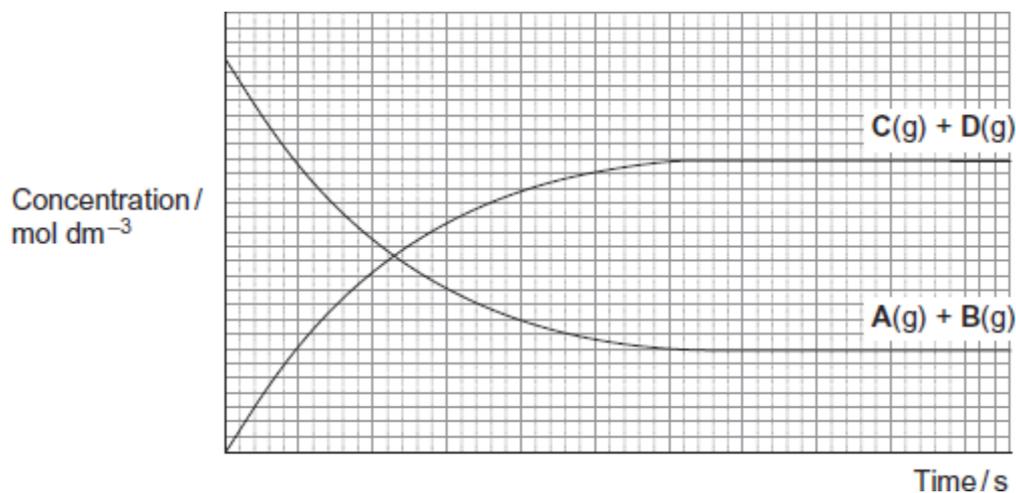


**Q11.**

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



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.

(1)

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

(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 _____

(2)

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

Effect _____

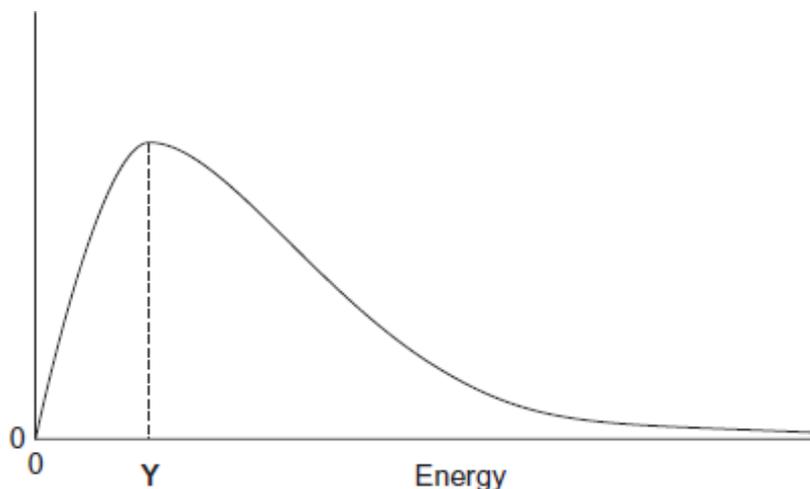
Explanation _____

(3)

(Total 8 marks)

**Q12.**

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.

(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 .

(1)

(Total 6 marks)

Q13.

A student investigated how the initial rate of reaction between sulfuric acid and magnesium at $20\text{ }^{\circ}\text{C}$ is affected by the concentration of the acid.

The equation for the reaction is



- (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.

(2)

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

(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.

(1)

(Total 6 marks)

**Q14.**

When iodine molecules are dissolved in aqueous solutions containing iodide ions, they react to form triiodide ions (I_3^-).

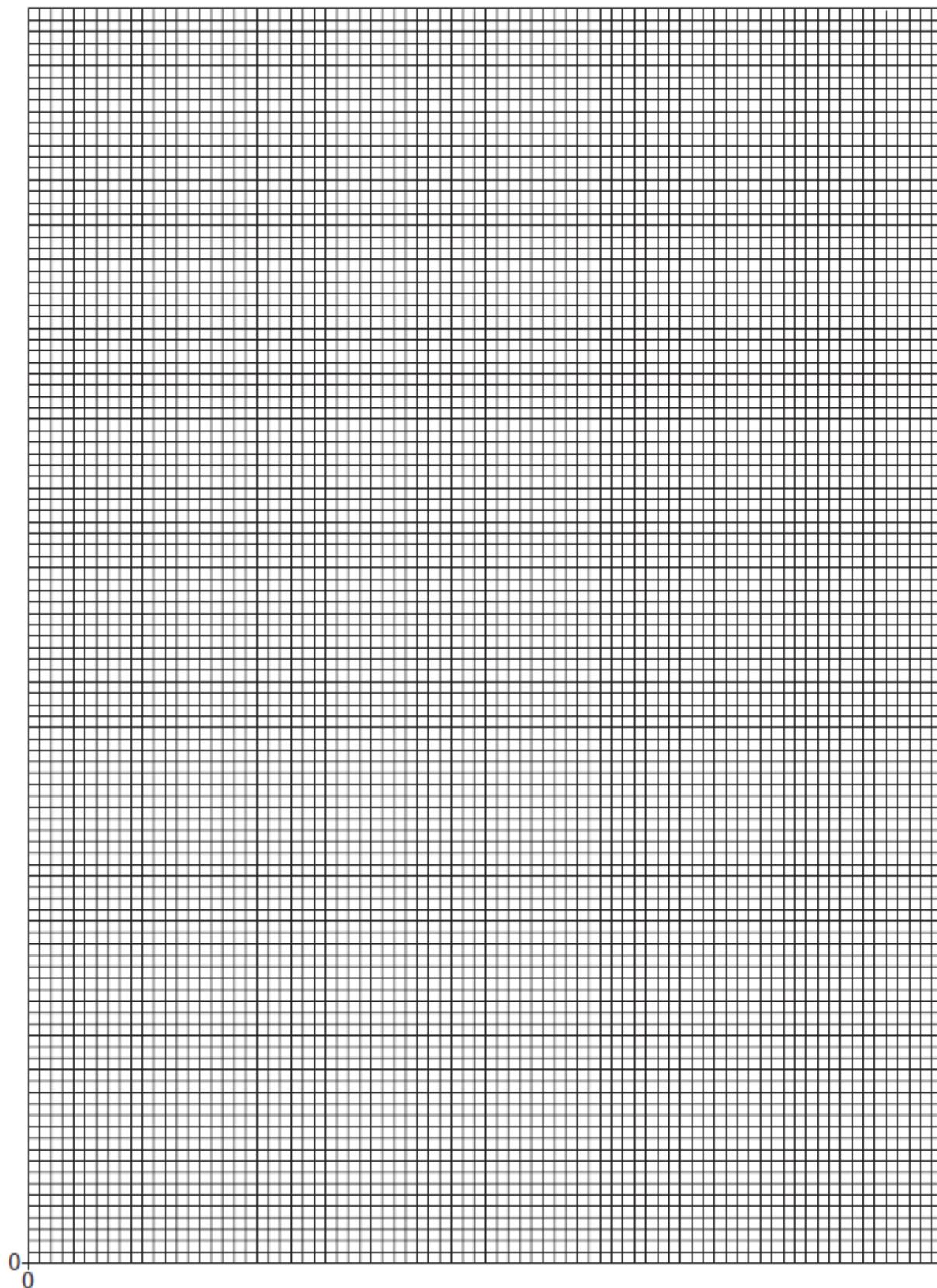


The rate of the oxidation of iodide ions to iodine by peroxodisulfate(VI) ions ($S_2O_8^{2-}$) was studied by measuring the concentration of the I_3^- ions at different times, starting at time = 0, when the reactants were mixed together. The concentration of the I_3^- ions was determined by measuring the absorption of light using a spectrometer.

The table below shows the results.

Time / s	Concentration of I_3^- / mol dm ⁻³
10	0.23
20	0.34
30	0.39
40	0.42
50	0.47
60	0.44
70	0.45

- (a) Plot the values of the concentration of I_3^- (y-axis) against time on the grid below.



- (b) A graph of these results should include an additional point. On the grid, draw a ring around this additional point.

(2)

(1)



(c) Draw a best-fit curve on the grid, **including the extra point from part (b)**.

(2)

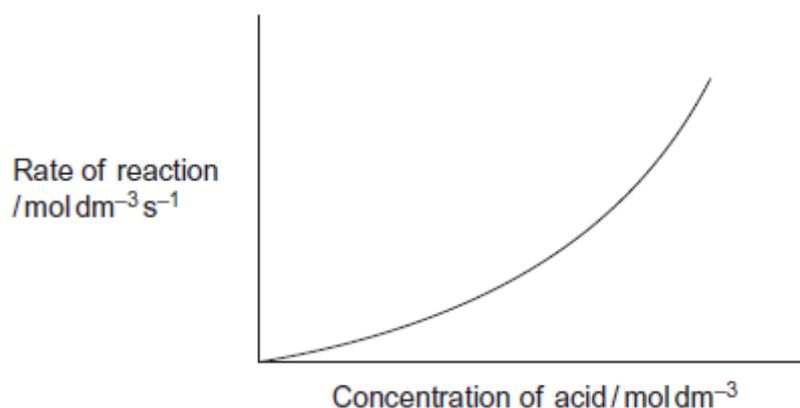
(d) Draw a tangent to your curve at time = 30 seconds. Calculate the slope (gradient) of this tangent and hence the rate of reaction at 30 seconds. Include units with your final answer. Show your working.

(4)

(Total 9 marks)

Q15.

(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.

(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.

(2)

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

Difference 1 _____

Difference 2 _____

(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.

(3)

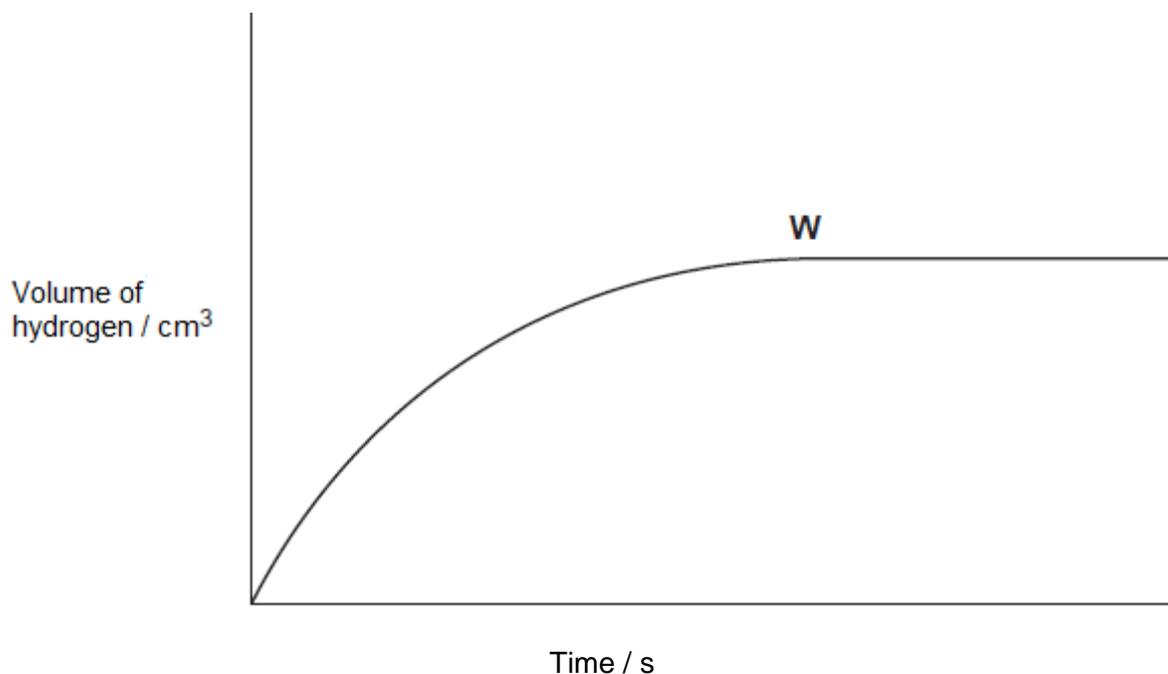
(Total 10 marks)

**Q16.**

- (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*.

(1)

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

(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.

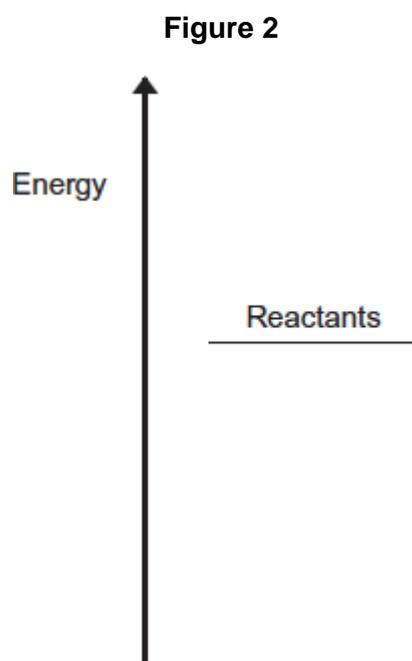
(2)

- (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*.

(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.



(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.

(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

Observation

(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 _____

Explanation _____

(2)

(Total 13 marks)

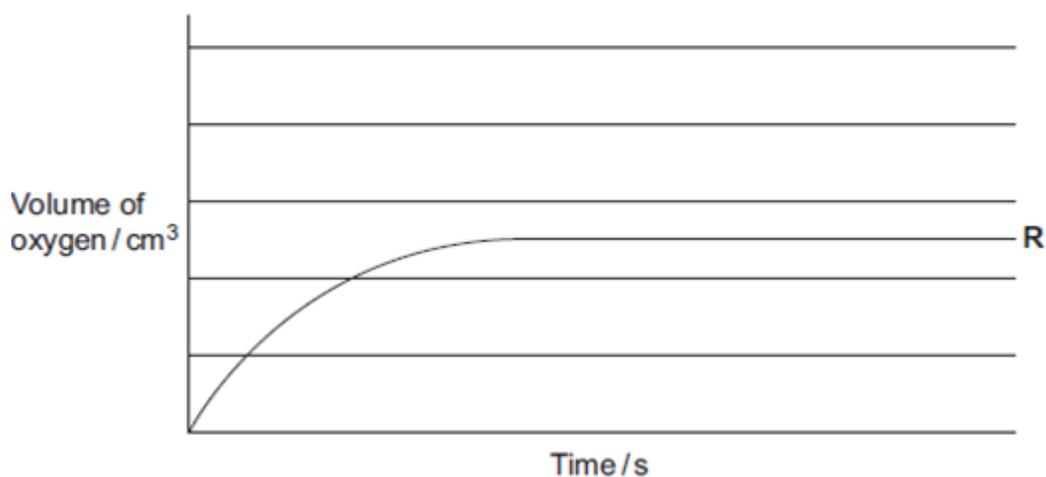
**Q17.**

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

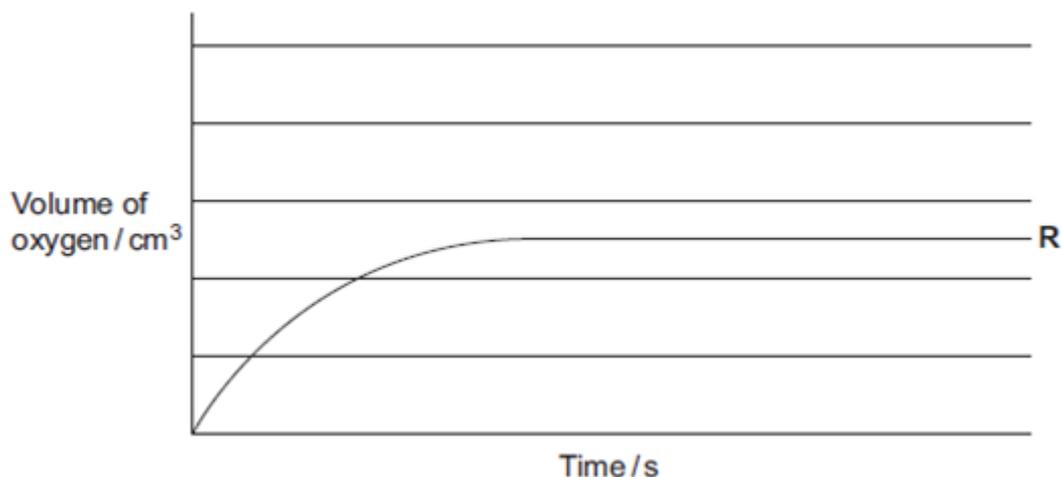
The student used 100 cm^3 of a 1.0 mol dm^{-3} solution of hydrogen peroxide at 298 K and measured the volume of oxygen collected.

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)**

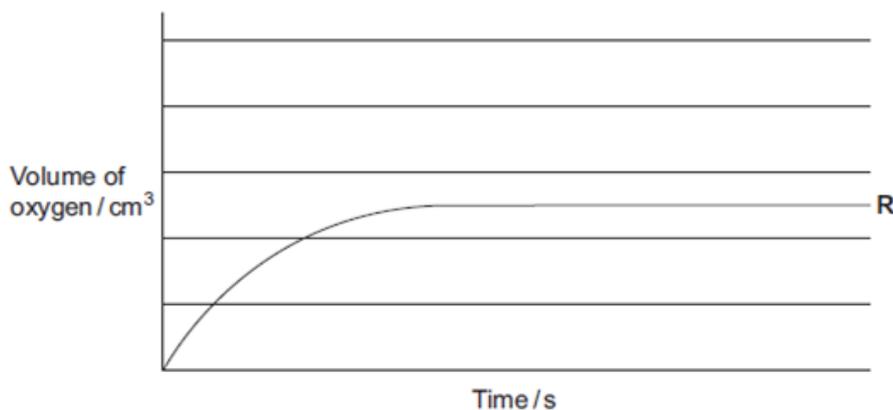
- (b) Draw a curve on **Figure 2** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 0.4 mol dm^{-3} solution of hydrogen peroxide.

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.

(2)

- (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.



- (i) Write an equation for the overall reaction.

(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.

(1)

(Total 10 marks)

**Q11.**

- (a) (i) Award mark for **X on the time axis** at the point where the lines just become **horizontal**

Allow this mark if X is above the letters "sh" in the word "show" in part(ii) - in the range of lines 31 to 33.

1

- (ii) They are equal / the same

OR

Forward (rate) = Reverse / backward (rate)

Allow the word 'speed' in this context.

Ignore reference to concentration.

1

- (b) Both **OR** forward and reverse reactions occur at the same time

OR both are occurring at once

OR both occur all of the time

OR both are ongoing

OR both never stop

Ignore 'at equal rates'.

Ignore reference to concentration or equilibrium.

The idea that both reactions occur simultaneously is essential.

The simple idea of 'both reactions occurring' is insufficient for the mark.

1

- (c) (i) **M1** No effect / no change / none / stays the same

M2 requires correct **M1**

*In **M2**, ignore reference to particles or atoms.*

M2 Equal (number of) moles / molecules on both sides

2

- (ii) **M1** Less time or it decreases or (equilibrium) reached faster (ie **M1** is a reference to time taken)

*If **M1** is 'more time / it increases' or 'no effect', then **CE=0** for the clip.*

*Reference to faster / increased rate / increased speed alone penalises **M1**, but mark on **M2** and **M3**.*

M2 More particles / molecules in a given volume / space

OR the particles / molecules are closer together

*If **M1** is blank, then look for all three marks in the text.*

M3 More successful / productive collisions in a given time



OR more collisions with $E > E_{Act}$ in a given time

OR more frequent successful / productive collisions

OR increased / greater successful / productive collision frequency / rate

Ignore reference to reactants / products.

*Penalise **M3** if an increase / decrease in the value of E_{Act} is stated.*

3

[8]

Q12.

(a) Amount / number / proportion / percentage / fraction / moles of molecules / particles

Penalise an incorrect qualification of the number eg NOT number of molecules with E greater than E_a .

Not 'atoms'.

1

(b) There are no molecules / particles with zero energy

OR

All of the molecules / particles are moving / have some energy

Not 'atoms'.

The answer should relate the energy to the molecules.

1

(c) **C** (The most probable energy)

1

(d) **M1** The peak of the new curve is displaced to the right and lower than the original

M2 All of the following needed

- The new curve starts at the origin and should begin to separate from the original almost immediately
- and the new curve only crosses the original curve once
- and the total area under the new curve is approximately the same as the original
- and an attempt has been made to draw the new curve correctly towards the axis above the original curve but not to touch the original curve

2

(e) None / no effect / stays the same

1

[6]

Q13.

(a) (Measure the) volume of gas / mass of the container + contents

1



Suitable named piece of equipment

Gas syringe (or inverted burette or measuring cylinder, as long as student has referred to the cylinder being filled with water) / balance.

Equipment must be correct for the measurement stated.

1

(b) Any **one** of:

- Mass of magnesium
Allow amount of magnesium.
- Surface area of magnesium

1

(c) (i) Gravity: Conical flask or beaker and funnel /

Vacuum: Sealed container with a side arm and Buchner or Hirsch funnel
Must be either gravity filtration (with a V-shaped funnel) or vacuum filtration (with a side-arm conical flask) appropriately drawn.

1

Filter paper

Must show filter paper as at least two sides of a triangle (V-shaped) for gravity filtration or horizontal filter paper for vacuum filtration.

1

(ii) Wash with / add (a small amount of cold) water
Ignore filtering.

1

[6]

Q14.

(a) Sensible scales

Plotted points (including 0,0) must cover more than half the graph paper.

If axis wrong way round lose this mark but mark on consequentially.

Do not allow broken axis.

1

Plots points correctly

1

(b) Ring around the origin

1

(c) Line through points is smooth

Line must pass within ± 1 small square of each plotted point except the anomaly (allow one plot ± 2 small square – at 40 or 60s).

1



Line through points is best fit and ignores anomaly (allow one plot ± 2 small square)

Lose this mark if student's line is doubled.

Kinked line loses this mark.

Lose this mark if the line does not pass through the origin $+/- 1$ small square.

Lose this mark if the line deviates to anomaly.

1

(d) Draws suitable tangent

Must touch the curve at 30s and must not cross the curve.

Lose this mark if the tangent is unsuitable but mark on.

1

Chooses appropriate x and y values from their graph

Mark consequentially if axes plotted the wrong way around.

Allow information clearly shown on graph.

1

Correctly calculates y/x

Difference in x values and y values must be at least 10 small squares in either direction.

1

Gives answer with correct units ($\text{mol dm}^{-3} \text{s}^{-1}$) or correct variant

Lose this mark if answer not to minimum of 2 significant figures and no units or incorrect units are given.

If student has used axis the wrong way round, the unit mark can be awarded for either the correct unit based on their graph or for the correct unit for rate.

1

[9]

Q15.

(a) As concentration increases the amount of heat given out increases / temperature increases **(M1)**

Any order.

Ignore references to an exothermic reaction.

1

More successful collisions or reactions in a given time **OR** more particles have the activation energy **(M2)**

Allow could be a second / n^{th} order reaction.

1

(An increase in temperature or more heat given out) increases the rate of a reaction **(M3)**

1

(b) The magnesium is coated with an oxide / MgO **(M1)**

Allow magnesium hydroxide.

1



MgO / the coating / the corrosion product has to be removed before Mg will react
OR Mg and MgO / the coating / the corrosion product react at different rates
OR Initially MgO / the coating / the corrosion product reacts not Mg **(M2)**

Ignore inert coating.

1

(c) Any **two** from:

Any order.

Slower with hot water or faster with steam

The hot water produces Mg(OH)₂ / the hydroxide **OR** steam produces MgO / the oxide

(Slow) bubbling with hot water **OR** bright white light / flame / white solid with steam

2 max

(d) Magnesium sulfate is soluble and calcium sulfate is insoluble / slightly soluble / magnesium sulfate is more soluble / calcium sulfate is less soluble / correct trend in solubility **(M1)**

Any order.

M1 requires a comparison of the two solubilities.

Calcium sulfate coats the surface of the calcium **(M2)**

Coating prevents further contact with / reaction by the acid **(M3)**

'Calcium sulfate forms a protective coating' scores M2 only.

3

[10]

Q16.

(a) (i) Change in concentration (of a substance / reactant / product) in unit time / given time / per (specified) unit of time

*This may be written mathematically **OR** may refer to the gradient of a graph of concentration / volume against time*

OR

Amount of substance formed / used up in unit time / given time / per (specified) unit of time

Ignore additional information including reference to collisions

1

(ii) At **W**

M1 (QoL)

The rate / it is zero

M2

The magnesium has all reacted / has been used up

Ignore reference to the acid being used up



OR

No more collisions possible between acid and Mg

OR

Reaction is complete / it has stopped

OR

No more hydrogen / product is produced

2

(iii) M1

Twice / double as many particles / hydrogen ions (in a given volume)

Penalise reference to (hydrochloric acid) molecules in M1

Penalise reference to "HCl particles" in M1

OR

Twice / double as much hydrochloric acid

M2

Twice / double as many effective / successful collisions (in a given time)

OR

Twice / double as many collisions with either sufficient energy to react **OR** with $E \geq E_a$

OR

double the successful / effective collision frequency

2

(b) (i) The activation energy is the minimum energy for a reaction to go / start

OR

Minimum energy for a successful/ effective collision

1

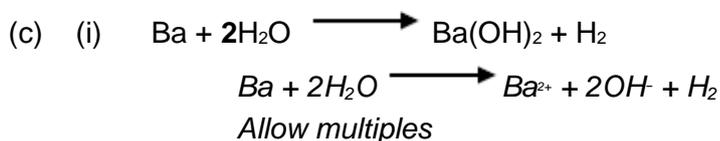
(ii) M1 Products lower than reactants on the profile

Mark independently

M2 Activation energy (E_a) shown and labelled correctly from reactants to peak of curve

Mark independently

2





Ignore state symbols

1



Ignore state symbols in M1

Not multiples in M1

M2 White precipitate / solid

Extra ions must be cancelled

Penalise contradictory observations in M2

2

(iii) M1 Barium meal / barium swallow / barium enema

Accept a correct reference to M1 written in the explanation in M2, unless contradictory

OR used in X-rays **OR** to block X-rays **OR** X-ray contrast medium **OR** CT scans

M2 BaSO₄ / barium sulfate is insoluble (and therefore not toxic)

For M2 NOT barium ions

NOT barium

NOT barium meal and NOT "It"

Ignore radio-tracing

2

[13]

Q17.

(a) **Award in either order for curve**

"Steeper" requires line to be on the left of the original line, starting from the origin

M1 curve is steeper than original and starts at the origin

M2 curve levels at the top line on the graph

2

(b) **Award in either order for curve**

"Shallower" requires line to be on the right of the original line, starting from the origin

M1 curve is shallower than original and starts at the origin

M2 curve levels at the first line on the graph

2

(c) **M1** curve would be steeper than original

"Steeper" requires line to be on the left of the original line, starting from the origin

M2 curve levels at the same original volume of O₂

2



- (d) **M1** The (concentration / amount of) H₂O₂ or reactant falls / decreases / used up
Mark independently

OR

The number of H₂O₂ or reactant molecules/ particles falls / decreases

M2

The rate of reaction / rate of decomposition / rate of formation of oxygen / frequency of collisions / (effective) collisions in a given time decreases / is slower

2

- (e) (i) $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$

Ignore state symbols

Accept only this equation or its multiples

Extra species must be crossed through

1

- (ii) hydrogen bromide / it does not appear in the overall equation

OR

hydrogen bromide / it is not used up in the reaction / unchanged at the end of the reaction

OR

hydrogen bromide / it is regenerated / re-formed (in Step 2)

1

[10]