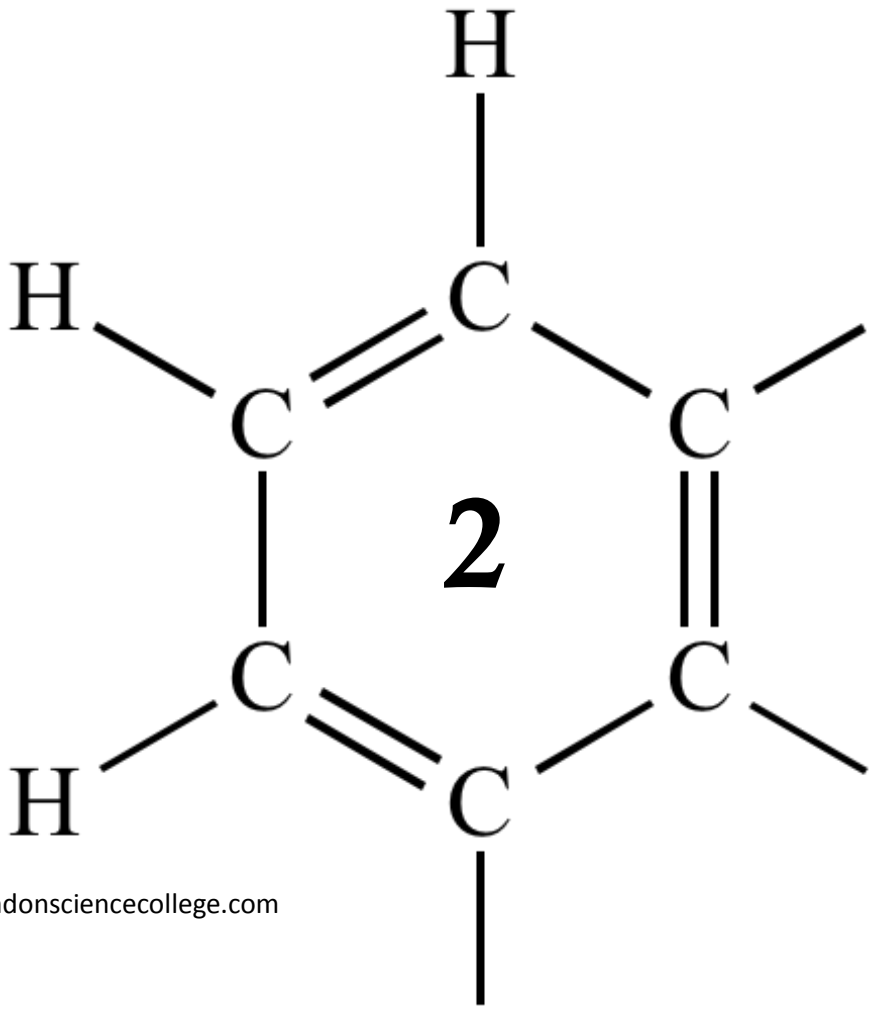
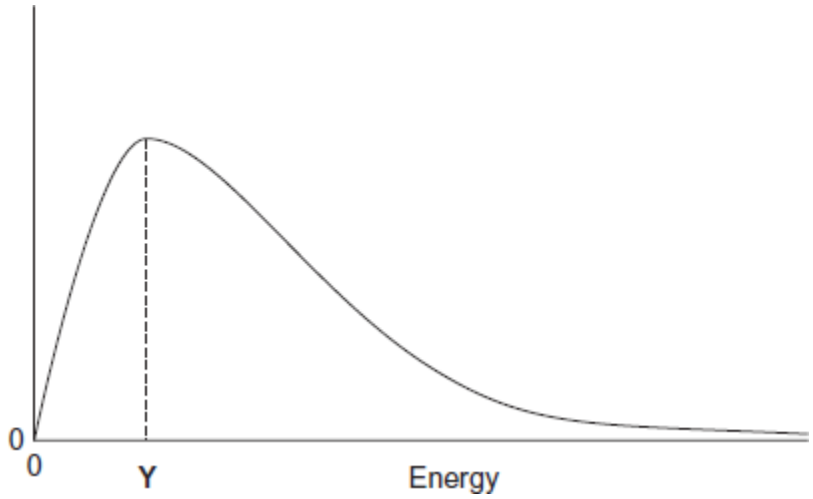
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

KINETICS



1 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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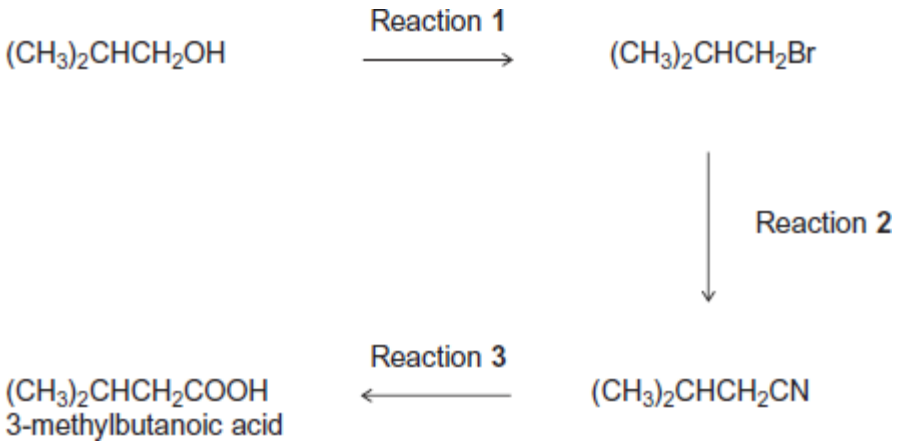
(1)

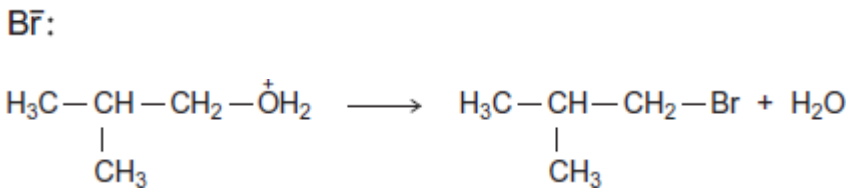
(Total 6 marks)

2 The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes.
The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



(a) One of the steps in the mechanism for Reaction **1** involves the replacement of the functional group by bromine.

(i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.



(2)

(ii) Deduce the name of the mechanism in part (i).

Give the IUPAC name of $(CH_3)_2CHCH_2Br$

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(2)

(b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group.
Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(CH_3)_2CHCH_2CN$ and a **different** bond in $(CH_3)_2CHCH_2COOH$ that can be used with infrared spectroscopy to distinguish between each compound.
For each of these bonds, give the range of wavenumbers at which the bond absorbs.
Use **Table A** on the Data Sheet when answering this question.

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(3)

(c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.

$$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons \underset{\text{an ester}}{(CH_3)_2CHCH_2COOCH_2CH_3} + H_2O$$

The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

(i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

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(Extra space) .....

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(3)

(ii) Explain how a catalyst increases the rate of a reaction.

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(Extra space) .....

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(2)

(Total 12 marks)

3 A student investigated how the initial rate of reaction between sulfuric acid and magnesium at 20 °C is affected by the concentration of the acid.

The equation for the reaction is

$$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(aq) + H_2(g)$$

(a) The student made measurements every 20 seconds for 5 minutes. The student then repeated the experiment using double the concentration of sulfuric acid.

State a measurement that the student should make every 20 seconds. Identify the apparatus that the student could use to make this measurement.

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(2)

(b) State **one** condition, other than temperature and pressure, that would need to be kept constant in this investigation.

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(1)

(c) When the student had finished the investigation, an excess of sodium hydroxide solution was added to the reaction mixture. This was to neutralise any unreacted sulfuric acid. The student found that a further reaction took place, producing magnesium hydroxide.

(i) Draw a diagram to show how the student could separate the magnesium hydroxide from the reaction mixture.

(2)

(ii) Suggest **one** method the student could use for removing soluble impurities from the sample of magnesium hydroxide that has been separated.

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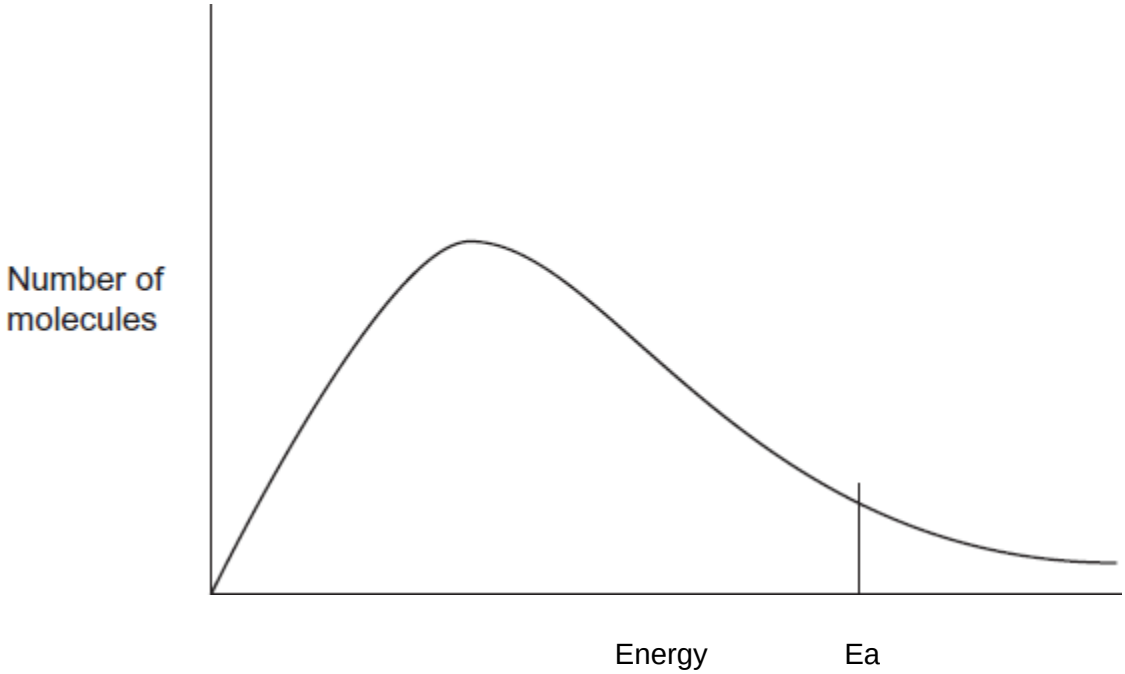
(1)
(Total 6 marks)

4 The diagram shows the Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



E_{mp} is the most probable value for the energy of the molecules.

(a) On the appropriate axis of this diagram, mark the value of E_{mp} for **this** distribution.

On this diagram, sketch a new distribution for the same sample of gas at a **lower** temperature.

(3)

(b) With reference to the Maxwell–Boltzmann distribution, explain why a decrease in temperature decreases the rate of decomposition of this gas.

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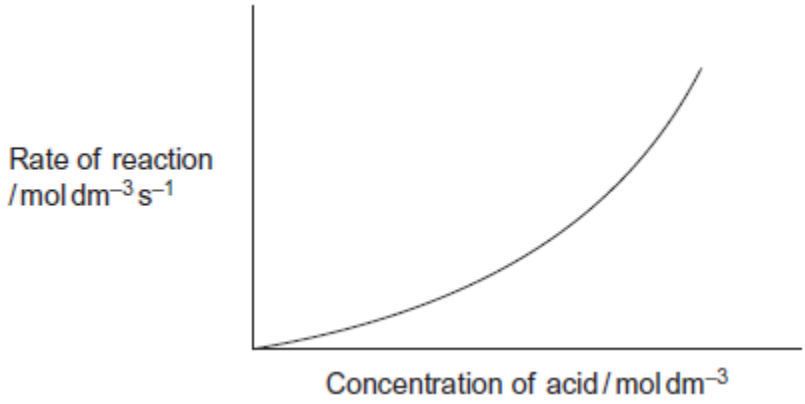
(2)
(Total 5 marks)

5 (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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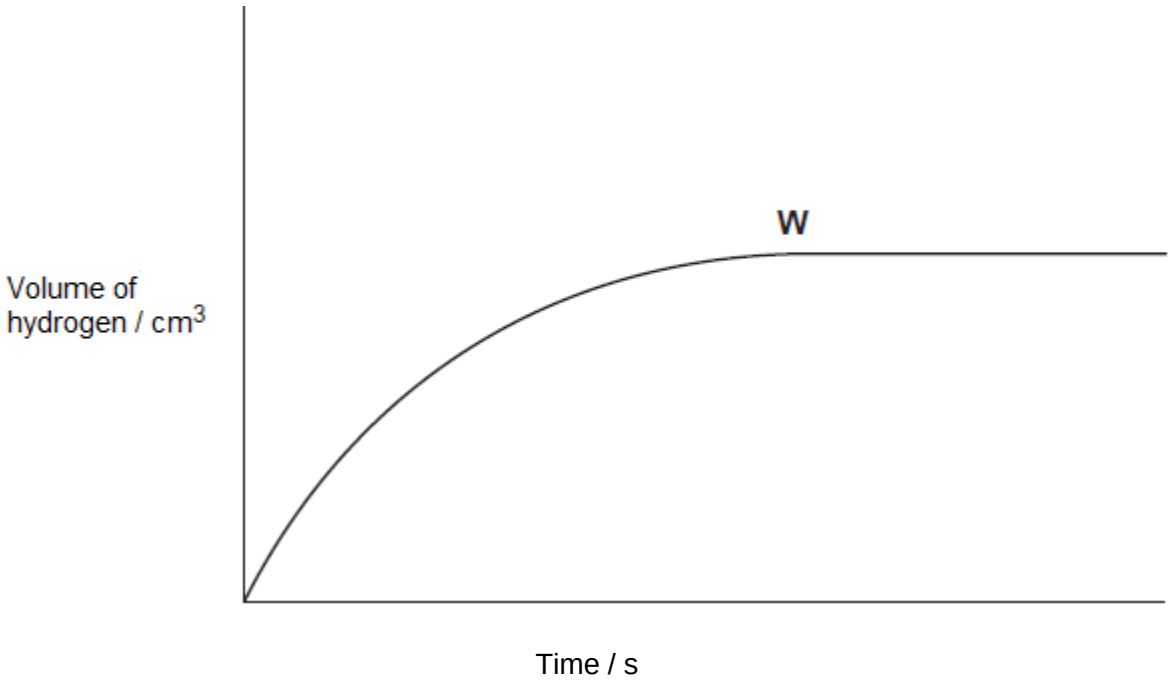
(3)
(Total 10 marks)

6 (a) **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

Figure 1



(i) State the meaning of the term *rate of reaction*.

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(1)

(ii) State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

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(2)

(iii) In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.

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(2)

(b) In a study of the reaction in part (a), a student referred to activation energy.

(i) State the meaning of the term *activation energy*.

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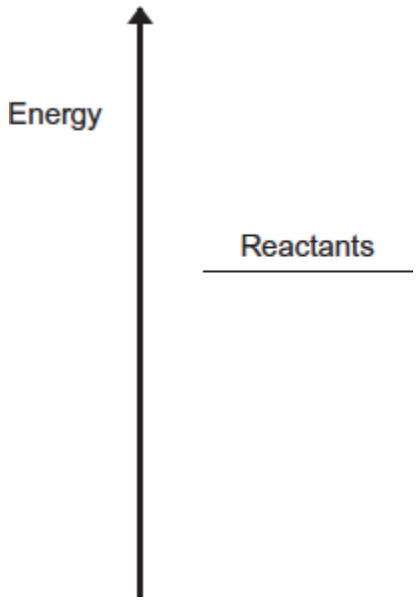
(1)

(ii) Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

Figure 2



(2)

(c) Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

(i) Write an equation for the reaction of barium with water.

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(1)

(ii) A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

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Observation

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(2)

(iii) State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

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Explanation .....

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(2)
(Total 13 marks)

7 A study of equilibrium is important for understanding chemical reactions.

(a) State le Chatelier's principle.

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(Extra space) .....

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(1)

(b) Catalysts play an important role in many reactions.

(i) State the meaning of the term *catalyst*.
Explain, in general terms, how catalysts work.

Meaning of the term *catalyst* .....

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How catalysts work .....

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(3)

(Extra space) .....

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(ii) State the effect, if any, of a catalyst on the time taken to reach equilibrium.

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(1)

(iii) State the effect, if any, of a catalyst on the position of an equilibrium.

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(1)

(c) Consider the following equilibrium reactions.

				$\Delta H^{\ominus}$ / kJ mol^{-1}
P	$H_2(g) + I_2(g)$	$\rightleftharpoons$	$2HI(g)$	−10
Q	$CO_2(g) + 3H_2(g)$	$\rightleftharpoons$	$CH_3OH(g) + H_2O(g)$	−49
R	$N_2O_4(g)$	$\rightleftharpoons$	$2NO_2(g)$	+58
S	$N_2(g) + 3H_2(g)$	$\rightleftharpoons$	$2NH_3(g)$	−92
T	$C_2H_4(g) + H_2O(g)$	$\rightleftharpoons$	$CH_3CH_2OH(g)$	−42

In each of parts (c)(i) to (c)(v), you should record in the box one of the letters, **P, Q, R, S** or **T**, that corresponds to the equilibrium that best fits the information provided.
You may use each letter once, more than once or not at all.

(i) A decrease in temperature at constant pressure shifts the position of this equilibrium from right to left.

(1)

(ii) This equilibrium uses concentrated phosphoric acid as a catalyst in a hydration reaction.

(1)

(iii) A decrease in pressure at constant temperature shifts the position of this equilibrium from left to right.

(1)

(iv) There is no change in the position of this equilibrium when the pressure is increased at constant temperature.

(1)

(v) An increase in the concentration of steam at constant temperature and constant pressure shifts the position of this equilibrium from right to left.

☐

(1)

(Total 11 marks)

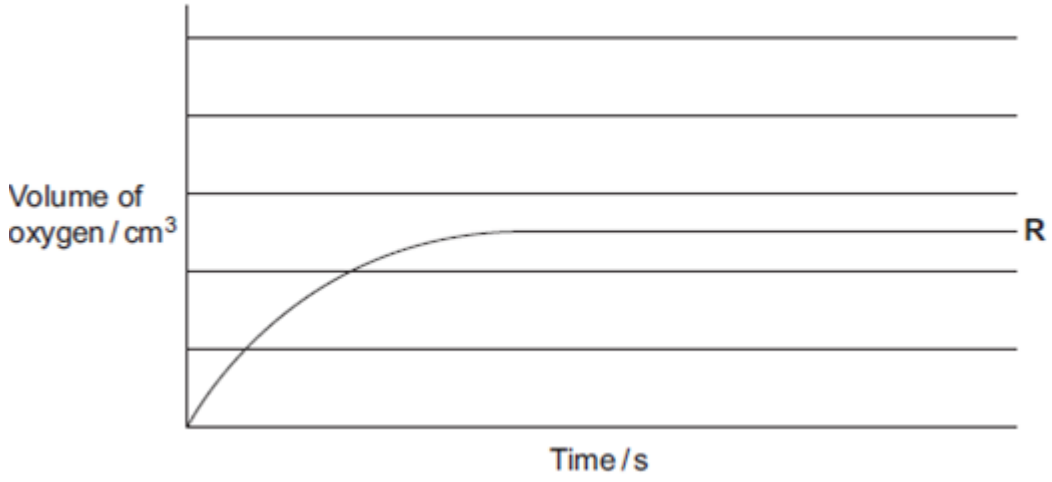
8 A student carried out an experiment to determine the rate of decomposition of hydrogen peroxide into water and oxygen gas.

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.

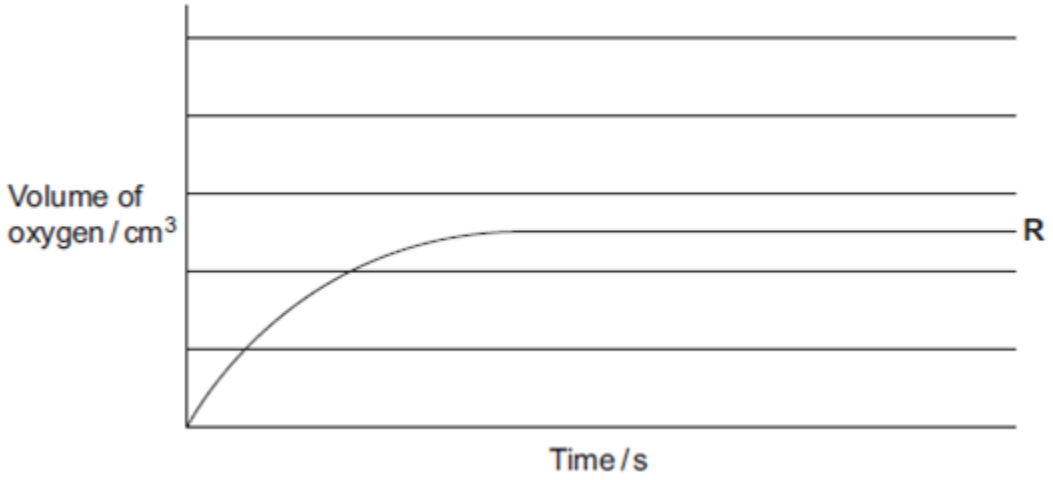
Figure 1



(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.

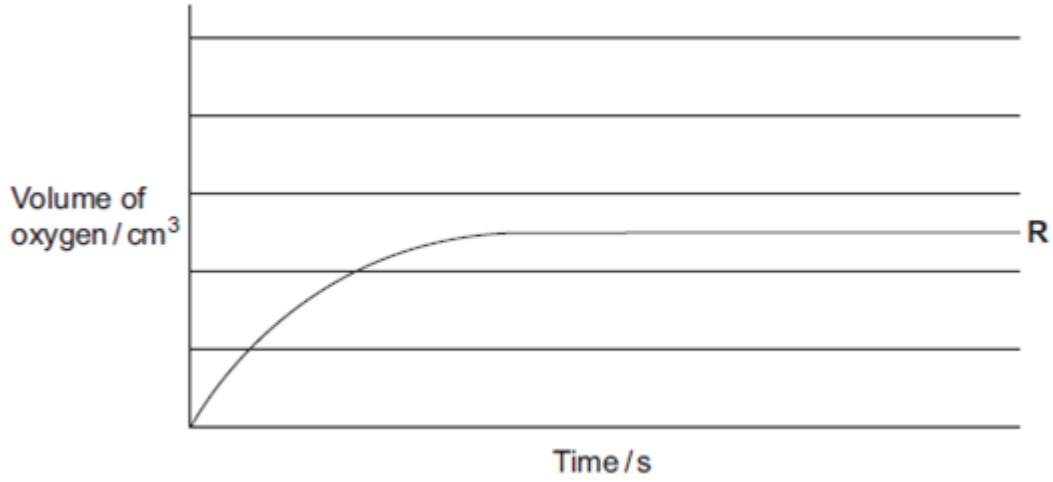
Figure 2



(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)

9 A student calculated that a value for the enthalpy change of neutralisation is –51.2 kJ mol^{-1}.

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat.
A 40 °C temperature rise was thought to be suitable.

(a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by 40 °C. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}.
Assume that all of the heat energy given out is used to heat the reaction mixture.

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(2)

(b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of –51.2 kJ mol^{-1} to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube.
(If you could not complete the calculation in part (a) assume that the heat energy required was 77 400 J. This is **not** the correct answer).

Show your working.

Moles of NaOH .....

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Mass of NaOH .....

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(3)

(c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3}, of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

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(1)

(d) Suggest **one** possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

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(1)

(e) A commercial hand-warmer uses powdered iron sealed in a plastic container.
A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(lll) oxide. The heat released warms the container.

(i) Write an equation for this reaction between iron and oxygen to form iron(lll) oxide.

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(1)

(ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours.
Other than by increasing the amount of iron in the container, state **one** change to the iron in the hand-warmer that would increase this time.
Explain why this change to the iron might **not** be an advantage.

Change to the iron .....

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Explanation .....

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(3)

(f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.
When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable 'super-saturated' solution until crystallisation is triggered.
Heat energy is then released when the sodium thiosulfate crystallises.

(i) This type of hand-warmer is re-usable.
Suggest **one** environmental advantage that a sodium thiosulfate hand-warmer has over the other two types.

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(1)

(ii) Describe the **two** steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 .....

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Step 2 .....

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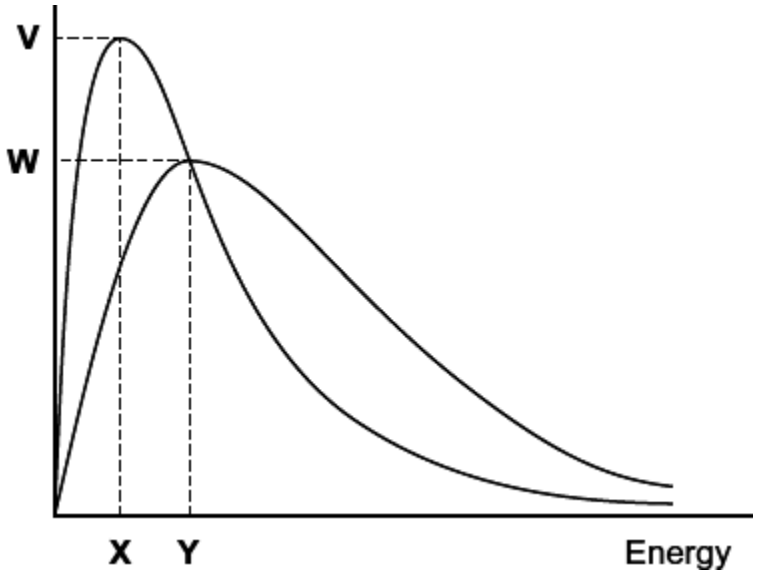
(2)

(Total 14 marks)

10 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)