Q1. This question involves the use of kinetic data to deduce the order of a reaction and calculate a value for a rate constant.

The data in **Table 1** were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

Table 1

Experiment	**Initial concentration of A / mol dm^{-3}**	**Initial concentration of B / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.12	0.26	2.10×10^{-4}
2	0.36	0.26	1.89×10^{-3}
3	0.72	0.13	$3.78 \times 10_{-3}$

(a) Show how these data can be used to deduce the rate expression for the reaction between **A** and **B**.

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(3)

The data in **Table 2** were obtained in two experiments on the rate of the reaction between compounds **C** and **D** at a constant temperature.

Table 2

Experiment	Initial concentration of C / mol dm^{-3}	Initial concentration of D / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
4	1.9×10^{-2}	3.5×10^{-2}	7.2×10^{-4}
5	3.6×10^{-2}	5.4×10^{-2}	To be calculated

The rate equation for this reaction is

$$rate = k[\mathbf{C}]^2[\mathbf{D}]$$

(b) Use the data from experiment **4** to calculate a value for the rate constant, *k*, at this temperature. Deduce the units of *k*.

k = ... Units = ...

(3)

(c) Calculate a value for the initial rate in experiment **5**.

Initial rate = ... mol dm^{-3} s^{-1}

(1)

(d) The rate equation for a reaction is

$rate = k[\mathbf{E}]$

Explain qualitatively why doubling the temperature has a much greater effect on the rate of the reaction than doubling the concentration of **E**.

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(3)

(e) A slow reaction has a rate constant $k = 6.51 \times 10^{-3}$ mol^{-1} dm^3 at 300 K.

Use the equation $\ln k = \ln A - E_a / RT$ to calculate a value, in kJ mol^{-1}, for the activation energy of this reaction.

The constant $A = 2.57 \times 10^{10}$ mol^{-1} dm^3.
The gas constant $R = 8.31$ J K^{-1} mol^{-1}.

Activation energy = ...

(2)
(Total 12 marks)

Q2. Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

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(1)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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(3)

(c) Strontium metal is used in the manufacture of alloys.

(i) Explain why strontium has a higher melting point than barium.

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(2)

(ii) Write an equation for the reaction of strontium with water.

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(1)

(d) Magnesium can be used in the extraction of titanium.

(i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

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(1)

(ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

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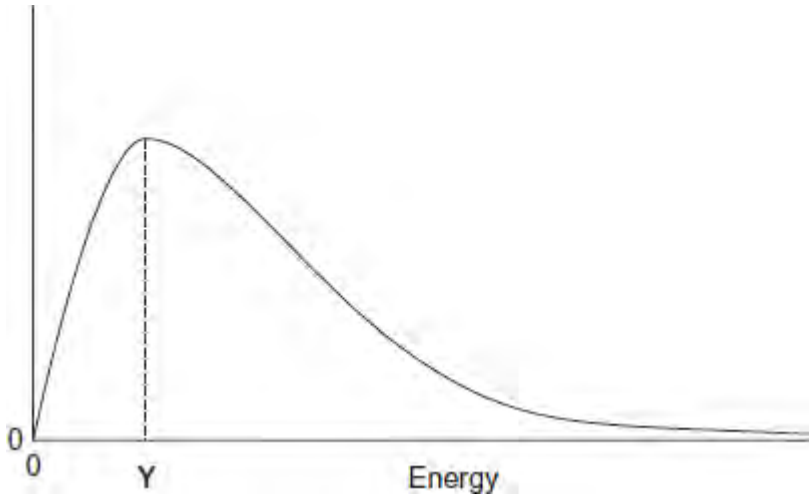
(1)
(Total 9 marks)

Q3. The following figure shows the Maxwell.Boltzmann distribution of molecular energies in a sample of gas at temperature *T*.



(a) One of the axes is labelled.
Label the other axis.

(1)

(b) State why the curve starts at the origin.

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(1)

(c) Which of the following, **A**, **B** or **C**, describes what the value of **Y** represents in the figure?
Write the correct letter, **A**, **B** or **C**, in the box.

A The energy needed for a successful collision
B The minimum energy needed for a reaction to occur
C The most probable energy

(1)

(d) On the figure above, draw a distribution of molecular energies in this sample of gas at a **higher** temperature.

(2)

(e) The pressure of the original sample of gas is doubled at temperature *T*.

State the effect, if any, of this change on the value of **Y**.

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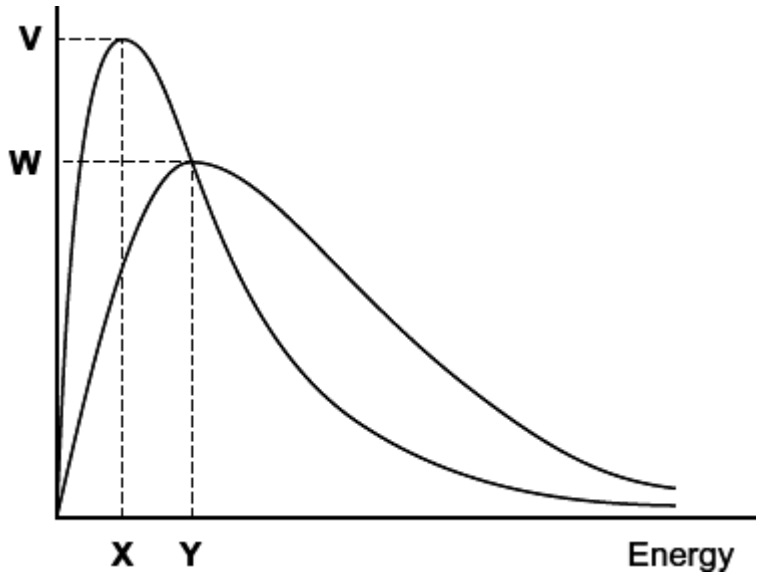
(1)
(Total 6 marks)

Q4. The diagram shows the Maxwell-Boltzmann distribution of molecular energies in a gas at two different temperatures.



(a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1)

(b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

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(1)

(c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1)

(d) Explain what must happen for a reaction to occur between molecules of two different gases.

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(2)

(e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

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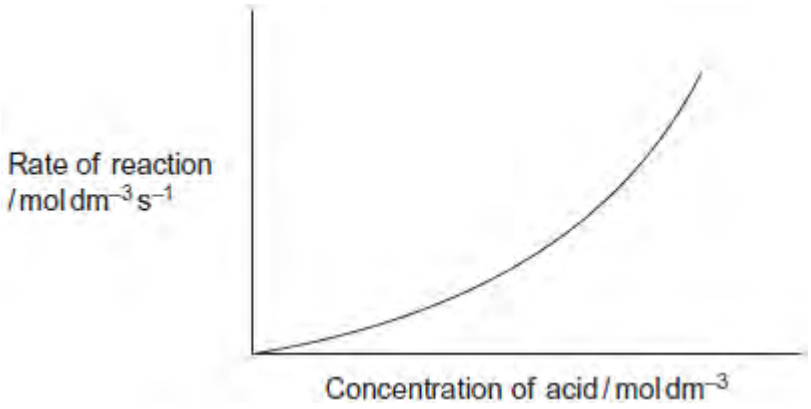
(1)
(Total 6 marks)

Q5.(a) In an investigation of the rate of reaction between hydrochloric acid and pure magnesium, a student obtained the following curve.



The reaction of magnesium with dilute hydrochloric acid is exothermic.

Use your understanding of collision theory to explain why the student did **not** obtain a straight line.

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(3)

(b) The magnesium used in a laboratory experiment was supplied as a ribbon. The ribbon was stored in an open plastic bag exposed to the air.

Explain why it is important to clean the surface of this magnesium ribbon when investigating the rate of its reaction with hydrochloric acid.

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(2)

(c) Magnesium ribbon reacts with hot water. Heated magnesium ribbon reacts with steam. State **two** differences between these reactions.

Difference 1 .....

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Difference 2 .....

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(2)

(d) Pure magnesium reacts completely with an excess of dilute sulfuric acid.
The reaction of pure calcium with an excess of dilute sulfuric acid is very rapid initially.
This reaction slows down and stops before all of the calcium has reacted.

Use your knowledge of the solubilities of Group 2 sulfates to explain why these reactions of magnesium and calcium with dilute sulfuric acid are so different.

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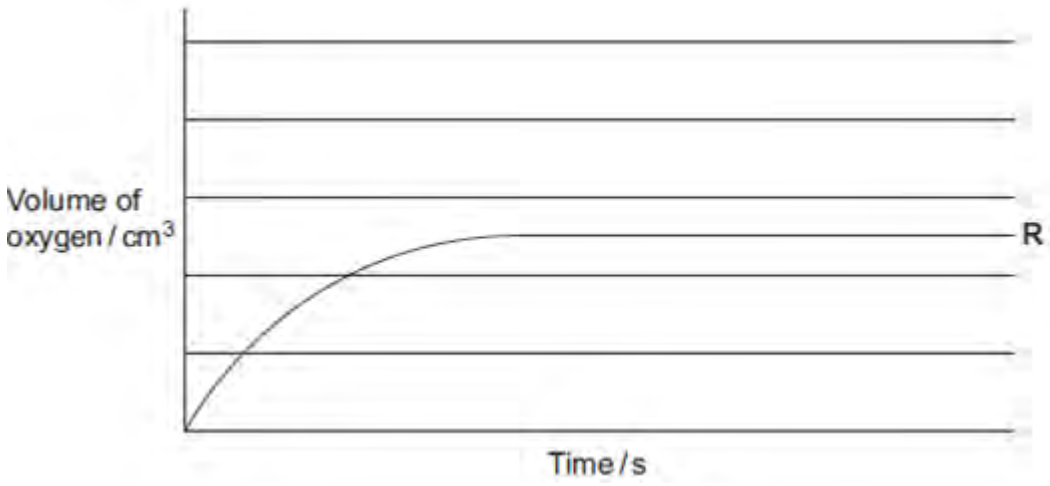
(3)
(Total 10 marks)

Q6. A student carried out an experiment to determine the rate of decomposition of hydrogen peroxide into water and oxygen gas.
The student used 100 cm^3 of a 1.0 mol dm^{-3} solution of hydrogen peroxide at 298 K and measured the volume of oxygen collected.
Curve **R**, in each of **Figures 1**, **2** and **3**, shows how the total volume of oxygen collected changed with time under these conditions.

(a) Draw a curve on **Figure 1** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide.

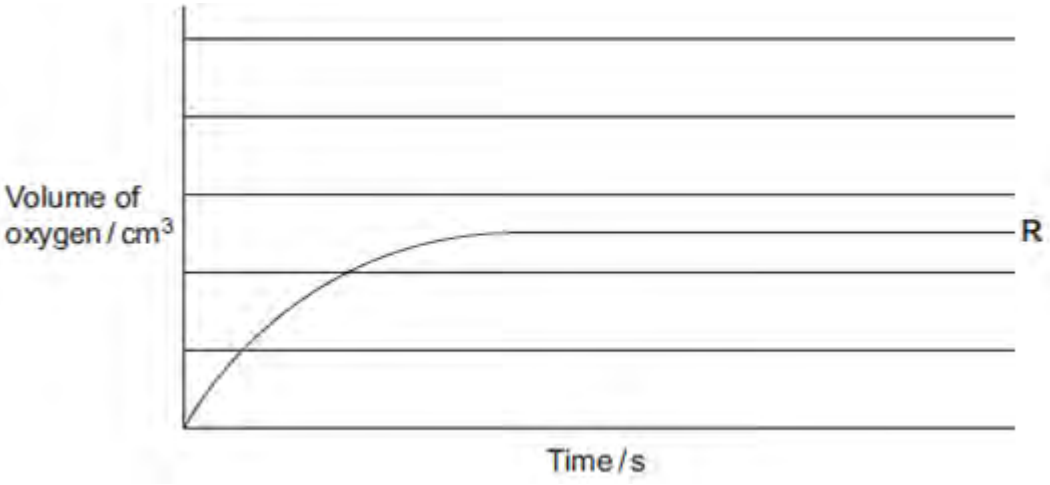
Figure 1



(2)

(b) Draw a curve on **Figure 2** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 0.4 mol dm^{-3} solution of hydrogen peroxide.

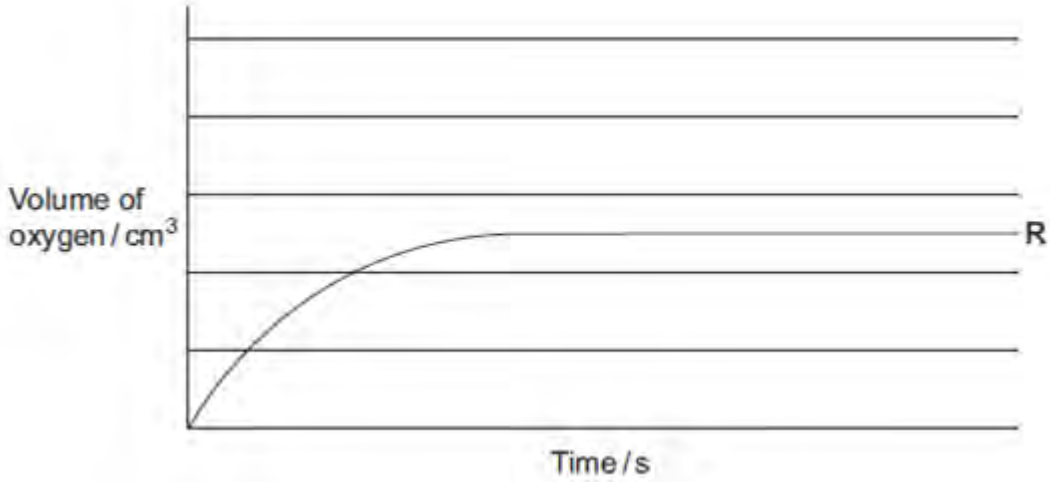
Figure 2



(2)

(c) Draw a curve on **Figure 3** to show how the total volume of oxygen collected will change with time if the **original** experiment is repeated at a temperature higher than 298 K.
You should assume that the gas is collected at a temperature of 298 K.

Figure 3



(2)

(d) Explain why the slope (gradient) of curve **R** decreases as time increases.

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(Extra space) .....

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(e) The student discovered that hydrogen peroxide decomposes at a faster rate when a few drops of aqueous hydrogen bromide are added to the solution.
The student found on the Internet that this decomposition is thought to proceed in two steps as shown by the following equations.

Step **1** $H_2O_2 + HBr \longrightarrow HBrO + H_2O$

Step **2** $HBrO + H_2O_2 \longrightarrow H_2O + O_2 + HBr$

(i) Write an equation for the overall reaction.

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(1)

(ii) Give **one** reason, other than the increase in rate of reaction, why the student was able to deduce that hydrogen bromide behaves as a catalyst in this two-step reaction.

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(1)