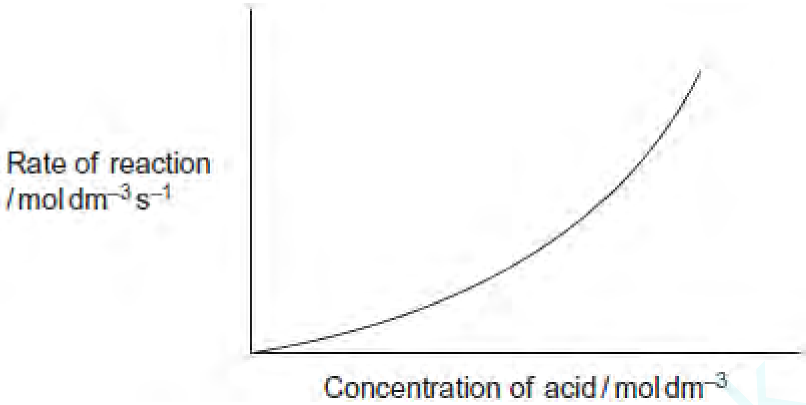
Q1.

(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 ____

____

Difference 2 ____

____

(2)

Q2.

(a) Define the term *activation energy* for a chemical reaction.

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(2)

(c) Give **one** reason why most collisions between gas-phase reactants do not lead to a reaction. State and explain **two** ways of speeding up a gas-phase reaction other than by changing the temperature.

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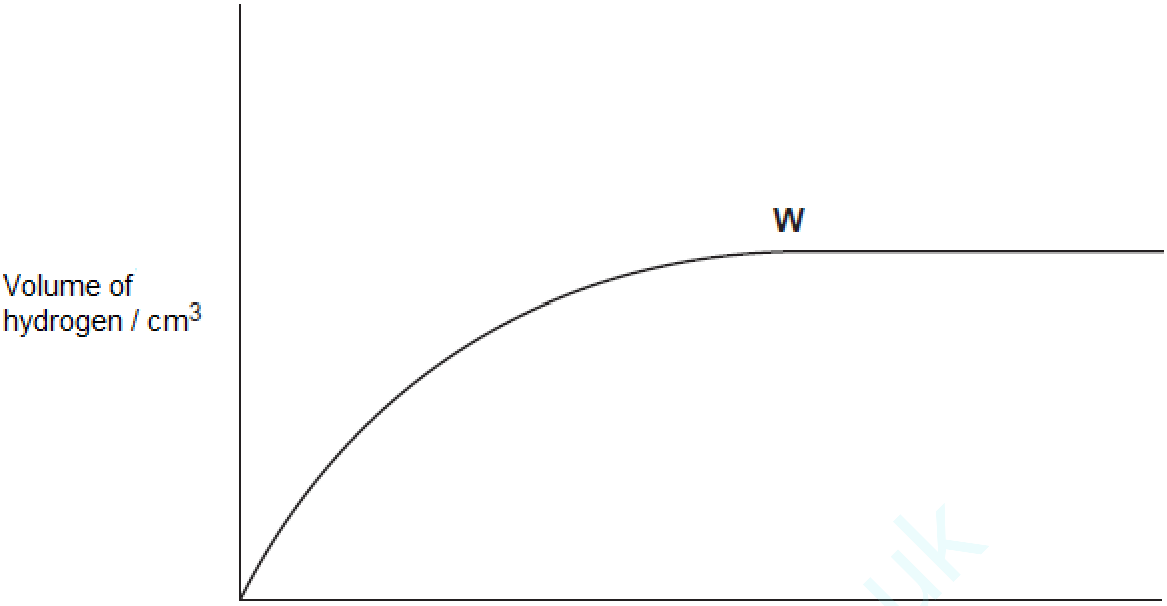
(5)

Q3.

(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*.

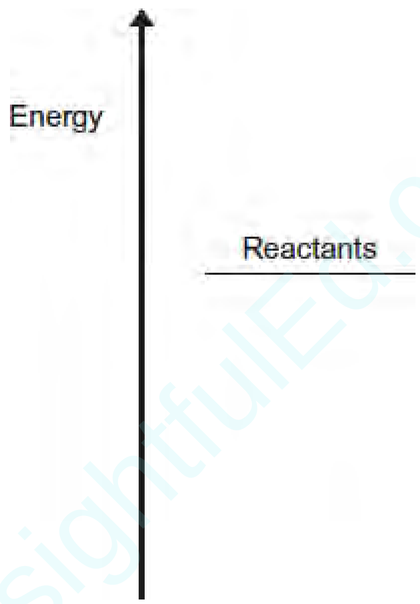
____

____

(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.

____

(1)

Q4.

The gas-phase reaction between hydrogen and chlorine is very slow at room temperature.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

(a) Define the term *activation energy*.

____

____

(2)

(b) Give **one** reason why the reaction between hydrogen and chlorine is very slow at room temperature.

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(1)

(c) Explain why an increase in pressure, at constant temperature, increases the rate of reaction between hydrogen and chlorine.

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(2)

(d) Explain why a small increase in temperature can lead to a large increase in the rate of reaction between hydrogen and chlorine.

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(2)

(e) Give the meaning of the term *catalyst*.

____

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(1)

(f) Suggest **one** reason why a solid catalyst for a gas-phase reaction is often in the form of a powder.

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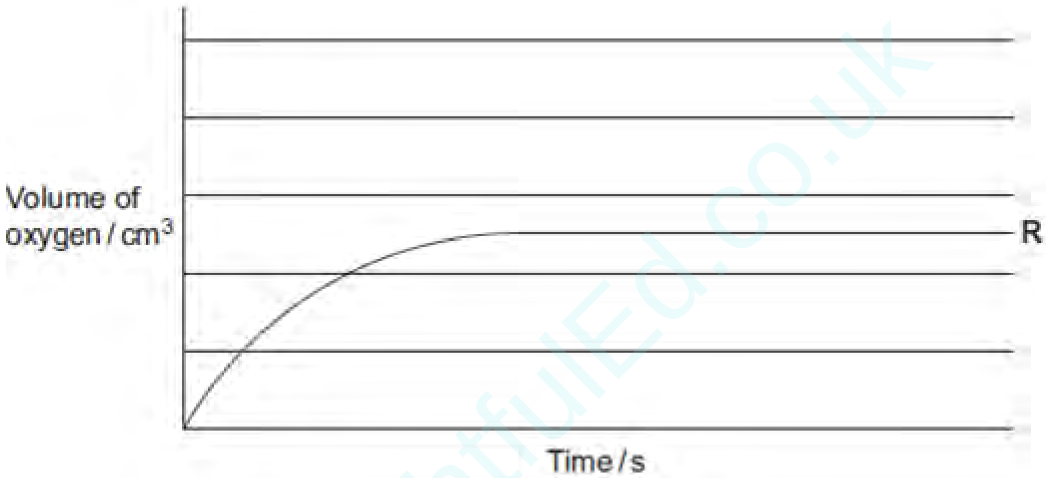
(1)
(Total 9 marks)

Q5.

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.

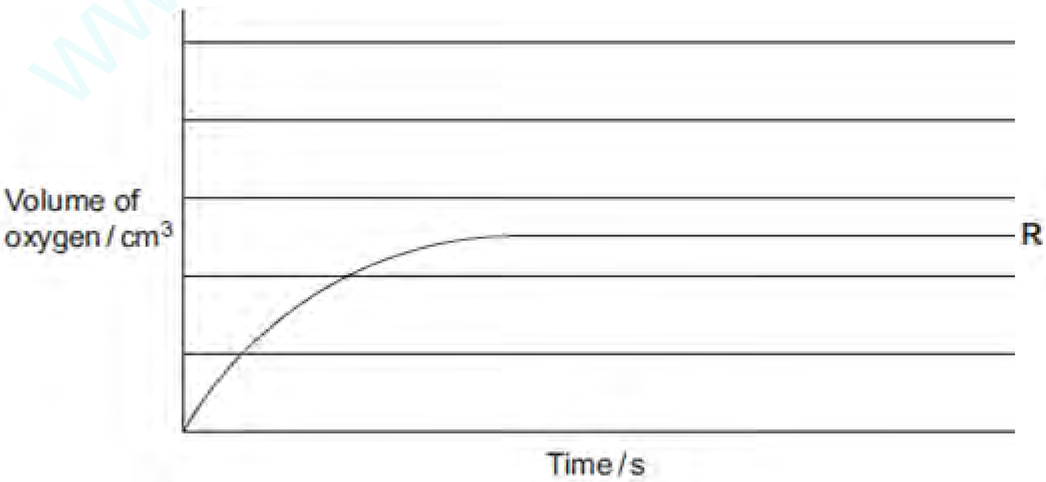
Figure 1



(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.

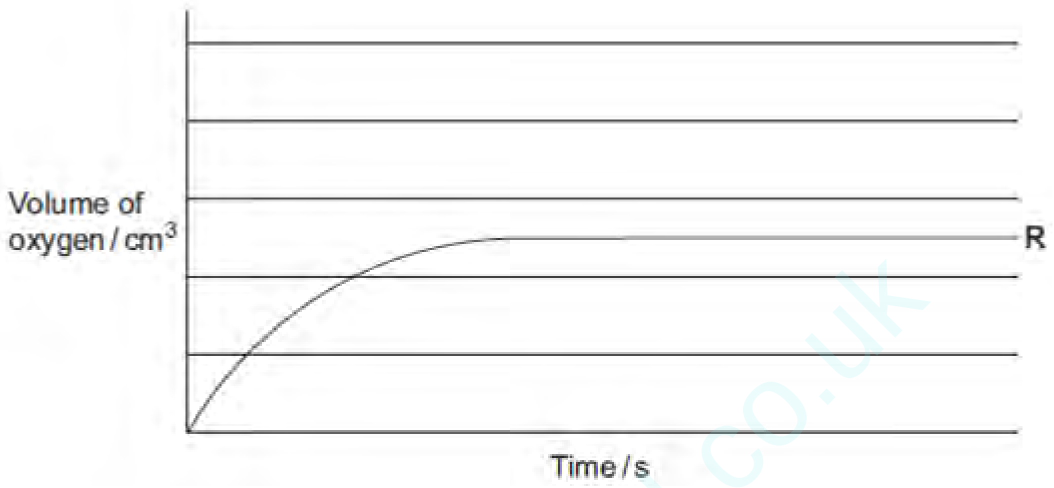
Figure 2



(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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____

____

(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.

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.

____

(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)**

Q6.

This question is about rates of reaction.

Potassium manganate(VII), $KMnO_4$, reacts with sodium ethanedioate, $Na_2C_2O_4$, in the presence of dilute sulfuric acid.

$$2\ MnO_4^-(aq) + 16\ H^+(aq) + 5\ C_2O_4^{2-}(aq) \rightarrow 2\ Mn^{2+}(aq) + 8\ H_2O(l) + 10\ CO_2(g)$$

The reaction mixture is purple at the start and goes colourless when all the $MnO_4^-(aq)$ ions have reacted.

The rate of reaction can be measured as $\frac{1000}{t}$ where t = the time taken for the mixture to go colourless.

A student investigated how long it takes for this reaction mixture to go colourless at different temperatures. The same concentrations and volumes of each reagent were used in an experiment at each temperature. The table below shows the results.

Temperature / °C	32	38	44	54	67
Time *t* / s	155	85	50	22	9
$\frac{1000}{t}$	6.45	11.8	20.0	45.5	

(a) Complete the table above.

(1)

(b) State the independent variable in this investigation.

____

(1)

(c) The student noticed that the temperature of each reaction mixture decreased during each experiment.

Suggest how the student calculated the temperature values in the table above.

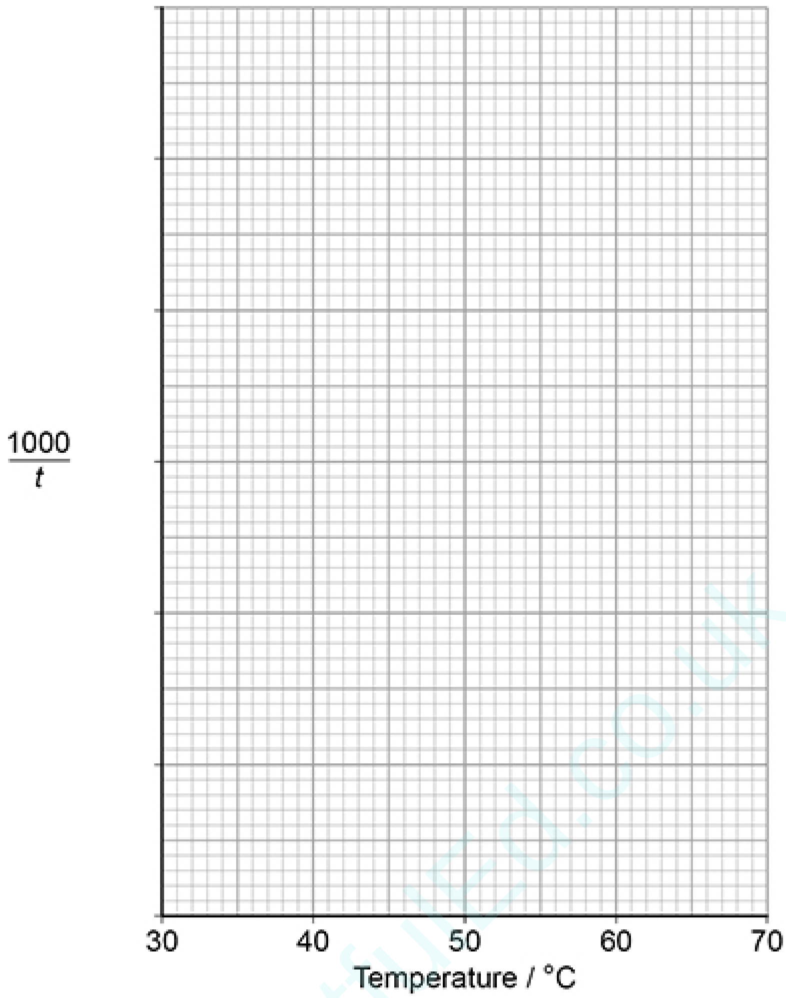
____

____

____

(1)

(d) Use the data in the table to plot a graph of $\frac{1000}{t}$ against temperature.



(3)

(e) Use your graph in part (d) to find the time taken for the mixture to go colourless at 60 °C
Show your working.

Time t ___________ s

(1)

(f) The investigation shows that increasing the temperature causes the rate of reaction to increase.

Explain why a small increase in temperature causes a large increase in the rate of reaction.

____

____

(2)
(Total 9 marks)

Q7.

A student investigates the effect of temperature on the rate of reaction between sodium thiosulfate solution and dilute hydrochloric acid.

$$Na_2S_2O_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$$

The student mixes the solutions together in a flask and places the flask on a piece of paper marked with a cross.

The student records the time for the cross to disappear. The cross disappears because the mixture becomes cloudy.

The table shows the student's results.

Temperature / °C	22	31	36	42	49	54
Time, t, for cross to disappear / s	87	48	36	26	44	12
$\frac{1}{t}$ / s^{-1}	0.0115	0.0208	0.0278	0.0385	0.0227	

(a) The student uses a stopwatch to measure the time. The stopwatch shows each time to the nearest 0.01 s

Suggest why the student records the times to the nearest second and not to the nearest 0.01 s

(1)

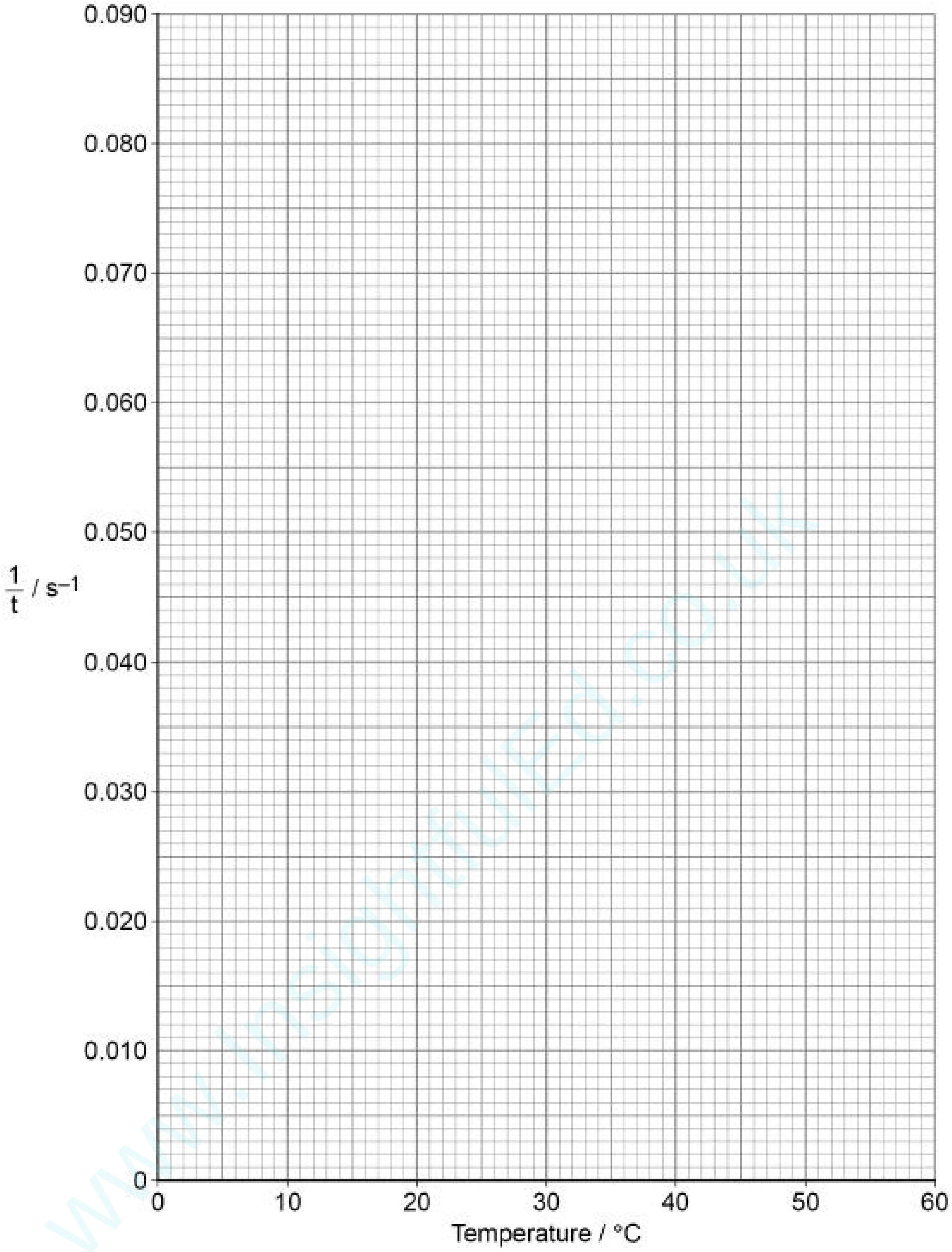
(b) The rate of reaction is proportional to $\frac{1}{t}$

Complete the table above.

(1)

(c) Plot the values of $\frac{1}{t}$ against temperature on the graph below.

Draw a line of best fit.



(2)

(d) Use your line of best fit to estimate the time for the cross to disappear at 40 °C
Show your working.

Time _______________ s

(1)

(e) Suggest, by considering the products of this reaction, why small amounts of reactants are used in this experiment.

____

____

____

(1)

(f) The student could do the experiment at lower temperatures using an ice bath.

Suggest why the student chose **not** to carry out experiments at temperatures in the range 1–10 °C

____

____

____

(1)

(Total 7 marks)

Mark schemes

Q1.

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

Any order.

Ignore references to an exothermic reaction.

1

More <u>successful</u> collisions or reactions <u>in a given time</u> **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 <u>oxide / MgO</u> **(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

[10]

Q2.

(a) the minimum energy;

1

<u>Energy</u> required for a reaction to occur;

(or to start a reaction or for successful collisions)

1

(c) molecules *(or particles or collisions)* do not have enough energy;

(or orientation may be wrong)

1

increase the pressure;

1

(or increase the concentration or reduce the volume)
increases the collision frequency;

(or more collisions)
(do not allow if stated to be due to increase in energy implied by temperature increase)

1

add a catalyst;

1

lowers activation energy (or E_a) *(Q of L mark);*

1

[15]

Q3.

(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

(c) (i) $Ba + \mathbf{2}H_2O \longrightarrow Ba(OH)_2 + H_2$

$Ba + 2H_2O \longrightarrow Ba^{2+} + 2OH^- + H_2$
Allow multiples
Ignore state symbols

1

[13]

Q4.

(a) minimum energy

1

to start a reaction/ for a reaction to occur/ for a successful collision

1

(b) activation energy is high / few molecules/particles have sufficient energy to react/few molecules/particles have the required activation energy
(or breaking bonds needs much energy)

1

(c) molecules are closer together/ more particles in a given volume 1

therefore collide more often 1

(d) many 1

more molecules have energy greater than activation energy (QoL) 1

(e) speeds up a reaction but is chemically unchanged at the end 1

(f) increases the surface area 1

[9]

Q5.

(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 O_2 2

(d) **M1** The (concentration / amount of) H_2O_2 or reactant falls / decreases / used up

Mark independently

OR

The number of H_2O_2 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) $\mathbf{2}H_2O_2 \rightarrow \mathbf{2}H_2O + O_2$

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 <u>used up</u> in the reaction / <u>unchanged at the end</u> of the reaction

OR

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

1

[10]

Q6.

(a) 111(.1)

Allow an answer to a finite number of sig figs (that is correctly rounded)

Allow 110

Do not allow answers with recurring dot above number (ignore dots after the final number)

1

(b) temperature

1

(c) Measure the temperature at the start and end of the reaction <u>and</u> find the mean/average

Measure the temperature at regular intervals during the reaction <u>and</u> find the mean/average

Allow idea of doing the reaction in a water bath

1

(d) **M1** suitable vertical scale

***M1** should use more than half the axis to cover the four points given and the point for 67°C (if plotted)*

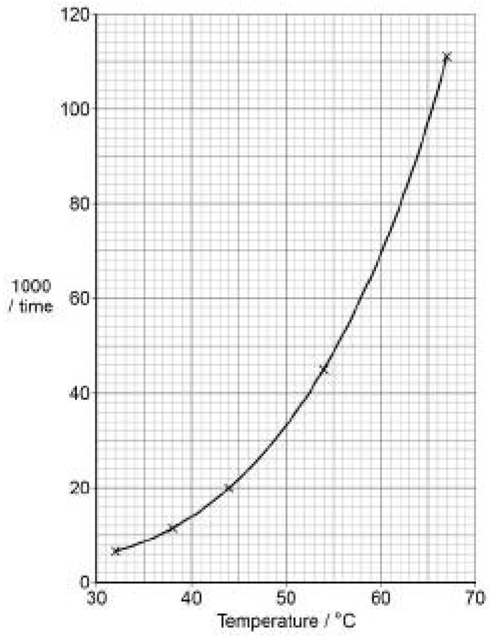
1

M2 points plotted correctly (±½ small square per point)

***M2** allow ECF for plotting of point found in part (a) (if no value found in part (a) allow graph that omits this)*

1

M3 best fit line drawn (within one small square of each point and should be a smooth curve)



M3 *allow ECF for a line based on their plotted points, but only where the line continues to rise throughout the temperature range*

1

(e) $\text{Time} = \dfrac{1000}{\text{value from graph at 60°C}}$

Answers should be at least 2 sf

Working needs to be shown that includes a value from the graph at 60 °C and/or construction line(s) showing 1000/t at 60 °C on the graph

Use the value their line shows at 60 °C (±½ small square)

1

(f) **M1** many more particles/ions have (energy ≥) activation energy

M1 *need the idea that it is many / much more particles; allow reference to atoms / molecules instead of particles / ions*

1

M2 more successful collisions per unit time / greater frequency of successful collisions

M2 *allow higher proportion of the collisions are successful*

1

[9]

Q7.

(a) Idea that it is hard to judge to the nearest 0.01 second *or* Idea that it is hard to judge the exact moment (that it becomes too cloudy / the cross disappears) *or* the idea of reaction time

Ignore ideas relating to accuracy (unless qualified)

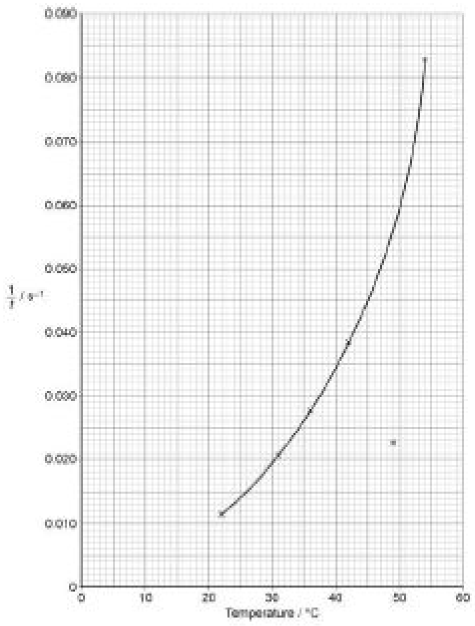
1

(b) 0.083(3….)

1

(c) **M1** points plotted correctly (allow ±1/2 small square for each)

M2 suitable best fit curve that misses point at 49°C and passes within one small square of the other five points



If any points plotted incorrectly: best fit line based on their plotted points which may need to be more than one square away from some points

*If no value calculated in (b), then **M1** and **M2** based on the other points (except the fifth anomalous point). A straight line may be allowed for **M2** for the first four points.*

*If incorrect value calculated in (b): **M1** based on all values being plotted correctly; **M2** based on suitable best fit line for the plotted points (except the fifth anomalous point).*

*Penalise **M2** if best fit line goes to 0,0.*

2

(d)

$$\frac{1}{\text{value from their best fit line at 40°C}}$$

eg $\frac{1}{0.0345}$ *= 29 (s)*

Ignore units

1

(e) as it forms a toxic gas or
SO_2 is toxic/poisonous or
to limit amount of SO_2 formed

Ignore reference to SO_2 being harmful

Ignore reference to acid rain / pollutant

1

(f) reaction would take too long / too slow / take a long time / very slow

Ignore reaction may not occur
Allow idea that it makes judging the moment when the cross disappears more difficult

1

[7]