Q1.

Hydrogen peroxide solution decomposes to form water and oxygen.

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

The reaction is catalysed by manganese(IV) oxide.

A student determines the order of this reaction with respect to hydrogen peroxide. The student uses a continuous monitoring method in the experiment.

The student places hydrogen peroxide solution in a conical flask with the catalyst and uses a gas syringe to collect the oxygen formed. The student records the volume of oxygen every 10 seconds for 100 seconds.

(a) Explain why the reaction is fastest at the start.

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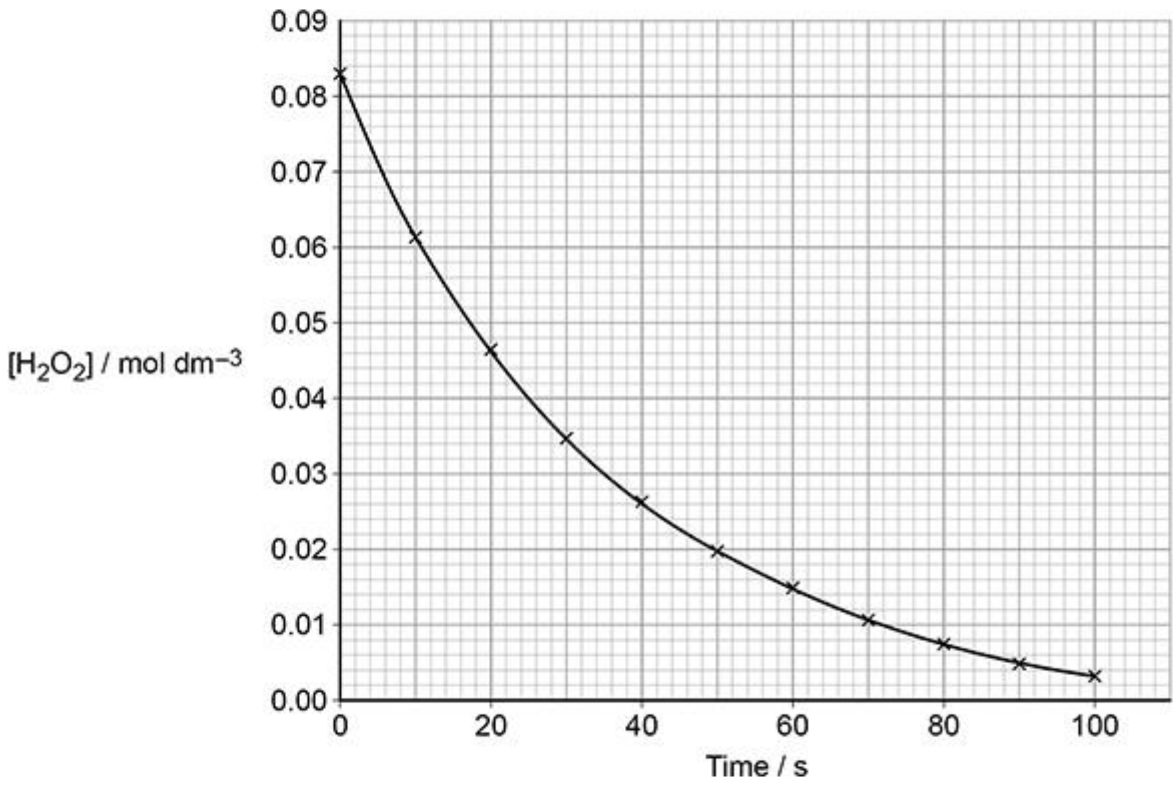
(2)

(b) The graph in **Figure 1** shows how the concentration of hydrogen peroxide changes with time in this experiment.

Figure 1



Tangents to the curve in **Figure 1** can be used to determine rates of reaction.

Draw a tangent to the curve when the concentration of hydrogen peroxide solution is 0.05 mol dm^{-3}

Use your tangent to calculate the gradient of the curve at this point.

Gradient _______________ mol dm^{-3} s^{-1}

(2)

(c) The concentration of hydrogen peroxide solution at time *t* during the experiment can be calculated using this expression.

$$[H_2O_2]_t = [H_2O_2]_{initial}\left(\frac{V_{max} - V_t}{V_{max}}\right)$$

$[H_2O_2]_t$ = concentration of hydrogen peroxide solution at time *t* / mol dm^{-3}

$[H_2O_2]_{initial}$ = concentration of hydrogen peroxide solution at the start / mol dm^{-3}

V_{max} = total volume of oxygen gas collected during the whole experiment / cm^3

V_t = volume of oxygen gas collected at time *t* / cm^3

In this experiment, V_{max} = 100 cm^3

Use **Figure 1** and the expression to calculate $[H_2O_2]_t$ when 20 cm^3 of oxygen has been collected.

$[H_2O_2]_t$ _______________ mol dm^{-3}

(2)

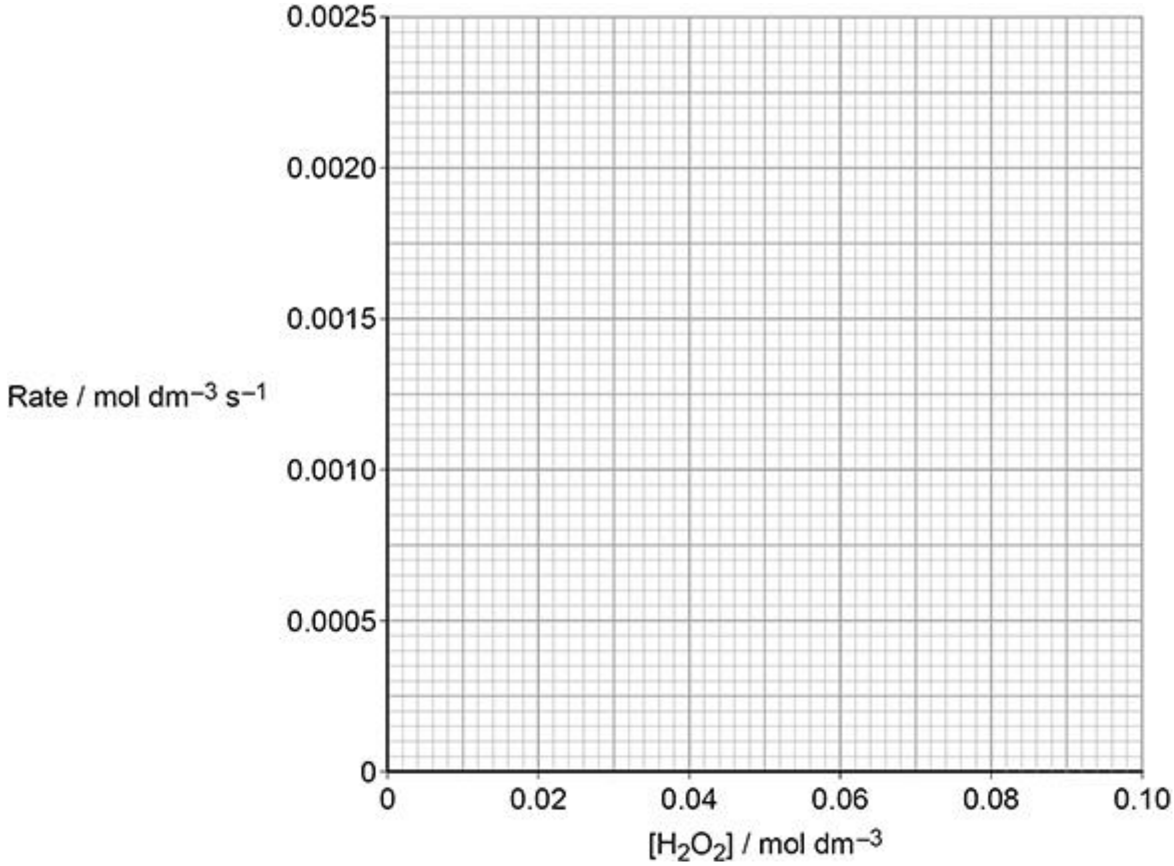
The table below shows data from a similar experiment.

$[H_2O_2]$ / mol dm^{-3}	0.02	0.03	0.05	0.07	0.09
Rate / mol dm^{-3} s^{-1}	0.00049	0.00073	0.00124	0.00168	0.00219

(d) Plot the data from the table above on the grid in **Figure 2**.

Draw a line of best fit.

Figure 2



(2)

(e) Use **Figure 2** to determine the order of reaction with respect to H_2O_2

State how the graph shows this order.

Order ____

How the graph shows this order ______________________________

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(2)
(Total 10 marks)

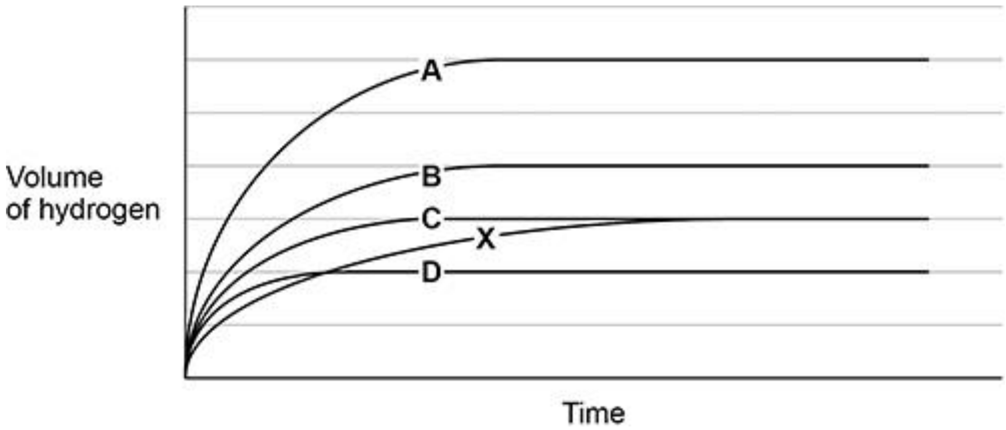
Q2.

An excess of magnesium reacts with hydrochloric acid to form hydrogen gas.

Line **X** on the graph shows how the volume of hydrogen produced changes with time as magnesium reacts with 30 cm^3 of 1.0 mol dm^{-3} hydrochloric acid.

The reaction is repeated using 20 cm^3 of 2.0 mol dm^{-3} hydrochloric acid, with all other conditions the same.

Which line shows how the volume of hydrogen produced changes with time?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

Q3.

Methanol (CH_3OH) is an important alcohol with many uses.

(a) Draw a diagram to show how two methanol molecules interact with each other through hydrogen bonding in the liquid phase.

Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(b) The bond angle around the oxygen atom in methanol is slightly smaller than the regular tetrahedral angle of 109.5°

Explain why this bond angle is smaller than 109.5°

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(1)

(c) Methanol is made by the reaction of carbon monoxide with hydrogen.

$$CO + 2\,H_2 \rightleftharpoons CH_3OH \qquad \Delta H = -91\ \text{kJ mol}^{-1}$$

The reaction uses a copper-based catalyst, a pressure of 10 MPa and a temperature of 550 K

These conditions are used to provide a balance between equilibrium yield, reaction rate and cost.

Describe how the use of a catalyst, and changes in pressure and temperature, each affect equilibrium yield, reaction rate and cost.

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(6)
(Total 10 marks)

Q4.

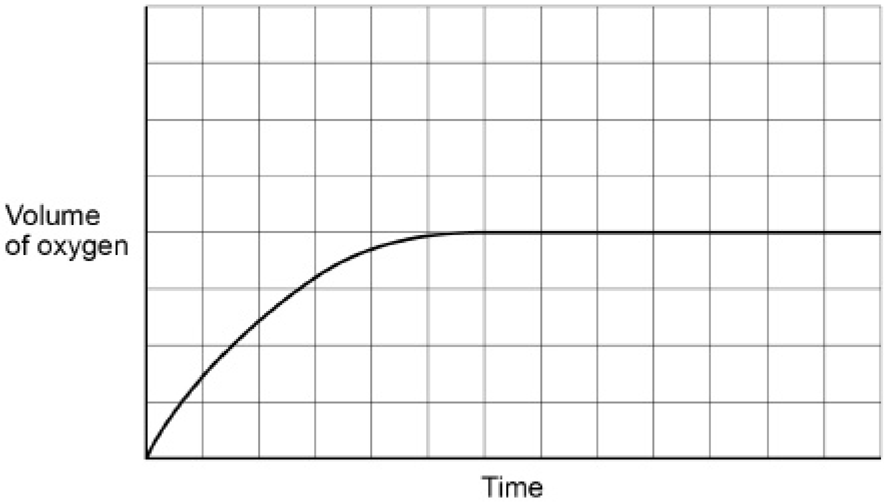
Hydrogen peroxide solution decomposes slowly to form water and oxygen.
The reaction is much faster in the presence of a manganese(IV) oxide catalyst.

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

Three experiments, shown in the table, were carried out to investigate how the volume of oxygen produced varied over time under different conditions. The same mass of catalyst was used in each experiment.

Experiment	**Concentration of H_2O_2(aq) / mol dm^{-3}**	**Volume of H_2O_2(aq) / cm^3**	**Temperature / °C**	**Catalyst**
1	1.0	50	20	lumps
2	1.0	50	20	powder
3	0.5	50	20	lumps

The graph shows how the volume of oxygen collected varied with time in Experiment **1**.



(a) Explain, in general terms, how a catalyst increases the rate of a reaction.

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(2)

(b) Draw **two** lines on the graph to show how the volume of oxygen collected varied with time in Experiments **2** and **3**.
Label each line with the experiment number.

(2)

(c) Explain, in terms of collision theory, the effect of increasing the concentration of hydrogen peroxide on the rate of reaction.

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(2)
(Total 6 marks)

Q5.

Iodide ions are oxidised to iodine by hydrogen peroxide in acidic conditions.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

The rate equation for this reaction can be written as

$$rate = k\,[H_2O_2]^a\,[I^-]^b\,[H^+]^c$$

In an experiment to determine the order with respect to H^+(aq), a reaction mixture is made containing H^+(aq) with a concentration of 0.500 mol dm^{-3}

A large excess of both H_2O_2 and I^- is used in this reaction mixture so that the rate equation can be simplified to

$$rate = k_1\,[H^+]^c$$

(a) Explain why the use of a large excess of H_2O_2 and I^- means that the rate of reaction at a fixed temperature depends only on the concentration of H^+(aq).

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(2)

(b) Samples of the reaction mixture are removed at timed intervals and titrated with alkali to determine the concentration of $H^+(aq)$.

State and explain what must be done to each sample before it is titrated with alkali.

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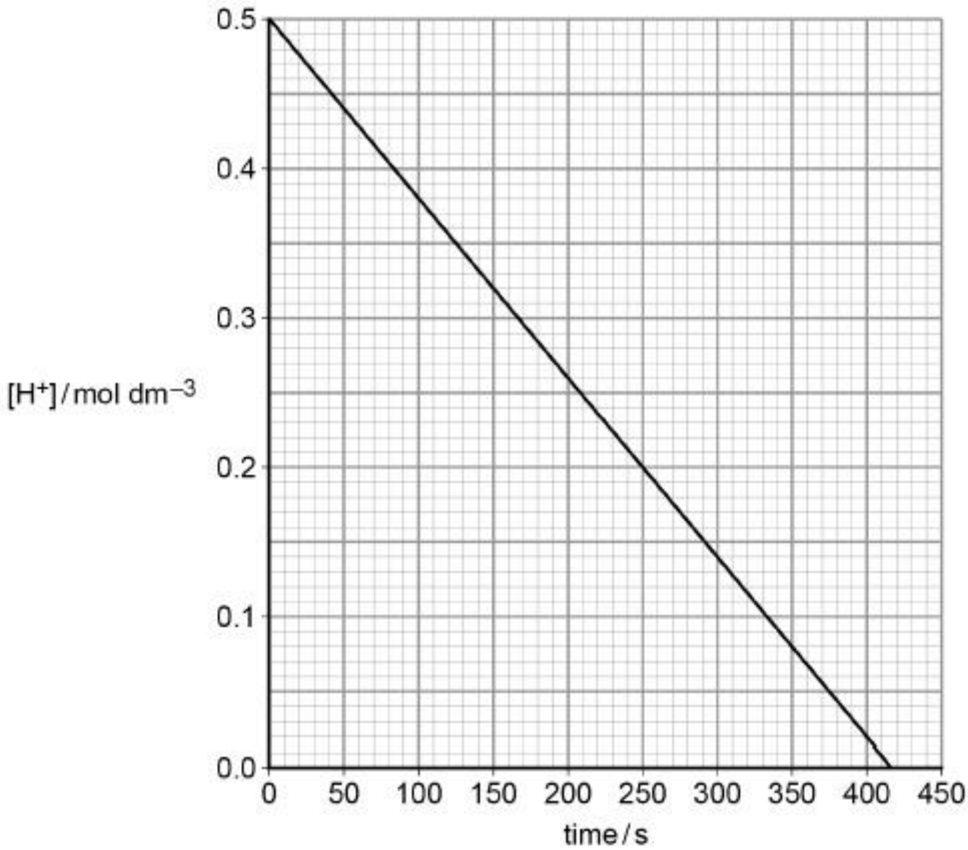
(2)

(c) A graph of the results is shown in **Figure 1**.

Figure 1



Explain how the graph shows that the order with respect to $H^+(aq)$ is zero.

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(2)

(d) Use the graph in **Figure 1** to calculate the value of k_1

Give the units of k_1

k_1 ____________________

Units ____________________

(3)

(e) A second reaction mixture is made at the same temperature. The initial concentrations of H^+(aq) and I^-(aq) in this mixture are both 0.500 mol dm^{-3}

There is a large excess of H_2O_2

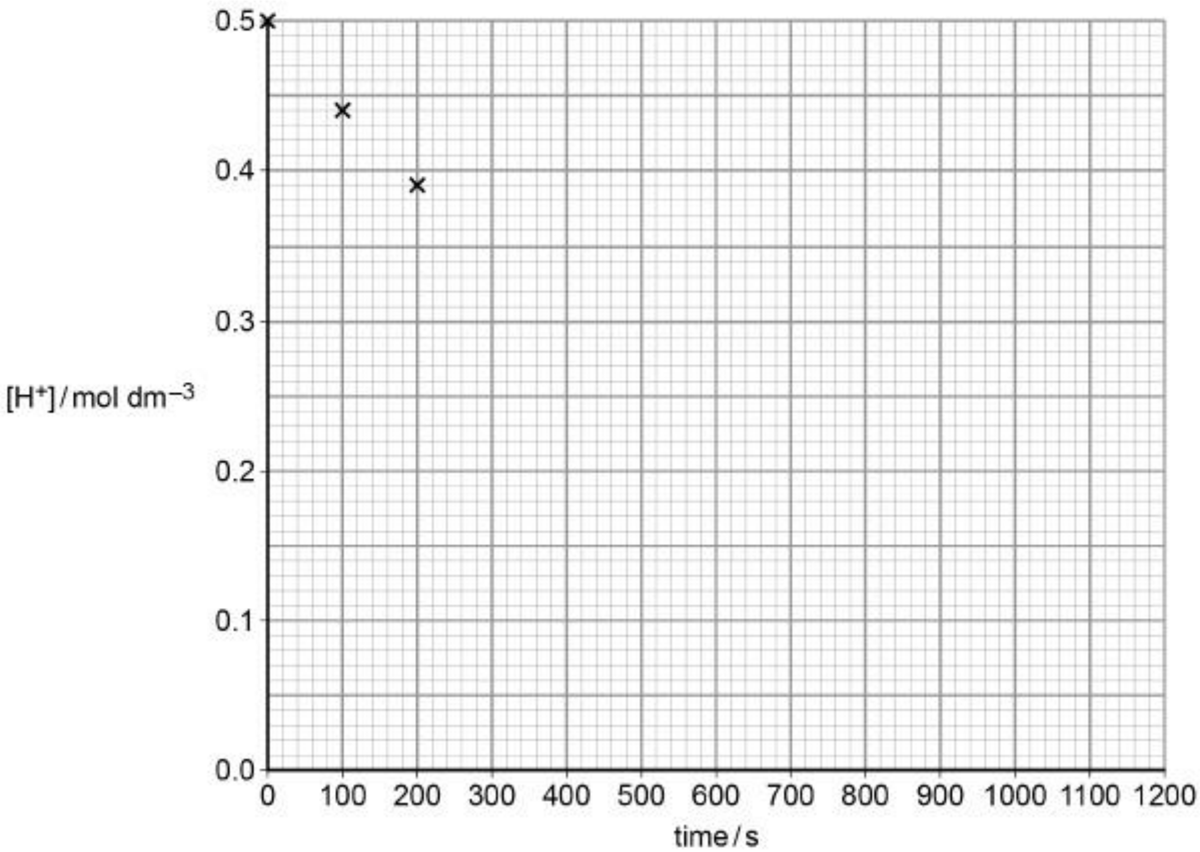
In this reaction mixture, the rate depends only on the concentration of I^-(aq).

The results are shown in the table.

Time / s	0	100	200	400	600	800	1000	1200
[H^+] / mol dm^{-3}	0.50	0.44	0.39	0.31	0.24	0.19	0.15	0.12

Plot these results on the grid in **Figure 2**. The first three points have been plotted.

Figure 2



(1)

(f) Draw a line of best fit on the grid in **Figure 2**.

(1)

(g) Calculate the rate of reaction when $[H^+]$ = 0.35 mol dm^{-3}
Show your working using a suitable construction on the graph in **Figure 2**.

Rate ____________________ mol dm^{-3} s^{-1}

(2)

(h) A general equation for a reaction is shown.

A(aq) + **B**(aq) + **C**(aq) → **D**(aq) + **E**(aq)

In aqueous solution, **A**, **B**, **C** and **D** are all colourless but **E** is dark blue.

A reagent (**X**) is available that reacts rapidly with **E**. This means that, if a small amount of **X** is included in the initial reaction mixture, it will react with any **E** produced until all of the **X** has been used up.

Explain, giving brief experimental details, how you could use a series of experiments to determine the order of this reaction with respect to **A**. In each experiment you should obtain a measure of the initial rate of reaction.

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(6)
(Total 19 marks)

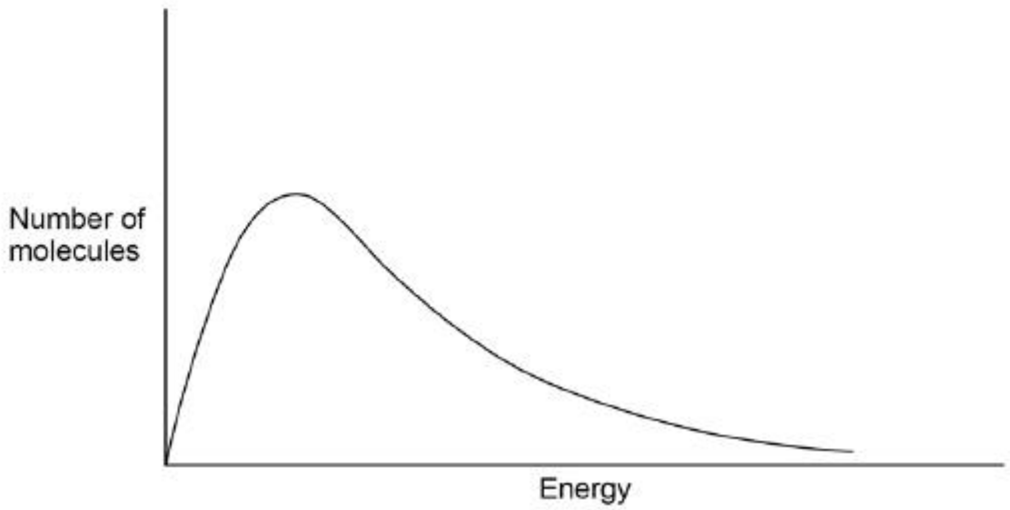
Q6.

Nitryl chloride reacts with nitrogen monoxide according to the equation:

$$ClNO_2(g) + NO(g) \longrightarrow NO_2(g) + ClNO(g)$$

The Maxwell–Boltzmann distribution curve in **Figure 1** shows the distribution of molecular energies in 1 mol of this gaseous reaction mixture (sample **1**) at 320 K.

Figure 1



(a) On the same axes, draw a curve for sample **1** at a lower temperature.

(2)

(b) Explain the effect that lowering the temperature would have on the rate of reaction.

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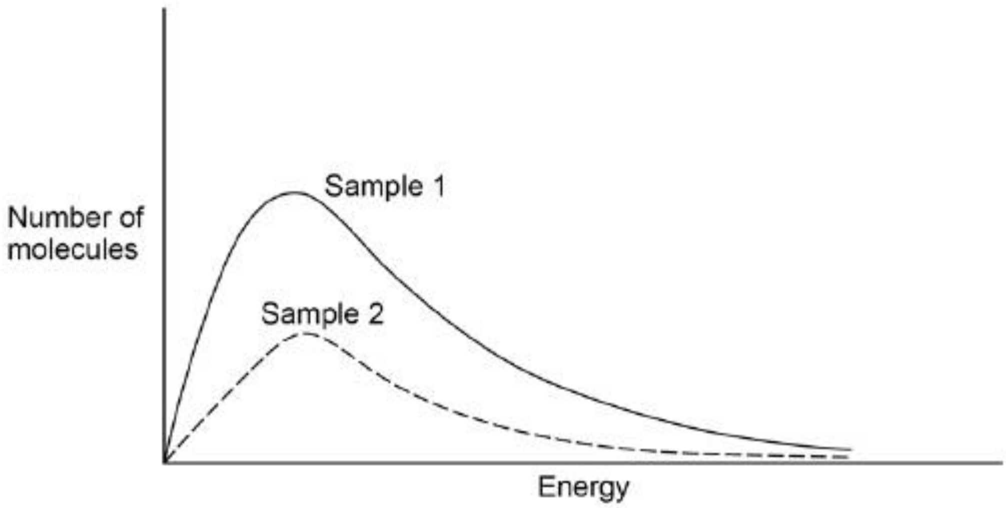
(2)

(c) A Maxwell–Boltzmann distribution curve was drawn for a second sample of the reaction mixture in the same reaction vessel. **Figure 2** shows the results.

Figure 2



Deduce the change that was made to the reaction conditions.

Explain the effect that this change has on the rate of reaction.

Change ____

____

Explanation ____

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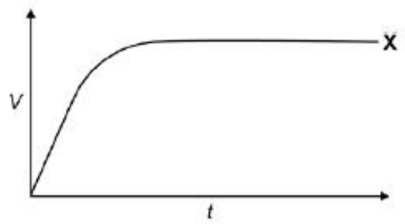
(3)

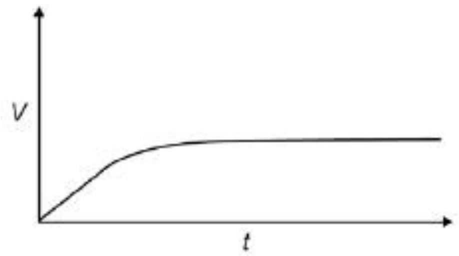
(Total 7 marks)

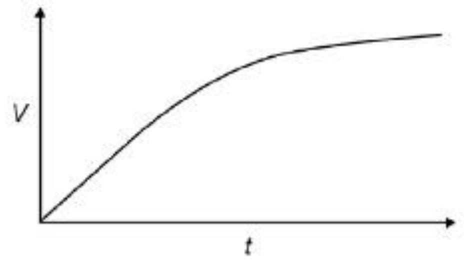
Q7.

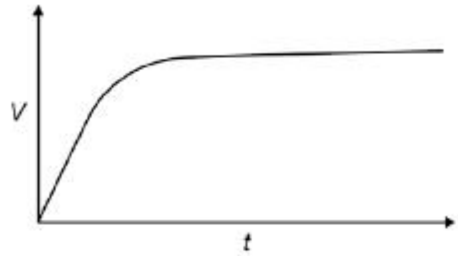
Line **X** in the diagram represents the volume (*V*) of gas formed with time (*t*) in a reaction between an excess of magnesium and aqueous sulfuric acid.

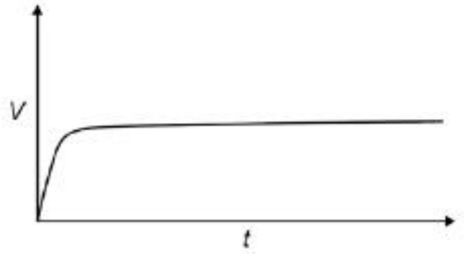


Which line represents the volume of hydrogen formed, at the same temperature and pressure, when the concentration of sulfuric acid has been halved?

A


B


C


D


(Total 1 mark)

Q8.

The experiment was repeated at 20 °C using a 250 cm^3 conical flask.

Which statement is correct about the time taken for the cross to disappear when using the larger conical flask?

A The time taken will **not** be affected by using the larger conical flask. ⬭

B The time taken will be decreased by using the larger conical flask. ⬭

C The time taken will be increased by using the larger conical flask. ⬭

D It is impossible to predict how the time taken will be affected by using the larger conical flask. ⬭

(Total 1 mark)

Q9.

Hydrogen is produced in industry from methane and steam in a two-stage process.

(a) In the first stage, carbon monoxide and hydrogen are formed.
The equation for this reaction is

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\ kJ\ mol^{-1}$$

(i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage.
Explain your answer.

Temperature ____

Explanation ____

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(3)

(ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

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(2)

(iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

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(2)

(b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}$$

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

Effect ____

Explanation ____

____

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(2)
(Total 9 marks)

Q10.

Calamine lotion can contain a mixture of zinc carbonate and zinc oxide in suspension in water. A manufacturer of calamine lotion claims that a sample contains 15.00 g of zinc carbonate and 5.00 g of zinc oxide made up to 100 cm^3 with distilled water.

(a) A chemist wanted to check the manufacturer's claim. The chemist took a 20.0 cm^3 sample of the calamine lotion and added it to an excess of sulfuric acid.
The volume of carbon dioxide evolved was measured over time. The chemist's results are shown in the table.

Time / s	0	15	30	45	60	75	90	105	120	135
Volume / cm^3	0	135	270	380	470	530	560	570	570	570

(i) Plot a graph of the results in the table on the grid. The volume should be on the *y*-axis. Draw a best-fit curve through **all** the points.

(3)

(ii) Estimate the time taken for the reaction to be completed.

____

(1)

(b) (i) The volume of carbon dioxide in part (a) was measured at 293 K and at a pressure of 100 kPa.

Use information from your graph to calculate the maximum amount, in moles, of carbon dioxide evolved from the zinc carbonate in this 20.0 cm^3 sample.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Show your working.

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(3)

(ii) Use your answer to part (i) to calculate the mass of zinc carbonate in the 20.0 cm^3 sample of calamine lotion.

(If you were unable to complete part (i), you may assume that the amount of carbon dioxide evolved was 0.0225 mol. This is **not** the correct answer.)

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(2)

(iii) Calculate the difference between your answer to part (ii) and the manufacturer's claim that there are 15.00 g of zinc carbonate in 100 cm^3 of the calamine lotion.

Express this difference as a percentage of the manufacturer's claim.

(If you were unable to complete part (ii), you may assume that the mass of zinc carbonate in the 20 cm^3 sample of calamine lotion was 2.87 g. This is **not** the correct answer.)

Difference ____

Percentage ____

____

(2)

(c) Draw a diagram of a suitable apparatus needed to perform the experiment outlined in part (a). Include in your diagram a method for collecting and measuring the carbon dioxide. The apparatus should be airtight.

(2)

(Total 13 marks)

Mark schemes

Q1.

(a) **M1** High**er**/**est** concentration of / more H_2O_2 / particles / molecules / reactants

1

M2 More frequent successful collisions

1

Alternative approach

M1 *Low**er**/**est** concentration of / fewer particles / molecules / reactants as time goes on*

M2 *Less frequent successful collisions (look for both ideas even if separated)*

Ignore *'chance' / 'probability'*

(b) **M1** Suitable tangent drawn

M1 *Tangent must be drawn with ruler and touch line at 0.05 mol dm^{-3} (± 1 square) and not cross the curve (if white seen between lines it crosses)*

1

M2 −0.00120 to –0.00155 (mol dm^{-3} s^{-1})

M2 Ignore *units*

Allow *ecf from unsuitable tangent i.e if M1 not awarded*

Ignore *sign of gradient*

1

(c) **M1** $[H_2O_2]_{initial}$ = 0.083 mol dm^{-3}

Allow *0.082 − 0.084*

1

M2 $[H_2O_2]_t$ = 0.0664 (mol dm^{-3})

Allow *0.0656 − 0.0672 (scores 2/2)*

2SF minimum

Allow *ecf from **M1** (M2 = M1 × 0.8)*

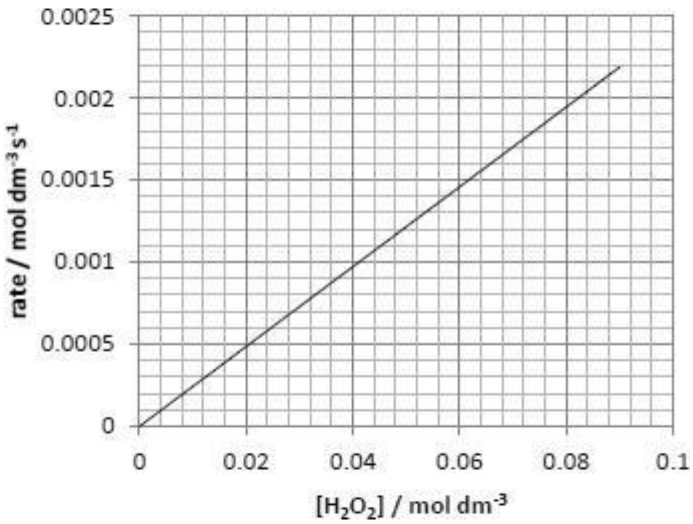
1

(d) **M1** Points plotted

M1 *allow each point (± 1/2 square)*

1

M2 best fit straight line drawn



***M2** line should be drawn with a ruler and cover the five points given going within 1 square of each point, no doubles no kinks. The line does not need to be extended to the origin*

***Allow** reasonable best fit line if points plotted incorrectly*

1

(e) **M1** 1st order

1

M2 straight line graph through the origin

***Ignore** rate is (directly) proportional to [H_2O_2]*

***Allow** constant gradient line through the origin*

***Allow** use of data from line to show e.g. x2 conc = x2 rate*

***Allow** if M1 missing*

***Not** if M1 wrong*

1

[10]

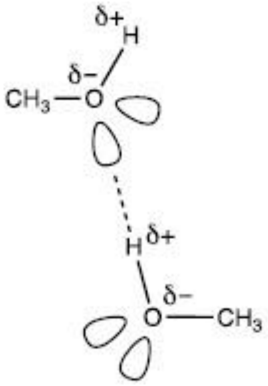
Q2.

B

[1]

Q3.

(a)



M1 on at least one O atom two lone pairs <u>and</u>
on at least one OH δ+ on H and δ- on O 1

M2 dotted line shown between lone pair on one molecule and the correct H on another 1

M3 O·····H–O in straight line 1

Accept pair of dots or crosses for lone pair in place of orbital shape (orbital shape may or may not include two electrons)

Ignore any partial charges on C–H or C–O bonds

*For straight line in **M3**, allow a deviation of up to 15°*

If a different molecule containing hydrogen bonding due to O–H bond drawn (e.g. ethanol, water) or an incorrect attempt at the structure of methanol, then maximum of 2 marks (i.e. only penalise if would score all three marks otherwise)

(b) Idea that lone pairs have greater repulsion than bonding pairs

There must be a comparison between the repulsion of a lone pair and bonding pair

Allow covalent bond = bonding pair 1

(c)

This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 marks**	**All stages are covered and the explanation of each stage is generally correct and virtually complete.** (6 v 5) Answer is well structured, with no repetition or irrelevant points, and covers all aspects of the question. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete** (4 v 3) Answer has some structure and covers most aspects of the question. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only minor errors in use of technical terms.
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete** (2 v 1) Answer includes statements which are

	presented in a logical order and/or linked.
0 marks	Insufficient correct chemistry to gain a mark.

Stage 1
Describes the effect of catalyst use
1a use of a catalyst has no impact on equilibrium yield
1b use of a catalyst gives faster rate
1c use of catalyst lowers costs

Stage 2
Describes the effect of pressure
2a higher pressure gives a higher equilibrium yield
2b higher pressure gives a faster rate
2c the higher the pressure, the greater the cost

Stage 3
Describes the effect of temperature
3a lower temperature gives a higher equilibrium yield
3b higher temperature gives a faster rate
3c the higher the temperature, the greater the cost
Note that converse statements are fine (e.g. 1a higher temperature gives a lower equilibrium yield)

6

[10]

Q4.

(a) **M1** provides a different route / mechanism / pathway

Ignore reference to (frequency of) collisions, surface area or active sites

1

M2 with lower activation energy

Penalise reference to increasing energy of particles (CE = 0)

Allow E_a / E_{act} or definition of activation energy in ***M2***

1

(b) **M1** line 2 = steeper than original and finishes at same height

1

M2 line 3 = less steep than original and finishes at half the height

If two correct lines are drawn but neither labelled, then allow 1 mark.

If two correct lines are drawn and only one is labelled, then allow 2 marks.

If only one correct line is drawn and neither are labelled, then 0 marks.

If two correct lines are drawn but line 2 is labelled 1 and line 3 is labelled 2, then allow 1 mark

Allow some unevenness in drawing of lines in terms of height it levels off at, with up to a quarter of a box of unevenness

At the start, lines must separate from the original before the first vertical line.

In terms of the origin, lines must start within one half of a square of the origin.

For each line ignore the time at which the line becomes horizontal – it is the fact it is more or less steep than the original line that matters (along with the height at which it finishes)

1

(c) **M1** more particles/molecules/reactants/H_2O_2/moles in given/same volume/space OR particles/molecules/reactants/H_2O_2/moles closer together

Penalise reference to changing the activation energy (CE = 0)

*For **M1** do not allow area*

1

M2 successful collisions are more frequent

*For **M2***

successful collisions – allow reference to collisions with sufficient energy or collisions with the activation energy or effective collisions

more frequent – allow reference to per unit time, per second (but ignore reference to rate of collisions, ignore chance of collisions, ignore likelihood of collisions)

1

[6]

Q5.

(a) H_2O_2 and/or I^- <u>concentration</u> change is negligible /
H_2O_2 and/or I^- <u>concentration</u> (effectively) constant

<u>Only</u> the <u>concentration</u> of H^+ changes.

so have a constant/no effect on the rate / so is zero order (w.r.t. H_2O_2 and I^-) / a and b are zero

Ignore references to H^+ is limiting reagent / rds / H_2O_2/I^- not in rate equation

Do not allow reference to catalyst.

2

(b) Stop the reaction / quench

By dilution / cooling / adding a reagent to react with H_2O_2/I^-

Allow valid suggestions about how to stop the reaction.

Do not allow reaction with acid/alkali / neutralisation for M2

Do not penalise other named reagents.

Ignore references to measuring volume and adding indicator

2

(c) M1: constant gradient

OR

change/decrease in concentration is proportional to time

Allow constant rate / rate = k

Ignore reference to straight line

Not increase in concentration / concentration is inversely proportional / concentration (on its own) is proportional

M2: as $[H^+]$ changes/decreases

M2 dependent on correct M1

Allow rate v concentration graph would give horizontal straight line owtte

Allow so $[H^+]$ has no effect on the rate

2

(d) evidence of attempt at calculation of gradient via Δy/Δx

allow construction lines on graph

$k_1 = 0.0012 / 1.2 \times 10^{-3}$

At least 2 sf (0.00118 – 0.00122)

Correct answer scores 2/2

No ecf from incorrect or inverted numbers in M1

$k_1 = -0.0012$ scores 1/2

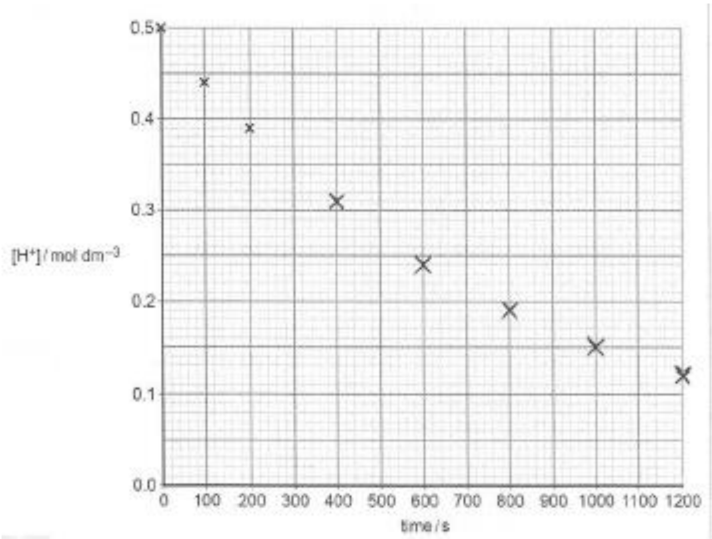
Additional processing of data such as including $[H^+]$ loses M2

units = <u>mol dm^{-3} s^{-1}</u>

M3 mark independently

3

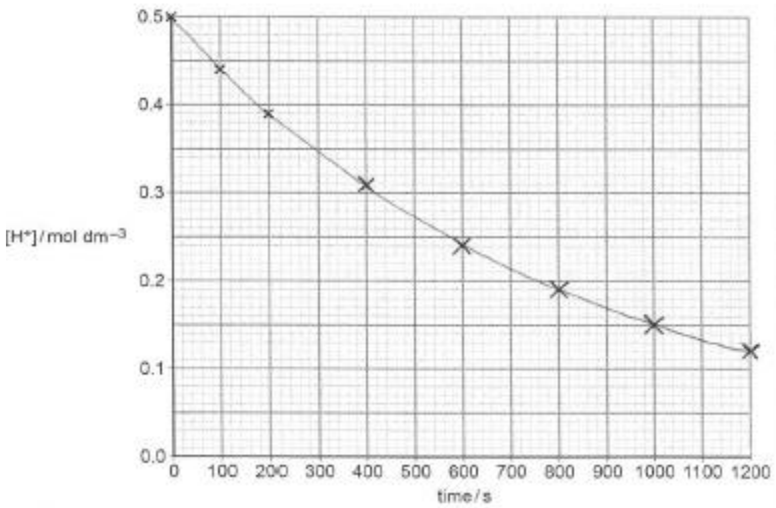
(e) 5 points correctly plotted



Allow ±half a small square for each point

1

(f)

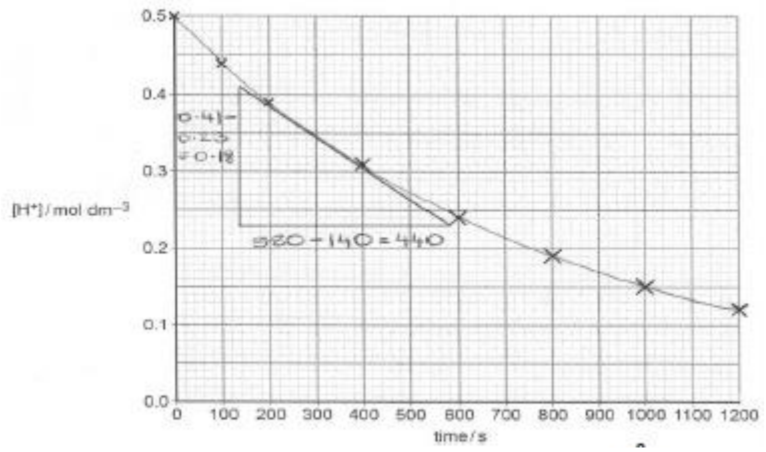


Smooth curve only within one small square of all points (ecf on part (e))

Not a series of straight lines between points

1

(g)



M1: Tangent to curve drawn at $[H_3O^+]$ = 0.35 mol dm^{-3}
e.g. 0.18/440

M1 for a tangent / triangle / other suitable working

Allow ECF for both M1 and M2 following on from straight line drawn in 01.6, but must show suitable construction on graph for M1

M2: Rate = 4.09×10^{-4} (mol dm^{-3} s^{-1})

Ignore negative signs

Allow value in range 3.70×10^{-4} - 4.50×10^{-4}

At least 2sf

ecf from any straight line for correctly calculated gradient

2

(h) This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question

Level 3	All stages are covered and the explanation of each

5-6 marks	stage is correct and virtually complete. Answer is coherent and shows progression through all three stages. A clear explanation of how the order is determined from the results is needed to show coherence.
Level 2 3-4 marks	All stages are covered (NB ‘covered’ means min 2 from stage 2) but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages covered and the explanations are generally correct and virtually complete Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** only one stage is covered but the explanation is generally correct and virtually complete Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct Chemistry to warrant a mark

Indicative Chemistry content Method 1

Stage 1 Preparation

1a Measure (suitable/known volumes of) some reagents (ignore quoted values for volume)
1b Measure (known amount of) **X** / use a colorimeter
1c into separate container(s) – (allow up to two reagents and **X** measured together into one container); reference to **A**, **B** or **C** added last. NOT if **X** added last.

Stage 2 Procedure

2a Start clock/timer at the point of mixing (don’t allow if only 2 reagents mixed) (allow even if **X** not added or added last)
2b Time recorded for appearance of blue colour/specific reading on colorimeter/disappearing cross
2c Use of same concentration of **B** and **C** / same total volume / same volume/amount of **X**
2d Same temperature/use water bath
2e Repeat with different concentrations of A (can be implied through different volumes of A and same total volume)

Stage 3 Use of Results

3a 1/time taken is a measure of the rate
3b plot of 1/time against volumes/concentrations of **A** or plot log(1/time) vs log(volume or concentration of **A**)
3c description of interpreting order from shape of 1/time vs volume or concentration

graph / gradient of log plot gives order / allow interpretation of time vs concentration graph / ratio between change in concentration and change in rate (e.g, 2x[A] = 2 × rate so 1st order)

Indicative Chemistry content – Alternative Method Using Colorimetry and repeated Continuous Monitoring

Stage 1 Preparation

1a Measure (suitable/known volumes of) **A**, **B** and **C** (ignore quoted values for volume)
1b Use of colorimeter
1c into separate container(s) – (allow up to two reagents measured together into one container) – ignore use of **X**

Stage 2 Procedure

2a Start clock/timer at the point of mixing
2b Take series of colorimeter readings at regular time intervals
2c Use of same concentration of **B** and **C** / same total volume / (same volume/amount of **X**)
2d Same temperature
2e Repeat with different concentrations of **A** (can be implied through different volumes of **A** and same total volume)

Stage 3 Use of Results

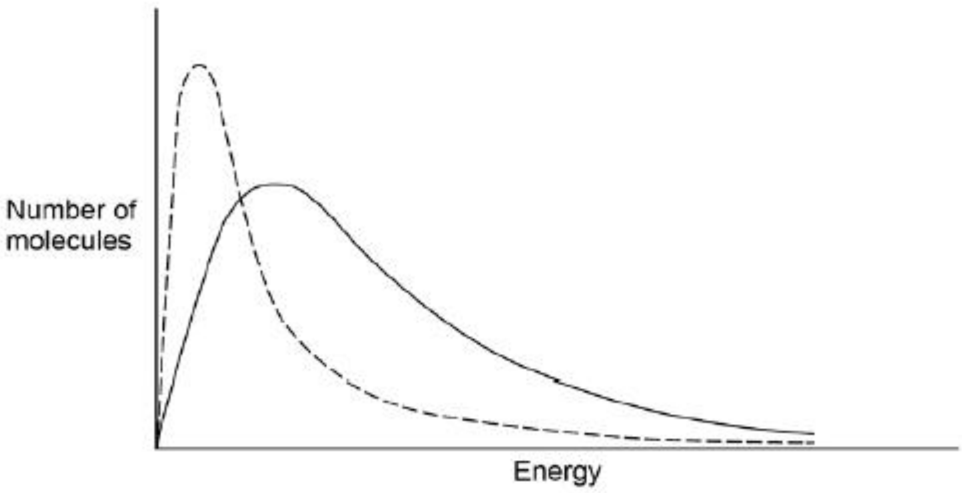
3a Plot absorbance vs time and measure/calculate gradient at time=0
3b plot of gradient against volumes/concentrations of **A** or plot log(1/time) vs log(volume or concentration of A)
3c description of interpreting order from shape of 1/time vs volume or concentration graph / gradient of log plot gives order

6

[19]

Q6.

(a)



M1 Curve is higher and displaced to the left

M2 Only crosses the original curve *<u>once</u>*

2

(b) Rate of reaction decreases (no mark)

Fewer particles will have energy greater than or equal to the activation energy
1

Fewer <u>successful</u> collisions in a given time

Less frequent <u>successful</u> collisions
1

(c) The amount of gas present (or number of molecules) has been reduced / or the pressure has been reduced
1

Rate of reaction decreases (no mark)

Particles are spread further apart
1

Fewer collisions between gas particles so fewer <u>successful</u> collisions
1

[7]

Q7.

A

[1]

Q8.

C

[1]

Q9.

(a) (i) **M1**

High (temperature) OR Increase (the temperature)

*If **M1** is incorrect **CE = 0** for the clip*

*If **M1** is blank, mark on and seek to **credit the correct information in the text***

M2

The (forward) reaction / to the right is <u>endothermic</u> or <u>takes in / absorbs heat</u>

OR

The reverse reaction / to the left is <u>exothermic</u> or <u>gives out / releases heat</u>

M3 depends on correct M2 and must refer to temperature / heat

M3** depends on a correct statement for **M2

At high temperature, the (position of) <u>equilibrium shifts / moves</u> left to right to <u>oppose the increase in temperature</u>

*For **M3**, the position of equilibrium shifts / moves*

to <u>absorb heat</u> OR

to <u>lower the temperature</u> OR

to <u>cool down the reaction</u>

3

(ii) **M1**
The reaction gets to equilibrium faster / in less time
OR
Produces a small yield faster / in less time
OR
Increases the rate (of reaction / of attainment of equilibrium)

Mark independently

M2

High pressure leads to **one** of the following

- more particles / molecules in a given volume
- particles / they are closer together
- higher concentration of particles / molecules

AND

- more collisions in a given time / increased collision frequency

*Penalise **M2** for reference to increased energy of the particles*

2

(iii) **M1** Increase in / more / large(r) / big(ger) surface area / surface sites

Mark independently

*For **M1** accept Éan increase in surface"*

M2 increase in / more successful / productive / effective collisions (in a given time) (on the surface of the catalyst / with the nickel)

*For **M2** not simply "more collisions"*

Ignore "the chance or likelihood" of collisions

2

(b) **M1**
No effect / None

*If **M1** is incorrect **CE = 0** for the clip*

*If **M1** is blank, mark on and seek to **credit the correct information in the text***

M2 requires a correct M1
Equal / same number / amount of moles / molecules / particles on either side of the equation
OR
2 moles / molecules / particles on the left and 2 moles / molecules / particles on the right

M2** depends on a correct statement for **M1

*In **M2 not** "atoms"*

2

[9]

Q10.

(a) (i) Uses sensible scales.

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the graph plot goes off the squared paper

Lose this mark if volume is plotted on the x-axis

1

All points plotted correctly

Allow ± one small square.

1

Smooth curve from 0 seconds to at least 135 seconds − the line must pass through or close to all points (± one small square).

Make some allowance for the difficulties of drawing a curve but do not allow very thick or doubled lines.

1

(ii) Any value in the range 91 to 105 s

Allow a range of times within this but not if 90 quoted.

1

(b) (i) Using pV = nRT

This mark can be gained in a correctly substituted equation.

1

$100\,000 \times 570 \times 10^{-6} = n \times 8.31 \times 293$

Correct answer with no working scores one mark only.

1

n = 0.0234 mol

Do not penalise precision of answer but must have a minimum of 2 significant figures.

1

(ii) Mol of $ZnCO_3$ = 0.0234

Mark consequentially on Q6

M1
1

Mass of $ZnCO_3$ = M1 × 125.4 = 2.9(3) or 2.9(4) g

If 0.0225 used then mass = 2.8(2) g

M2
1

(iii) Difference = (15.00 / 5) − Ans to b

If 2.87 g used then percentage is 4.3

M1
1

Percentage = (M1 / 3.00) × 100

Ignore precision beyond 2 significant figures in the final answer

If 2.82 g used from (ii) then percentage = 6.0

M2
1

(c) A reaction vessel which is clearly airtight round the bung

1

Gas collection over water or in a syringe

Collection vessel must be graduated by label or markings

Ignore any numbered volume markings.

1

[13]