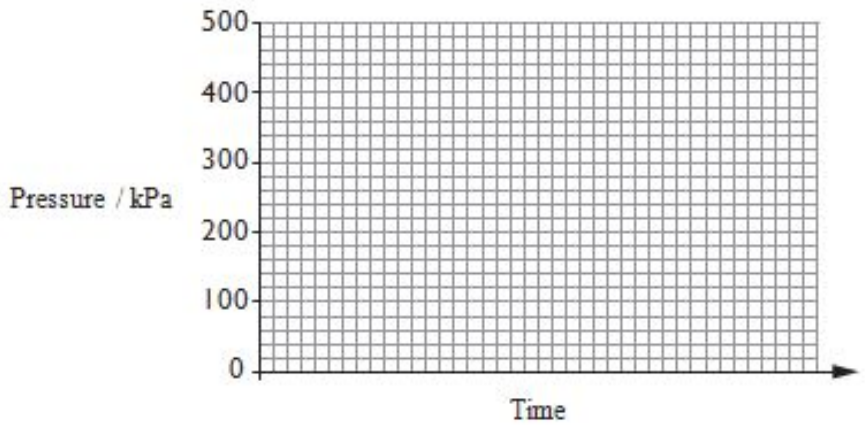
*(c)* The progress of the reaction could have been followed by monitoring changes in pressure. On the axes below sketch the results expected if the initial pressure of the $N_2O_5$ was 100 kPa and the reaction reached completion. [2]




Total [11]

2. Ammonium salts are very important chemicals as they are used as a nitrogen source in fertilisers.

*(a)* When cold aqueous sodium hydroxide is added to an ammonium salt, the following equilibrium exists.

$$NH_4^+(aq) + OH^-(aq) \rightleftharpoons NH_3(aq) + H_2O(l)$$

Identify the **two** acid-base conjugate pairs in the equilibrium. [2]

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*(b)* Ammonium chloride and sodium nitrite react together in aqueous solution to produce nitrogen gas. This can be represented by the ionic equation:

$$NH_4^+(aq) + NO_2^-(aq) \longrightarrow N_2(g) + 2H_2O(l)$$

The rate equation for the reaction is given below.

$$\text{Rate} = k[NH_4^+][NO_2^-]$$

(i) Complete the table of data for the above reaction. All experiments were carried out at the same temperature. [3]

| | $[NH_4^+(aq)]$ / mol dm$^{-3}$ | $[NO_2^-(aq)]$ / mol dm$^{-3}$ | Initial rate / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|---|
| **1** | 0.200 | 0.010 | $4.00 \times 10^{-7}$ |
| **2** | | 0.010 | $2.00 \times 10^{-7}$ |
| **3** | 0.200 | | $1.20 \times 10^{-6}$ |
| **4** | 0.100 | 0.020 | |

(ii) Calculate the value of the rate constant, *k*, giving its units. [2]

*Value of k* = .....

*Units* .....

(iii) State how the value of *k* will alter, if at all, if the concentration of $NH_4^+$ ions is increased. [1]

.....

(iv) State, giving a reason, how the value of *k* will alter, if at all, if the temperature is increased.

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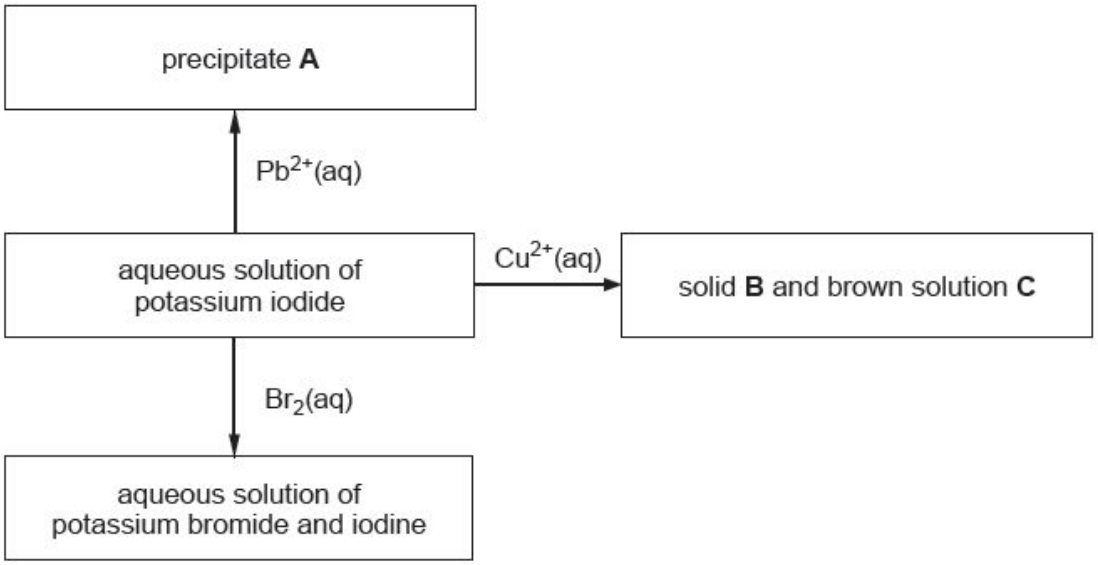
**(Total 10)**

3. The diagram below shows some of the reactions of potassium iodide solution.




*(a)* Identify precipitate **A** and give its colour. [2]

*(b)* Write an equation for the reaction of $Cu^{2+}(aq)$ and $I^-(aq)$, clearly identifying the precipitate. [2]

*(c)* Bromine reacts with aqueous potassium iodide as shown above, however bromine does not react with aqueous sodium chloride. Use the standard electrode potentials below to explain these observations. [3]
*QWC* [1]

| Half-equation | $E^\theta$/V |
|---|---|
| $I_2 + 2e^- \rightleftharpoons 2I^-$ | +0.54 |
| $Br_2 + 2e^- \rightleftharpoons 2Br^-$ | +1.09 |
| $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ | +1.36 |

(d) Solid potassium iodide reacts with concentrated sulfuric acid in the same way as sodium iodide.

Describe the observations made during this reaction and identify the products formed.

[3]

*(e)* Hydrogen peroxide reacts with acidified potassium iodide according to the equation below.

$$2H^+ + 2I^- + H_2O_2 \longrightarrow I_2 + 2H_2O$$

(i) This reaction was studied using an iodine clock reaction. Describe the principles of how the rate of a clock reaction is determined. Experimental details are not required. [2]

(ii) The rate of this reaction was studied by a different method for a range of concentrations of $H_2O_2(aq)$ and $I^-(aq)$ and pH values. These are listed in the table below.

| Experiment number | Initial concentration of $H_2O_2(aq)$ / mol $dm^{-3}$ | Initial concentration of $I^-(aq)$ / mol $dm^{-3}$ | pH | Initial rate / mol $dm^{-3}$ $s^{-1}$ |
|---|---|---|---|---|
| 1 | 0.0010 | 0.10 | 1 | $2.8 \times 10^{-6}$ |
| 2 | 0.0020 | 0.10 | 1 | $5.6 \times 10^{-6}$ |
| 3 | 0.0020 | 0.10 | 2 | $5.6 \times 10^{-6}$ |
| 4 | 0.0010 | 0.40 | 1 | $11.2 \times 10^{-6}$ |

I. Some experiments were undertaken at pH 1 and some at pH 2. Give the difference in the concentrations of $H^+$ ions in these two solutions. [1]

II. Use the data in the table to deduce the rate equation for this reaction, giving your reasoning. [3]

III. Calculate the value of the rate constant, *k*, giving its units. [2]

IV. The reaction is repeated at a higher temperature. State how the increase in temperature affects the rate equation and rate constant. [1]

Total [20]

4. Potassium peroxodisulfate(VI) (persulfate) is a white crystalline compound of formula $K_2S_2O_8$. It is a powerful oxidising agent and has uses as a food additive, in hair dyes and as a nappy steriliser.

*(a)* Unusually for potassium compounds, it is not very soluble in water.

| Temperature / °C | Solubility / g per 100 g $H_2O$ |
|---|---|
| 0 | 1.75 |
| 20 | 5.29 |

1 $dm^3$ of a saturated solution of potassium persulfate at 20 °C was cooled to 0 °C. Calculate the mass of solid potassium persulfate that crystallised from the solution. [2]

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*(b)* (i) A hot solution of potassium persulfate slowly decomposes, giving oxygen as one of the products.

$$2K_2S_2O_8(aq) + 2H_2O(l) \longrightarrow 4KHSO_4(aq) + O_2(g)$$

Calculate the maximum volume of oxygen gas that can be produced at 80 °C when a solution containing 0.100 mol of potassium persulfate decomposes as shown above. [2]

[At 80 °C 1 mol of oxygen has a volume of 29.0 $dm^3$]

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(ii) Suggest a way that the rate of decomposition of the potassium persulfate solution described in (i) could be measured. [1]

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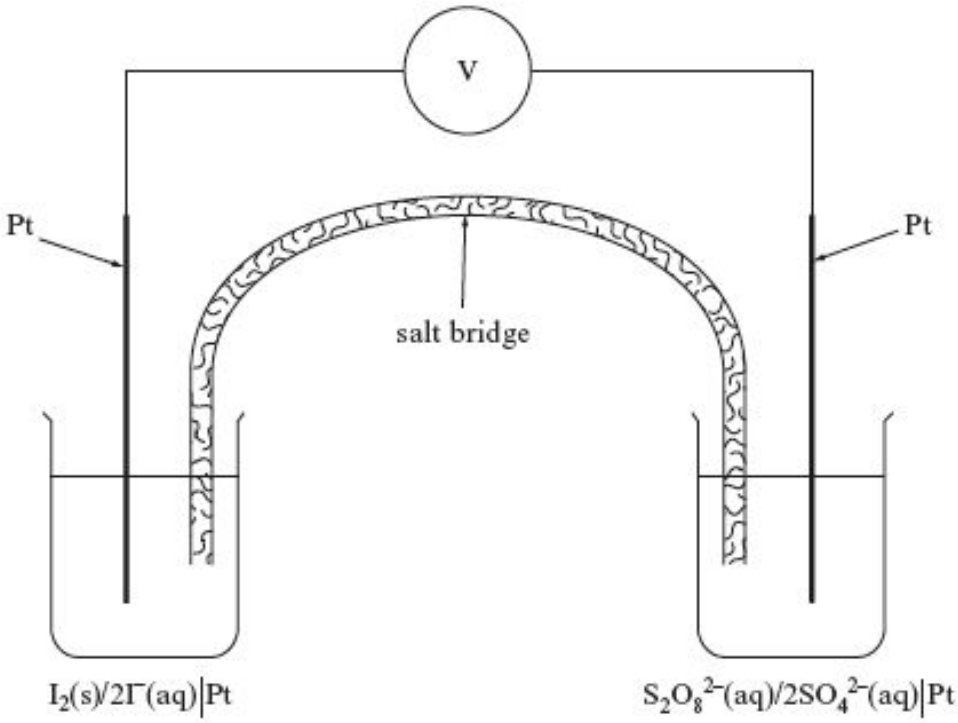
(c) The diagram below shows a cell that uses persulfate ions in aqueous solution.




(i) State the role of the platinum electrodes in this cell. [1]

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(ii) Use the information given in the equations to state and explain the direction of electron flow in the external circuit. [2]

$$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq) \qquad E^\ominus = +2.01\ V$$

$$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq) \qquad E^\ominus = +0.54\ V$$

.....

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.....

*(d)* The reaction between persulfate ions and iodide ions in aqueous solution is

$$S_2O_8^{2-} + 2I^- \longrightarrow 2SO_4^{2-} + I_2$$

In an experiment to follow the rate of this reaction, the values below were obtained.

| Experiment | Initial rate / mol $dm^{-3}s^{-1}$ | Initial concentration of $S_2O_8^{2-}$ / mol $dm^{-3}$ | Initial concentration of $I^-$ / mol $dm^{-3}$ |
|---|---|---|---|
| 1 | $8.64 \times 10^{-6}$ | 0.0400 | 0.0100 |
| 2 | $3.46 \times 10^{-5}$ | 0.0800 | 0.0200 |

(i) The reaction is first order with respect to iodide ions. Use both the initial rate values and the concentrations to show that the order with respect to persulfate ions is also first order. [2]

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.....

.....

(ii) Write the rate equation for this reaction and use it to calculate the value of the rate constant, $k$, giving its units. [3]

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.....

.....

..... *Units* .....

(iii) It is suggested that this reaction occurs in two steps.

Step 1 $S_2O_8^{2-} + I^- + H_2O \longrightarrow 2SO_4^{2-} + HOI + H^+$

Step 2 $HOI + H^+ + I^- \longrightarrow H_2O + I_2$

State, using your answer to (ii), why Step 1 is the rate-determining step. [1]

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.....

Total [14]

5. Judith carried out three experiments to study the reaction between powdered magnesium and hydrochloric acid.

She used a gas syringe to measure the volume of hydrogen evolved, at room temperature and pressure, at set intervals. In each case, the amount of acid used was sufficient to react with all the magnesium.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

The details of each experiment are shown in Table 1 below.

| Experiment | Mass of magnesium / g | Volume of HCl / $cm^3$ | Concentration of HCl / mol $dm^{-3}$ |
|---|---|---|---|
| **A** | 0.061 | 40.0 | 0.50 |
| **B** | 0.101 | 40.0 | 1.00 |
| **C** | 0.101 | 20.0 | 2.00 |

**Table 1**

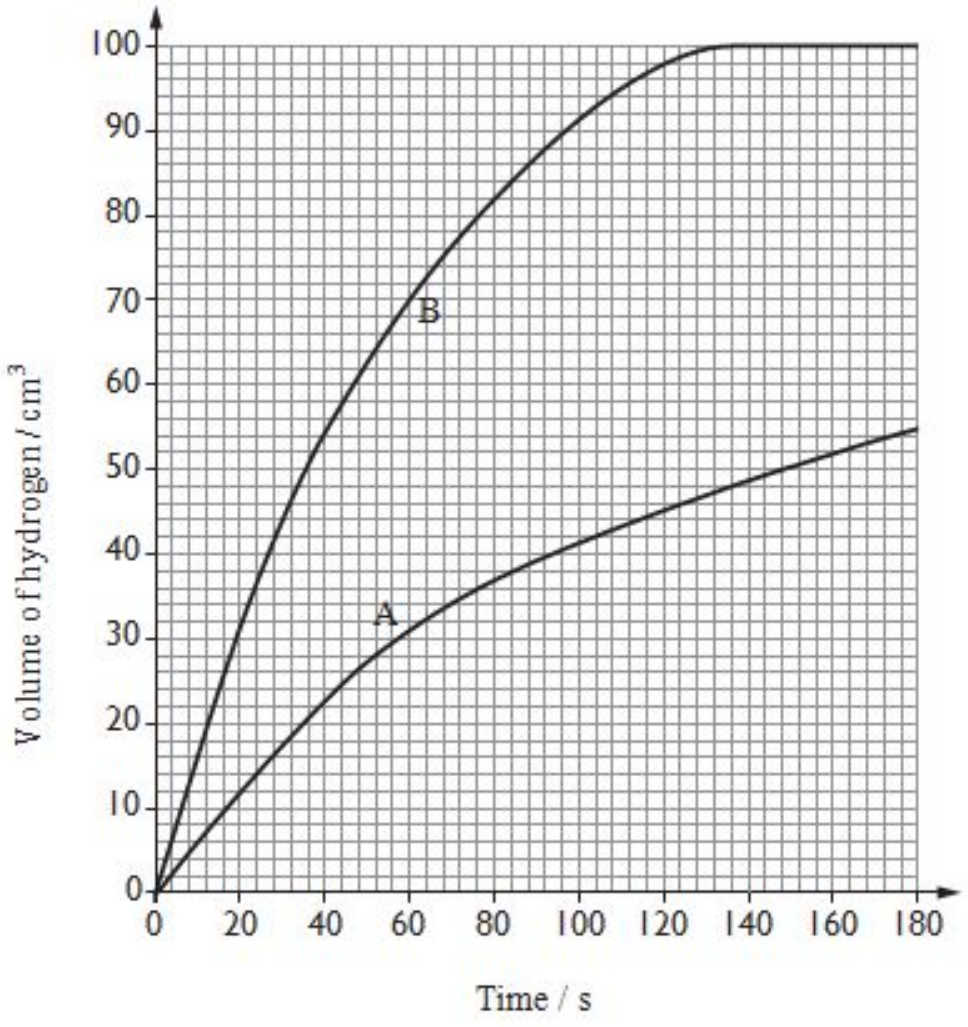
The results obtained in experiment **C** are shown in Table 2 below.

| Time / s | Volume of hydrogen / $cm^3$ |
|---|---|
| 0 | 0 |
| 20 | 50 |
| 40 | 75 |
| 60 | 88 |
| 80 | 92 |
| 100 | 100 |
| 120 | 100 |

**Table 2**

(a) The results for experiments **A** and **B** have already been plotted on the grid below. On the same grid, plot the results for experiment **C** and draw a line of best fit.

[3]




(b)(i) State in which experiment the reaction begins most rapidly and **use the graph** to explain your choice.

[2]

(ii) By referring to Table 1 give an explanation of your answer in part (i).

[1]

(c) State the volume of hydrogen evolved after 30 seconds in experiment **B**.

[1]

(d) Using **only** the values in Table 1, show that the acid is in excess in experiment **C**.

[2]

(e)(i) In experiment **A**, 0.061 g of magnesium produces 60 $cm^3$ of hydrogen. If 0.122 g of magnesium were used, under the same conditions, then 120 $cm^3$ would be produced. Explain why using 0.610 g would not produce 600 $cm^3$ of hydrogen.

[1]

(ii)Calculate the volume of hydrogen produced using 0.610 g of magnesium.

(1 mole of gas molecules occupies 24 $dm^3$ at 25 °C)

[2]

(f) State one method of slowing down the reaction in experiment **C** and use collision theory to explain your choice. Assume that the quantities of magnesium and hydrochloric acid are the same as those in Table 1.

[3] QWC [1]

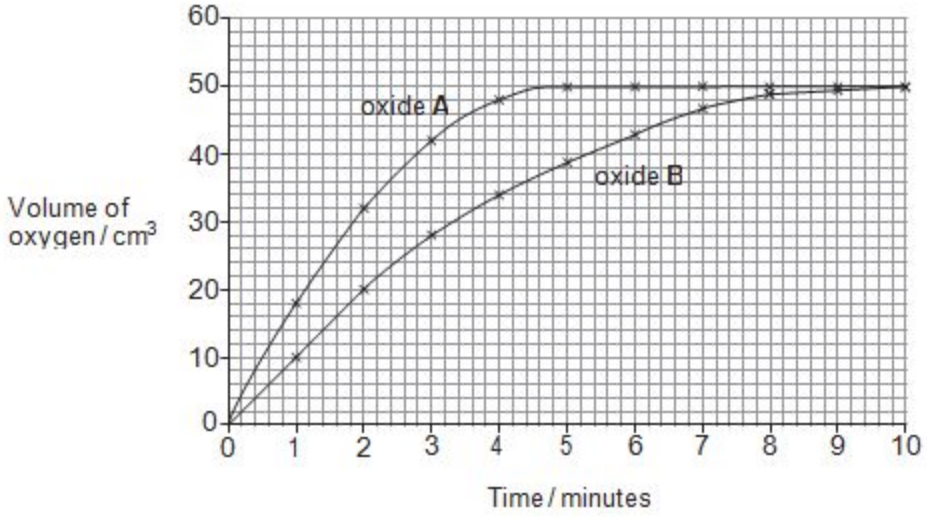
**(Total 16)**

6. Oxygen can be produced in the laboratory by the decomposition of hydrogen peroxide.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$$

Trystan carried out experiments to study the effect of using two metal oxides, **A** and **B**, to catalyse the reaction. He used 0.5 g of each metal oxide and diluted 10 $cm^3$ of a hydrogen peroxide solution with 90 $cm^3$ of water in each case. Following dilution the solutions were kept at a constant temperature of 35 °C throughout the experiment.

He plotted his results on the graph shown below.




(a) Outline a suitable method, including essential apparatus, for carrying out an experiment to obtain these results. You may include a diagram if you consider it helpful.

[4]

(b) State, giving a reason, which oxide is the more efficient catalyst.

[1]

(c) In the experiment with oxide **A**, calculate the volume of oxygen evolved,

(i) during the first minute,

[1]

(ii) during the third minute.

[1]

(d) Explain the difference between the answers in (c)(i) and (c)(ii).

[2]

(e) Give a reason why the total volume of oxygen obtained in the two experiments is the same.

[1]

(f) If Trystan repeated the experiment using 5 $cm^3$ of the original hydrogen peroxide solution diluted with 95 $cm^3$ of water, state the final volume of oxygen that would be evolved

1

(g) If he carried out the experiments at 45 °C instead of 35 °C, state what effect this would have on the time required to obtain the final volume of oxygen. Use collision theory to explain your answer.

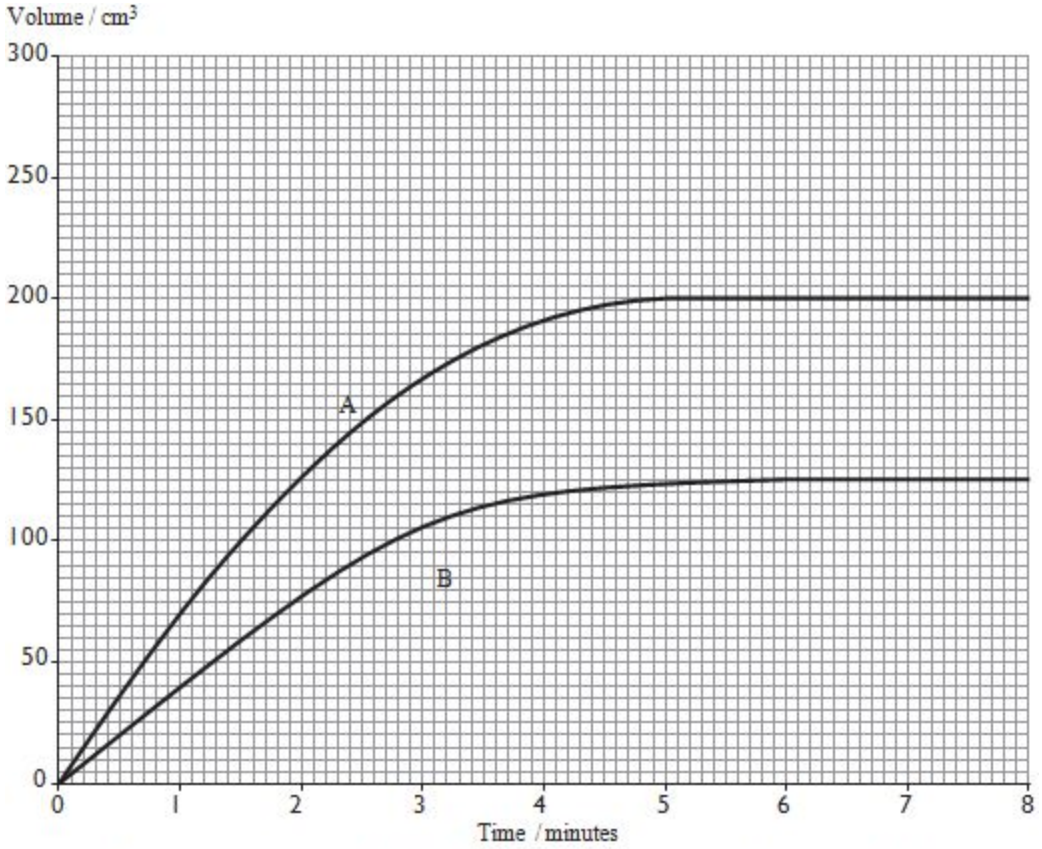
[3] QWC [1]

**(Total 15)**

7. Dolomite, $MgCO_3.CaCO_3$, is a mineral containing magnesium carbonate and calcium carbonate.

(a) Some students were asked to react samples of dolomite, each of mass 0.50 g, with an excess of dilute hydrochloric acid and to follow the rate of the reaction by measuring the volume of carbon dioxide evolved at suitable time intervals.

(i) Line **A** on the graph shows Natalie's results. Her teacher said that this was correct. David's line is labelled **B**. Although his line represents his results, the teacher said that he must have done something wrong during the experiment to obtain these results.



Suggest and explain **two** things that he might have done wrongly to obtain these results.

[2]

1. .....

2. .....

(ii) Explain why, in Natalie's experiment, 0.25 g of the dolomite has reacted in

1.5 minutes but the remaining 0.25 g has taken a further 3.5 minutes to react.

[2]

(iii) Emma asked what the volume of carbon dioxide collected from the samples would be if the temperature rose from 298 K to 323 K.

The teacher explained that, if the pressure remained the same, volume V (in cm3) and temperature T (in Kelvin) were linked by the equation

$$V = k \times T \text{ (where k is constant)}$$

The volume of carbon dioxide evolved at 298 K is 130 $cm^3$. By finding the value of k, or by other means, calculate the volume of this carbon dioxide when its temperature is raised to 323 K.

[2]

*Volume of carbon dioxide* = ..... $cm^3$

(b) In another experiment 0.623 g of dolomite reacted with an excess of dilute hydrochloric acid. The total volume of carbon dioxide evolved was 162 $cm^3$.

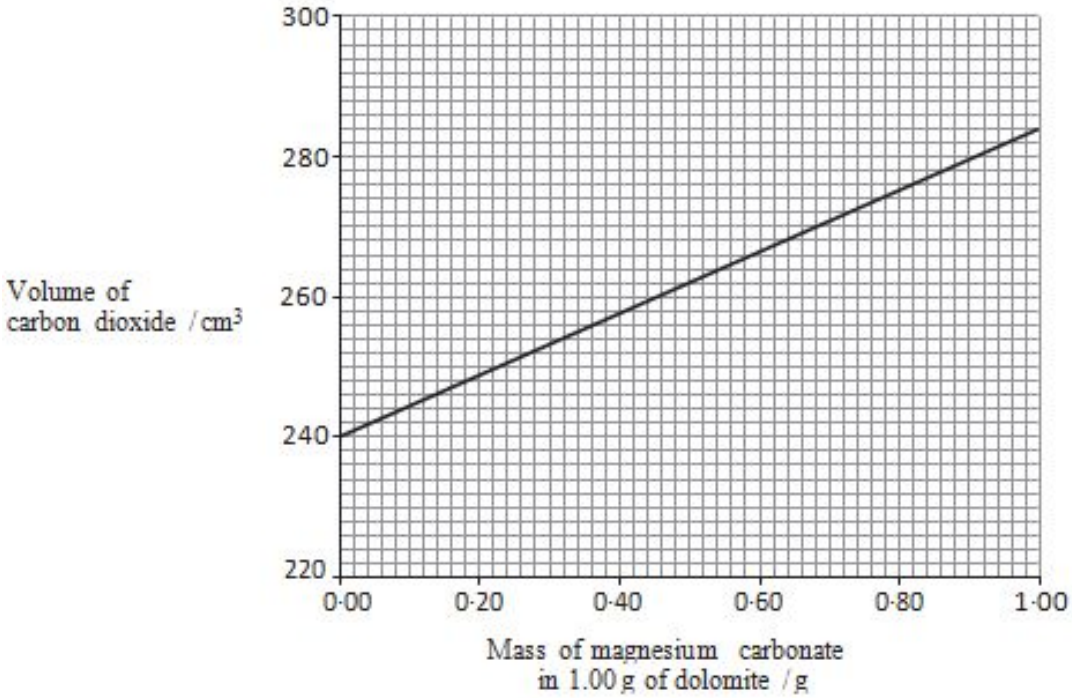
(i) Calculate the total volume of carbon dioxide that would be evolved if a sample of dolomite of mass 1.00 g was used under the same conditions.

[1]

*Volume of carbon dioxide* = ..... $cm^3$

(ii) Use the graph below to find the mass of magnesium carbonate present in this 1.00 g sample of dolomite.

[1]

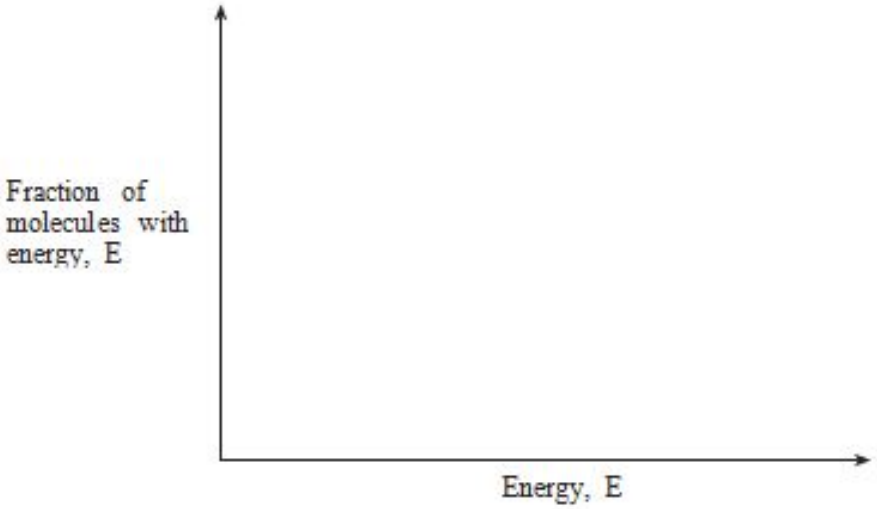



*Mass of magnesium carbonate* = ..... g

(c) The rate of the reaction between dolomite and hydrochloric acid increases by a large amount if the temperature is increased.

Complete the following energy distribution curve diagram by drawing two lines that show the distribution of energies at two different temperatures.
Label the line at lower temperature $T_1$ and the line at higher temperature $T_2$.
Use the diagram to help you explain why the rate increases as the temperature increases. [3]

*QWC* [1]

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(d) Briefly outline a different method of following the rate of the reaction between dolomite and hydrochloric acid.

[2]

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**(Total 14)**

8. Hydromagnesite is a mixture of magnesium carbonate and soluble impurities. A student crushed some hydromagnesite and added a sample of mass 0.889 g to excess dilute hydrochloric acid so that the magnesium carbonate component reacted fully.

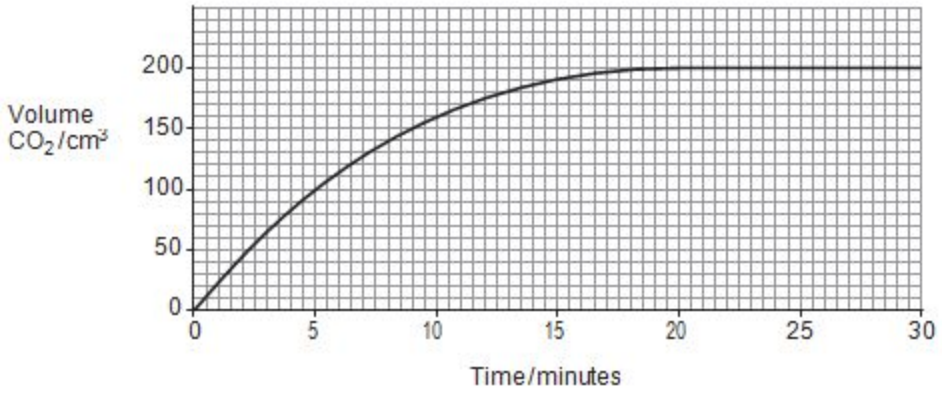
(a) Explain why the rock was crushed before being added to the acid.

[1]

(b) Write the equation for the reaction between magnesium carbonate and dilute hydrochloric acid.

[1]

(c) The gas formed was collected in a gas syringe and its volume was measured over a period of time. The volumes and times were plotted. The volume of 1 mol of gas under these conditions is 24.0 $dm^3$.




Describe what happened to the rate of the reaction over the 30 minute period.Explain why any changes in the rate occurred

[3]

(d) Other than by using an indicator, how would the student know that hydrochloric acid was in excess?

[1]

(e) (i) Use the graph to calculate how many moles of magnesium carbonate reacted with the hydrochloric acid. [2]

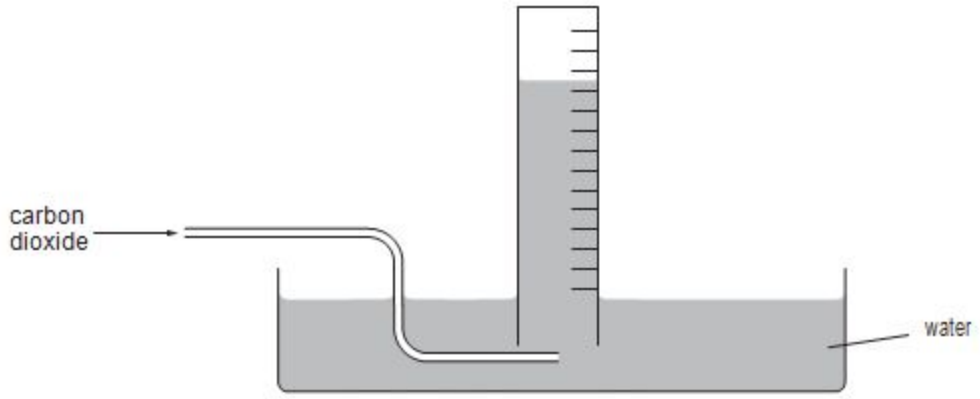
*Number of moles* $MgCO_3$ = ..... mol

(ii) Find the mass of magnesium carbonate that reacted and hence the percentage of magnesium carbonate present in hydromagnesite.

[2]

*Percentage of magnesium carbonate* = . . . . . %

(f) A student wanted to carry out this experiment on another sample of hydromagnesite. He did not have a gas syringe and therefore he decided to collect the carbon dioxide over water in a measuring cylinder.




Explain what effect this would have on the results of the experiment. You should assume that the gas syringe and the measuring cylinder can both be read to the same precision

[2]

(g) When magnesium carbonate is heated it decomposes to make magnesium oxide and carbon dioxide.

$$MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$$

Magnesium oxide has a very high melting temperature and so can be used to line furnaces.

What is the atom economy for the production of magnesium oxide from magnesium carbonate?

[2]

*Atom economy = . . . . . %*

**(Total 14)**