

ALyl Chem 26 EQ P5 22w to 02s Paper 5 Reaction kinetics 191marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than 3 minutes to complete.

Paper 5 Topic 26

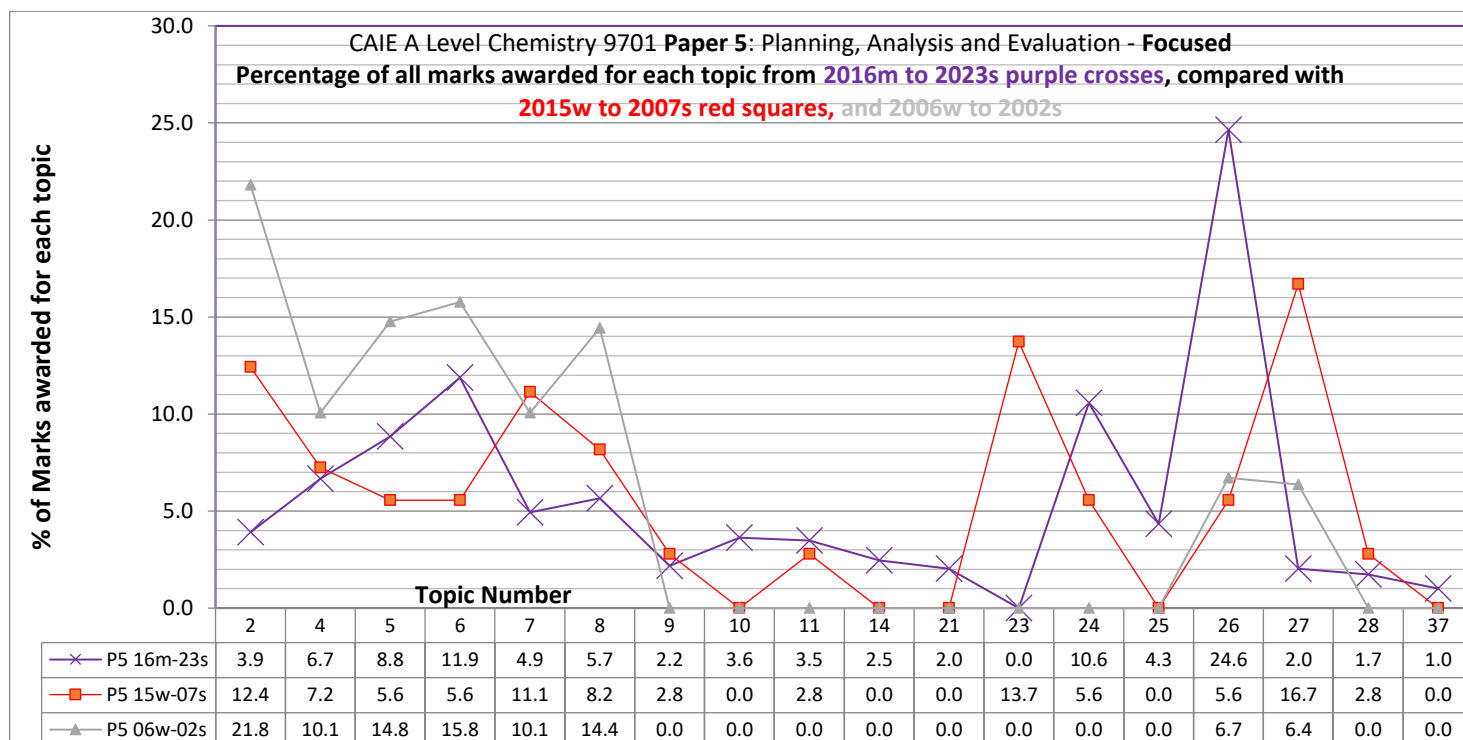
Checklist Tick each

task off as you go along

RANK:

Marks

		P5 Noob	P5 Novice	P5 Bronze	P5 Silver	P4 Gold	P5 ¹ Winner	P5 Hero	P5 Legend
		1 Q Started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	191		16	19	48	76	96	143	191
Time @150s/mark (minutes)	478		40	48	119	191	239	358	478



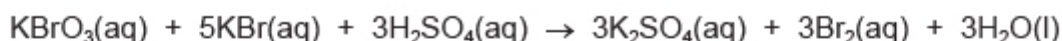
What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important outcome from skillful action in study is being better at any important tasks even if circumstances are do not feel ideal.

Learning how to manage oneself so we can more reliably get ambitious and successful outcomes out of our challenges in a productive and positive way is one aspect of life's most valuable pursuit summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each question, or page, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are using the marking scheme correctly; your correct answer might not be fully complete. The marks easiest to miss rely on providing more details fully described.

¹ DO NOT work on these higher levels of completion unless you have also achieved at least a "Gold" (40%) in the same topic in Paper 4, which is MOST of your A2 grade.

- 3 Potassium bromate(V) reacts with potassium bromide and sulfuric acid to form potassium sulfate, bromine and water according to the following equation.



A student is investigating how the rate of this reaction is affected by changing the concentration of the reactants in turn. This is done by keeping the total volume of mixture constant and adding different, small volumes of each reagent.

The reaction produces bromine which is orange in colour. The student times the reaction and then determines the rate as $\frac{1}{\text{time}}$.

The rate equation for the reaction is of the form:

$$\text{rate} = k[\text{KBrO}_3]^x[\text{KBr}]^y[\text{H}_2\text{SO}_4]^z$$

k is the rate constant for the reaction and x , y and z are the respective orders of the reaction for each reagent.

The student carried out the experiment and obtained the following data.

Table 3.1

mixture	$[\text{KBrO}_3]$ /mol dm ⁻³	$[\text{KBr}]$ /mol dm ⁻³	$[\text{H}_2\text{SO}_4]$ /mol dm ⁻³	rate of reaction /s ⁻¹
A	0.025	0.125	0.075	0.059
B	0.050	0.125	0.075	0.117
C	0.025	0.250	0.075	0.118
D	0.025	0.125	0.150	0.235
E	0.050	0.250	0.150	0.941

- (a) (i) Suggest how the student might time the reaction and judge the end point of the reaction for each mixture.

.....

 [1]

- (ii) By comparing the data for the mixtures deduce the values of x , y and z .

[2]



- (b) The student carried out each reaction using a boiling tube (capacity 50 cm^3) and varied the concentration by adding different volumes of each reagent. For example, in mixture A, 5.0 cm^3 of $\text{KBrO}_3(\text{aq})$ is required.

Name a suitable piece of apparatus which could be used to measure this volume.

..... [1]

- (c) Suggest why the reagents are heated to the same temperature before mixing.

..... [1]

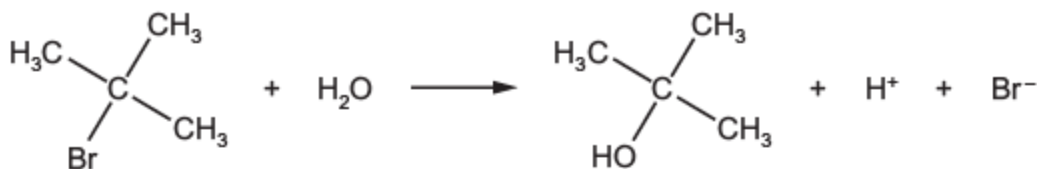
- (d) The solution of sulfuric acid used in each mixture was of concentration 0.150 mol dm^{-3} . This acid was prepared from a solution of concentration 1 mol dm^{-3} .

Briefly describe how to make the more dilute solution, stating the capacity of any apparatus used.

.....
.....
.....
..... [2]

[Total: 7]

2 A student plans to study the rate of hydrolysis of 2-bromo-2-methylpropane.



As the concentration of 2-bromo-2-methylpropane decreases during the reaction, the concentration of hydrogen ions increases.

The student plans the following method.

- Step 1** Place 100 cm³ of a mixture of propanone and water into a conical flask.
- Step 2** Heat the mixture to 35 °C and maintain this temperature.
- Step 3** Add 1.00 cm³ of 2-bromo-2-methylpropane to the mixture and start timing.
- Step 4** After 1 minute, transfer a 10.00 cm³ sample of the reaction mixture into a conical flask containing ice and 4 drops of methyl orange indicator.
- Step 5** Immediately titrate the 10.00 cm³ of the reaction mixture with 0.0200 mol dm⁻³ sodium hydroxide.
- Step 6** Repeat sampling and titrating at regular time intervals over a total time of 45 minutes.
- Step 7** Heat the reaction mixture to 50 °C, remove the final sample, and titrate this.
- (a) (i) State the apparatus you would use to maintain the temperature of the reaction mixture.

..... [1]

- (ii) Suggest why the experiment is carried out away from naked flames.

.....
 [1]

- (b) State the pieces of equipment and their capacities that you would use to:

- (i) measure 1.00 cm³ of 2-bromo-2-methylpropane in step 3

..... [1]

- (ii) transfer a 10.00 cm³ sample of the mixture in step 4.

..... [1]

(c) Explain why the reaction mixture is transferred into a conical flask containing ice.

[1]

(d) State the measured dependent variable for this experiment.

[1]

(e) (i) The student recorded the results. V_{final} is the final titre volume, 47.25 cm^3 in step 7.

Complete Table 2.1 by calculating the value of $V_{\text{final}} - V_t$.

Record the values to **2 decimal places**.

Table 2.1

time/s	titre, V_t/cm^3	$V_{\text{final}} - V_t/\text{cm}^3$
60	1.25	
300	7.75	
600	17.75	
900	20.00	
1200	24.25	
1500	28.40	
1800	31.15	
2700	38.00	
final	47.25	

[1]

(ii) The titre, V_t , is proportional to the concentration of the hydrogen ions.

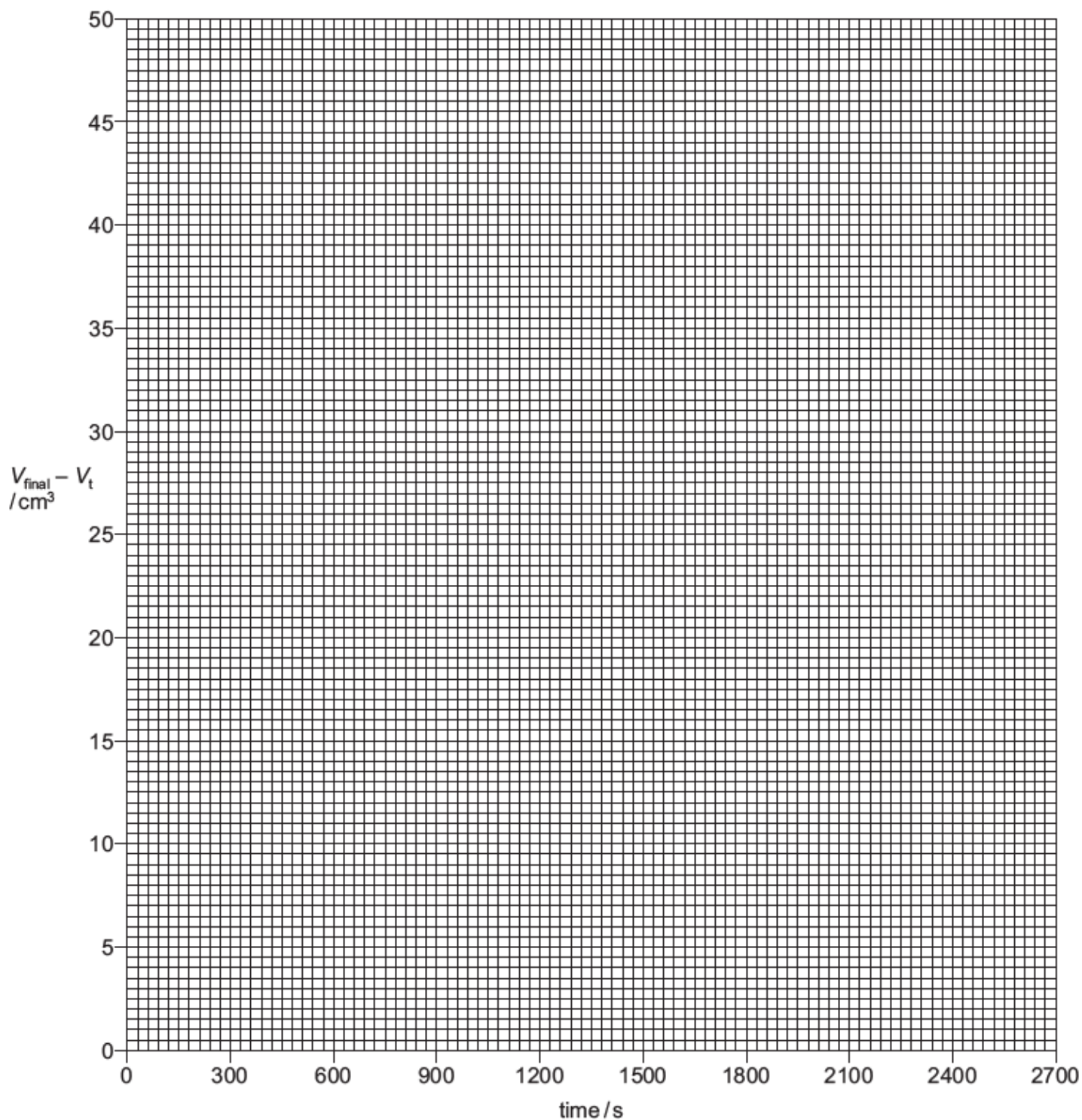
State what $V_{\text{final}} - V_t$ is proportional to.

[1]

(iii) Plot a graph on the grid to show the relationship between $V_{\text{final}} - V_t$ and time.

Use a cross (x) to plot each data point. Draw a curved line of best fit.

[2]



(iv) Circle the point on the graph you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during this experimental procedure.

.....
 [2]

(v) Use the graph to find two half-lives, $t_{\frac{1}{2}}$, for this reaction.

State the coordinates of both points you used in your calculations.

first $t_{\frac{1}{2}}$: coordinates and

half-life = s

second $t_{\frac{1}{2}}$: coordinates and

half-life = s

[3]

(vi) Use your answer to (e)(v) to state the order of the reaction with respect to 2-bromo-2-methylpropane. Explain your answer.

(If you were unable to obtain an answer to (e)(v) you may use the values 1050s and 1045s for the half-lives. These are **not** the correct values.)

order =

explanation

[1]

Q# 81/ ALvl Chemistry/2021/w/TZ 1/ Paper 5/Q# 2/www.SmashingScience.org :o)

2 The rate of reaction between calcium carbonate, CaCO_3 , and hydrochloric acid, HCl , can be followed by collecting and measuring the volume of carbon dioxide produced at 30-second intervals.

The equation for the reaction is:



(a) A student plans to collect the carbon dioxide by displacement of water.

Draw a labelled diagram of the apparatus that could be used to carry out this experiment.

The apparatus should allow the accurate recording of the volume of carbon dioxide produced.

- (b) The student carried out the investigation using an excess of calcium carbonate with dilute hydrochloric acid. The student stopped timing after 330 seconds had passed. The volume of carbon dioxide produced was 93 cm^3 .

V_{final} is the final volume of carbon dioxide collected at 330 seconds.

V_t is the volume of carbon dioxide collected at each interval of time, t .

$V_{\text{final}} - V_t$ is proportional to the concentration of hydrochloric acid at a given time.

time, t/s	volume of carbon dioxide collected / cm^3	$V_{\text{final}} - V_t / \text{cm}^3$
0	0	
30	22	
60	37	
90	50	
120	61	
150	68	
180	75	
210	78	
240	79	
270	87	
300	90	
330	93	

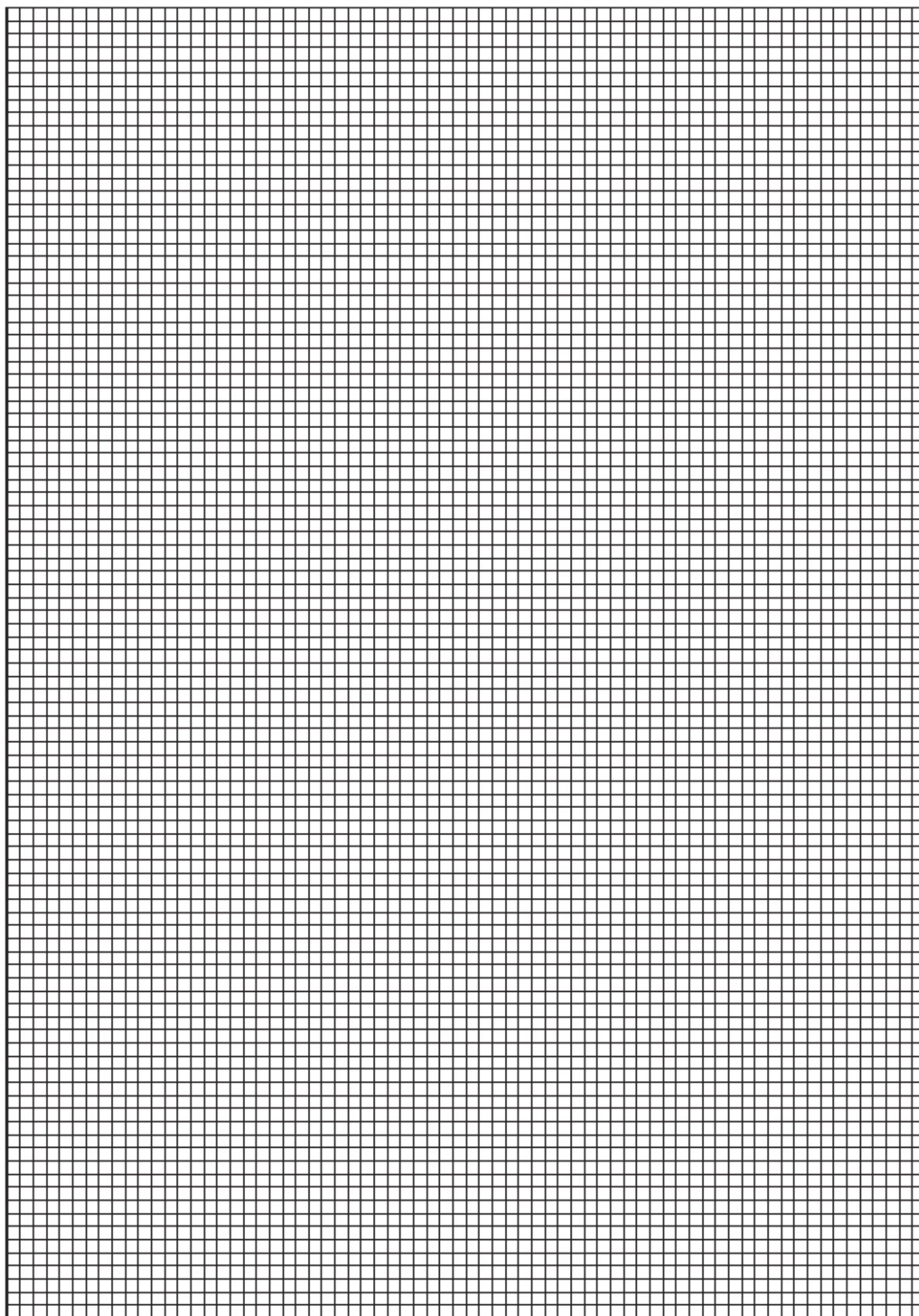
- (i) Complete the table.

[1]

(ii) Plot a graph of $V_{\text{final}} - V_t$ (y-axis) against time, t (x-axis).

Use a cross (×) to plot each data point. Draw a curved line of best fit.

V_t



time, t/s

(iii) Circle the point which you consider to be most anomalous.

[2]

[1]



(iv) Suggest **one** reason for this anomalous point.

.....
..... [1]

(v) Draw construction lines on the graph to calculate two consecutive half-lives for this reaction. Use these half-lives to determine the mean half-life, $t_{\frac{1}{2}}$.

first half-life = s

second half-life = s

mean half-life, $t_{\frac{1}{2}}$ = s
[2]

(vi) The rate constant, k , for this reaction can be calculated using the following expression.

$$t_{\frac{1}{2}} = \frac{0.693}{k}$$

Calculate k .

If you did not obtain a value for $t_{\frac{1}{2}}$ in (v) you may use 95 seconds. This is **not** the correct answer.

k = s⁻¹ [1]

(c) State how an increase in temperature would affect the value of k for this reaction. Explain your answer.

.....
..... [1]

(d) Calcium carbonate is a component of antacid tablets.

An alternative method of studying the rate of reaction between calcium carbonate and hydrochloric acid is:

- Place one antacid tablet into a beaker.
- Add 50 cm^3 , **an excess**, of 2.0 mol dm^{-3} hydrochloric acid and start the stop-clock immediately.
- Record the time taken for the fizzing to stop.

(i) An antacid tablet typically contains 1.0 g of CaCO_3 .

Complete columns A, B and C in the table to show four more concentrations of **excess** HCl(aq) which would allow this method to be carried out.

Each sample of HCl(aq) must be made by dilution of 2.0 mol dm^{-3} HCl .

[A_r : Ca, 40.1; C, 12.0; O, 16.0]

A	B	C	D
volume of 2.0 mol dm^{-3} HCl / cm^3	volume of distilled water / cm^3	concentration of HCl / mol dm^{-3}	time taken for fizzing to stop / s
50.0	0.0	2.0	

[2]

(ii) Identify the dependent variable in this investigation.

..... [1]

(iii) Suggest how the reliability of the results could be improved.

.....
..... [1]

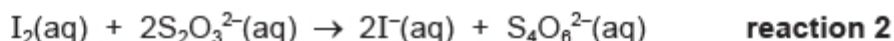
[Total: 16]

- 1 The reaction between hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, and iodide ions, $\text{I}^-(\text{aq})$, takes place in acidic conditions.



The rate of this reaction can be found by measuring the time taken for a given amount of iodine, $\text{I}_2(\text{aq})$, to form.

This is done by adding a known amount of thiosulfate ions, $\text{S}_2\text{O}_3^{2-}(\text{aq})$, and allowing the $\text{I}_2(\text{aq})$ formed in **reaction 1** to react with the $\text{S}_2\text{O}_3^{2-}(\text{aq})$.



After the $\text{S}_2\text{O}_3^{2-}(\text{aq})$ ions have all reacted in **reaction 2**, any further $\text{I}_2(\text{aq})$ formed in **reaction 1** can be detected using an indicator.

A student carried out a series of experiments to determine the order of reaction with respect to the concentration of $\text{I}^-(\text{aq})$ ions in **reaction 1**.

The student prepared the following solutions.

solution **A** 0.100 mol dm⁻³ KI(aq)

solution **B** 0.0500 mol dm⁻³ Na₂S₂O₃(aq)

The student also had access to the following chemicals.

solution **C** 0.100 mol dm⁻³ H₂O₂(aq)

0.2 mol dm⁻³ H₂SO₄(aq)

distilled water

a suitable indicator

(a) The student prepared solution **A** in a 250 cm³ volumetric flask.

- (i) The student used a balance accurate to two decimal places and a weighing boat. A weighing boat is a small container used to hold solid samples when they are weighed.

Determine the mass, in g, of KI needed to prepare 250.0 cm³ of solution **A**.

[A_r: K, 39.1; I, 126.9]

mass = g [2]



- (ii) The student weighed the empty weighing boat. The student then added solid KI to the weighing boat until the mass of KI calculated in (i) was reached. The student transferred all of the KI from the weighing boat into a 100 cm³ beaker.

Describe how the student could check that the mass of KI transferred into the 100 cm³ beaker was exactly the same as the mass calculated in (i).

.....
..... [1]

- (iii) The student dissolved the KI in the 100 cm³ beaker in distilled water and transferred the solution formed into a 250 cm³ volumetric flask. Distilled water was added to the volumetric flask until the volume of the solution was exactly 250 cm³. Care was taken to avoid parallax errors.

Describe:

- how the student should transfer all the KI solution from the beaker into the 250 cm³ volumetric flask
- how the student should fill the volumetric flask exactly up to the 250 cm³ mark.

.....
.....
.....
..... [2]

- (b) The student rinsed a burette with solution A before filling it with solution A.

Explain why this improves the accuracy of the results.

.....
..... [1]

- (c) The student was given a solution of 0.400 mol dm⁻³ Na₂S₂O₃(aq).

Determine the volume, in cm³, of this solution that should be added to a 100 cm³ volumetric flask to prepare 100.0 cm³ of solution B. Give your answer to **two** decimal places.

volume = cm³ [1]

(d) Experiment 1 was carried out using a series of steps.

- step 1** The student used a measuring cylinder to measure 25 cm^3 of $0.2\text{ mol dm}^{-3}\text{ H}_2\text{SO}_4(\text{aq})$. This was transferred to a conical flask.
- step 2** The student added 20.00 cm^3 of distilled water from a burette to the conical flask.
- step 3** The student added 5.00 cm^3 of solution **A** from a burette to the conical flask.
- step 4** The student added 5.00 cm^3 of solution **B** from a burette to the conical flask.
- step 5** The student added 1.0 cm^3 of indicator from a teat pipette to the conical flask.
- step 6** The student used a burette to add 10.00 cm^3 of solution **C** to a small beaker. The contents of the beaker were added to the conical flask and a stopclock was started immediately. The stopclock was stopped when the I_2 formed caused the indicator to change colour.

In Experiments 2–6 the student repeated **steps 1–6** but using the volumes of distilled water and solution **A** given in the table.

The student carried out two trials of each experiment.

experiment	volume of $\text{H}_2\text{SO}_4(\text{aq})$ / cm^3	volume of distilled water / cm^3	volume of solution A , v / cm^3	volume of solution B / cm^3	volume of indicator / cm^3	time for the indicator to change colour, t / s	
						trial 1	trial 2
1	25.0	20.00	5.00	5.00	1.0	218	220
2	25.0	15.00	10.00	5.00	1.0	112	113
3	25.0	12.50	12.50	5.00	1.0	100	
4	25.0	10.00	15.00	5.00	1.0	77	76
5	25.0	5.00	20.00	5.00	1.0	59	59
6	25.0	0.00	25.00	5.00	1.0	47	49

- (i) In Experiment 3, trial 2, the indicator changed colour as soon as the student added solution **C** to the conical flask. No results were recorded for Experiment 3, trial 2.

Suggest which step the student did **not** carry out in Experiment 3, trial 2.

..... [1]

- (ii) Suggest why the results shown in the table could be considered reliable.

.....
 [1]

- (iii) What was the percentage error in the burette reading for measuring the volume of solution **A** in Experiment 5?

percentage error = % [1]

- (iv) Suggest why a measuring cylinder was used to measure the volume of $\text{H}_2\text{SO}_4(\text{aq})$ rather than a more accurate piece of apparatus, such as a burette.

..... [1]

- (v) For Experiments 1–6, state:

- the independent variable
- the dependent variable.

[2]

- (e) The rate equation can be written as $\text{rate} = k[\text{I}^-]^n$ where $[\text{I}^-]$ is proportional to the volume of solution **A** and n is the order of reaction with respect to I^- .

- (i) Use only the results of Experiments 1–6 given in (d) to complete the table where:

- v is the volume of solution **A** used in cm^3
- t_{av} is the average time taken in trial 1 and trial 2 in s.

Give all values to **three** significant figures.

experiment	v / cm^3	$\log v$	t_{av} / s	$(1/t_{\text{av}}) / \text{s}^{-1}$	$\log(1/t_{\text{av}})$
1	5.00				
2	10.00				
3	12.50		100	0.0100	
4	15.00				
5	20.00				
6	25.00				

[2]

- (ii) Rate can be expressed as $(1/t_{\text{av}})$.
The rate equation can be expressed as shown.

$$\log(1/t_{\text{av}}) = n \log v + c$$

where:

- c is a constant
- v is proportional to $[\text{I}^-]$.

On the grid:

- Plot a graph of $\log(1/t_{\text{av}})$ against $\log v$. Use a cross (x) to plot each data point.
- Draw a line of best fit.

[2]

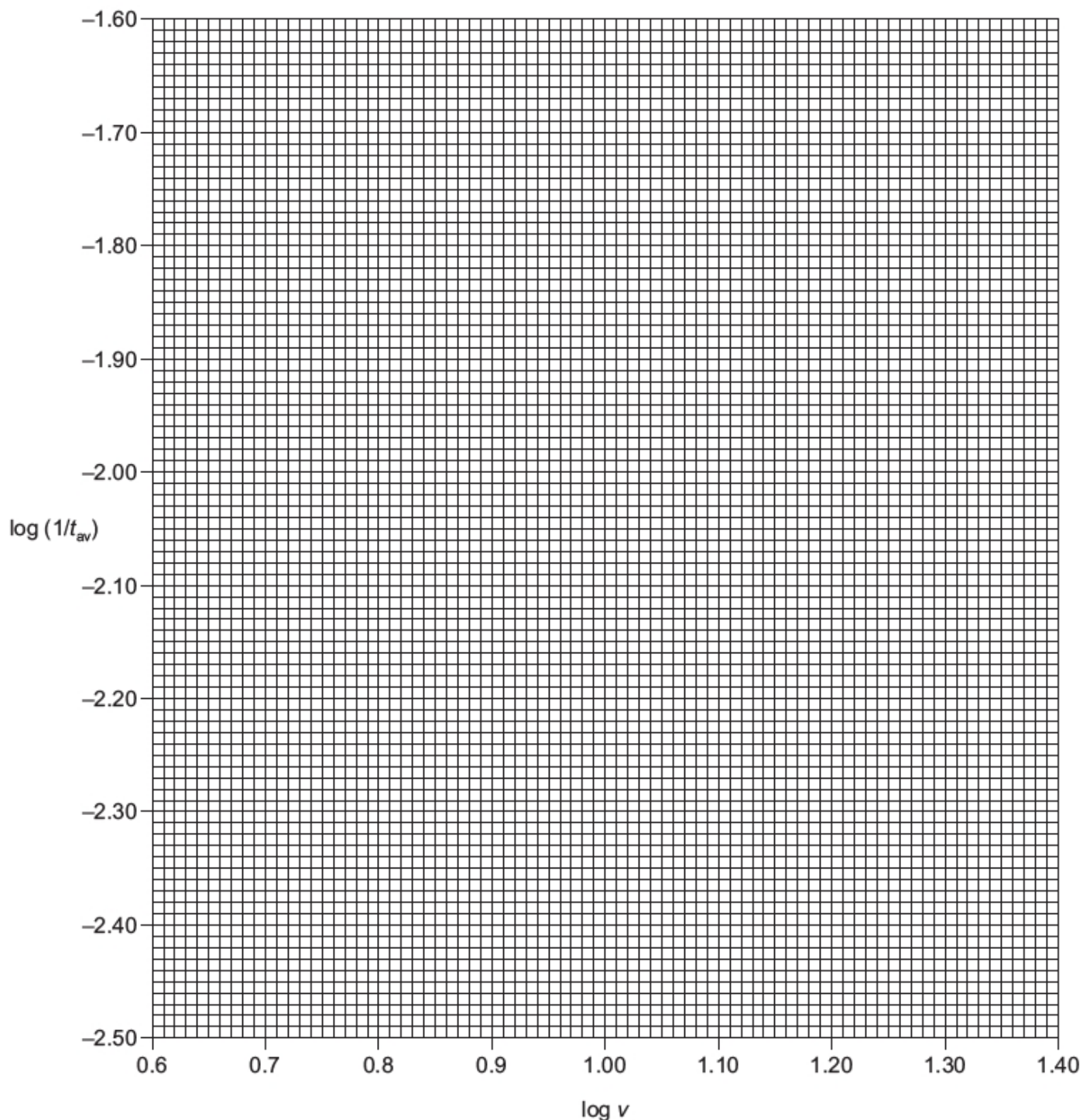
- (iii) Use your graph to determine the gradient of the line of best fit. State the coordinates of both points you used in your calculation. Give the gradient to **three** significant figures. Determine the order of reaction with respect to $I^-(aq)$.

co-ordinates 1 co-ordinates 2

gradient =

order of reaction with respect to $I^-(aq)$ =

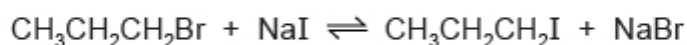
[3]



[Total: 20]

- 1 The Finkelstein reaction is a nucleophilic substitution reaction in which a halogen atom in a halogenoalkane is replaced by another halogen atom. The reaction is carried out using dry propanone as a solvent.

One example of the Finkelstein reaction is given.



- (a) (i) Explain why it is important for **dry** propanone to be used as a solvent for this reaction.

.....

.....

..... [1]

- (ii) The solubilities of NaBr and NaI in propanone are shown.

compound	solubility at 25 °C in g / 100 g of propanone
NaBr	0.00841
NaI	39.9

Use this information to explain why, although the reaction between $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ and NaI is reversible, the reaction produces a very high yield.

.....

.....

.....

.....

.....

..... [2]

(b) Some safety information for the organic compounds used in this reaction is shown.

- 1-bromopropane is **highly flammable** and **moderate health hazard**. It is irritating to eyes, the respiratory system and skin.
- 1-iodopropane is **flammable** and **moderate health hazard**. It is irritating to eyes, the respiratory system and skin.
- Propanone is **highly flammable** and **moderate health hazard**. It is irritating to eyes, and may cause dizziness and drowsiness.

Identify **two** different precautions, other than using protective equipment such as gloves, a lab coat or eye protection, that should be taken when carrying out this experiment. Explain each answer.

1 precaution

.....

explanation

.....

2 precaution

.....

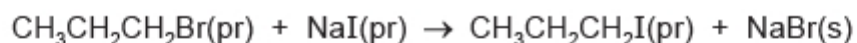
explanation

.....

[2]

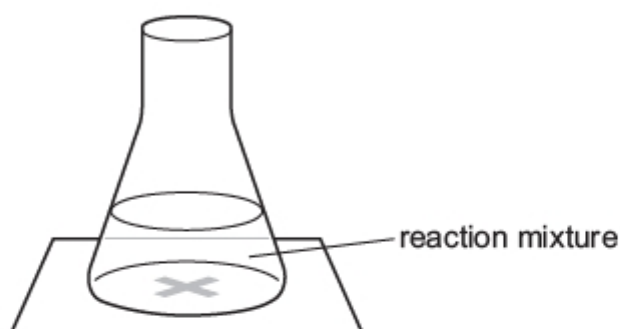
- (c) A student plans an experiment to show that the rate of the reaction is proportional to the concentration of NaI.

Propanone is used as the solvent in this reaction.



(pr) = substance is dissolved in propanone

The student plans to record the time it takes for the solid formed to obscure a cross on a piece of paper below the conical flask, as shown.



To carry out this experiment, the following materials are available.

- $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}(\text{l})$
- $\text{NaI}(\text{s})$
- dry propanone, $\text{CH}_3\text{COCH}_3(\text{l})$
- usual laboratory apparatus

- (i) Calculate the masses of $\text{NaI}(\text{s})$ and $\text{CH}_3\text{COCH}_3(\text{l})$ that would be needed to make 150 cm^3 of 0.50 mol dm^{-3} $\text{NaI}(\text{pr})$. Assume 150 cm^3 of propanone are required. Give your answers to **one decimal place**.

The density of $\text{CH}_3\text{COCH}_3(\text{l})$ is 0.79 g cm^{-3} .

[A_r : Na, 23.0; I, 126.9]

mass of $\text{NaI}(\text{s}) = \dots\dots\dots\text{ g}$

mass of $\text{CH}_3\text{COCH}_3(\text{l}) = \dots\dots\dots\text{ g}$
[2]

(ii) Part of the table the student used to record data is given.

Complete the table with appropriate volumes that the student could have used in four further experiments.

volume of 0.50 mol dm^{-3} $\text{NaI}(\text{pr})/\text{cm}^3$	volume of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}(\text{l})$ $/\text{cm}^3$	volume of $\text{CH}_3\text{COCH}_3(\text{l})$ $/\text{cm}^3$	total volume $/\text{cm}^3$	time $/\text{s}$
10.0	2.0	30.0	42.0	

[2]

(iii) The student uses the same experimental set-up each time.

In this experiment, identify the dependent variable.

..... [1]

(iv) Write an expression to show how the student could calculate the rate of the reaction.

[1]

(v) Identify the major source of inaccuracy of measurement in this reaction.

Suggest an improvement to the experiment to make it more accurate.

inaccuracy

.....

improvement

.....

[2]

(d) The reaction between $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ and NaI proceeds via an $\text{S}_{\text{N}}2$ mechanism.

The student repeated the experiment in (c) using an isomer of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ that reacts via both $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ mechanisms.

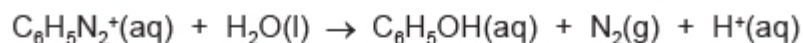
State and explain whether the student will be able to show that the rate of this reaction is proportional to the concentration of NaI .

[1]

[Total: 14]

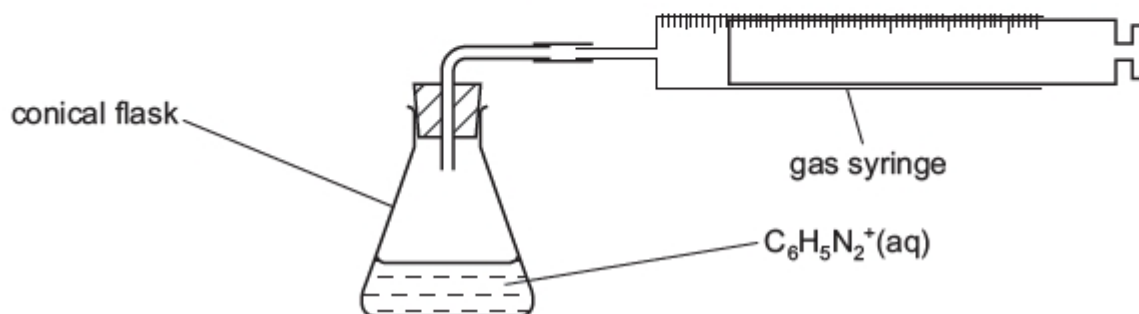
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2 At temperatures above 5°C , the benzenediazonium ion, $\text{C}_6\text{H}_5\text{N}_2^+$, reacts with water as shown.



A student investigates this reaction by measuring the volume of nitrogen gas produced at regular time intervals.

The diagram shows the experimental set-up used to investigate this reaction.



(a) The student finds that the reaction is very slow, so decides to investigate the reaction at 30°C .

Complete the diagram to show how the student could investigate this reaction at a constant 30°C . [2]

(b) The student prepared a solution of $\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})$ at 5°C . A 200.0 cm^3 sample of this solution was placed in a conical flask. The apparatus was allowed to equilibrate at 30°C . The gas syringe was then connected, a stop-clock was started and readings of time and gas volume were taken. When the decomposition of the $\text{C}_6\text{H}_5\text{N}_2^+$ ion was complete (as shown by no more gas production) the final volume of $\text{N}_2(\text{g})$ produced, V_{final} , was 72 cm^3 .

- (i) Show by calculation that when the stop-clock was started the concentration of $\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})$ was $0.0150\text{ mol dm}^{-3}$.

[The molar volume of gas under room conditions is 24.0 dm^3 .]

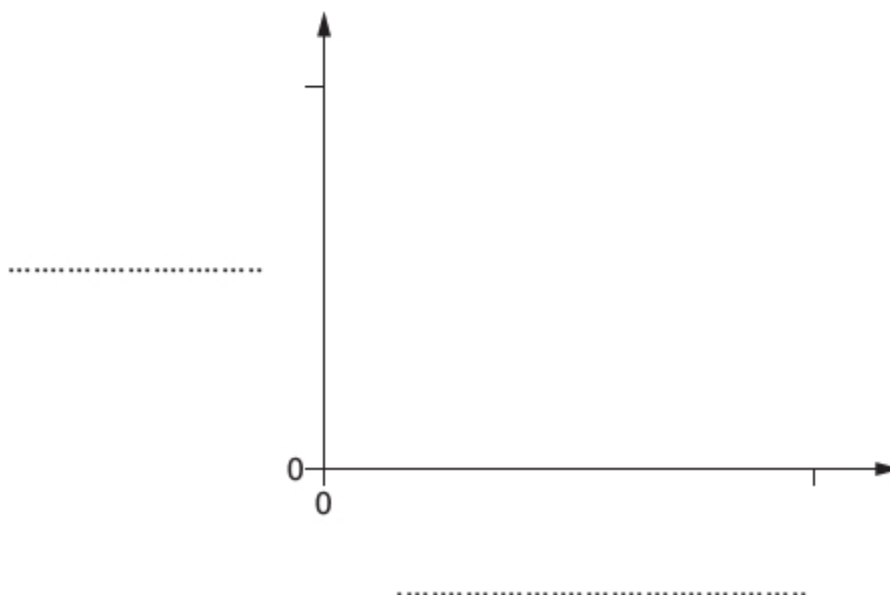
concentration of $\text{C}_6\text{H}_5\text{N}_2^+(\text{aq}) = \dots\dots\dots\text{ mol dm}^{-3}$ [2]

- (ii) The volume of nitrogen produced is proportional to the amount of $\text{C}_6\text{H}_5\text{N}_2^+$ that reacts. As $\text{C}_6\text{H}_5\text{N}_2^+$ reacts, its concentration in the solution falls.

Using the axes shown, sketch a graph to show the change in volume of $\text{N}_2(\text{g})$ produced with the change in concentration of $\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})$.

Label the axes $[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})]/\text{mol dm}^{-3}$ and volume of $\text{N}_2(\text{g})/\text{cm}^3$, putting the independent variable on the x-axis.

Include on the axes the maximum values for concentration and volume where the lines on the axes are shown.



[2]

(c) The results the student obtained are shown in the table.

To calculate the concentration of $\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})$ the student used the following equation.

$$[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})] = 0.0150 \times \left(1 - \frac{V}{V_{\text{final}}}\right)$$

V = volume of $\text{N}_2(\text{g})$ recorded at a specified time.

V_{final} = final volume of $\text{N}_2(\text{g})$ at complete decomposition of $\text{C}_6\text{H}_5\text{N}_2^+$.

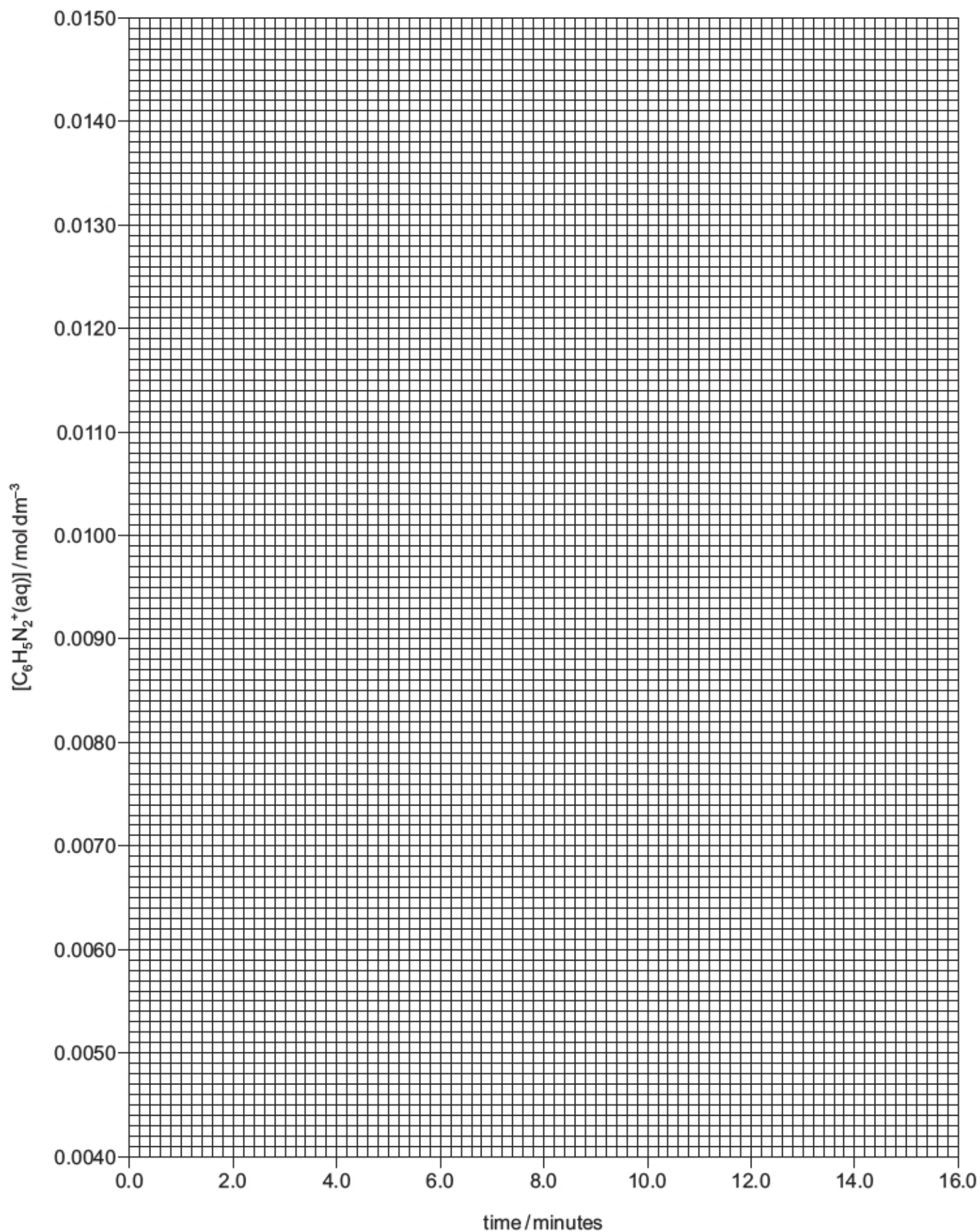
V_{final} is 72 cm^3 .

Complete columns **C** and **D** to **three** significant figures. You may use the space below for any working.

A	B	C	D
time / minutes	volume of $\text{N}_2(\text{g})$, V/cm^3	$\frac{V}{V_{\text{final}}}$	$[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})]/\text{mol dm}^{-3}$
0.0	0	0.000	0.0150
2.0	9	0.125	$0.0150 \times (1 - 0.125) = 0.0131$
4.0	17		
6.0	24		
8.0	30		
10.0	35		
12.0	40		
14.0	44		
16.0	48		

[2]

- (d) Plot a graph on the grid to show the relationship between $[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})]$ and time. Use a cross (x) to plot each data point. Draw a line of best fit.



[2]

- (e) Draw a tangent at time = 0.0 on your graph and use the tangent to determine the initial rate of reaction. State the units of the initial rate of reaction.

State the co-ordinates of both points you used in your calculation.

co-ordinates 1 co-ordinates 2

initial rate of reaction =

units =

[4]

- (f) Use your graph to complete the table and calculate the values of two half-lives. For the first half-life, concentrations have been chosen for you.

concentration 1	time 1	concentration 2	time 2	$t_{\frac{1}{2}}$
0.0120		0.0060		
.....				

[3]

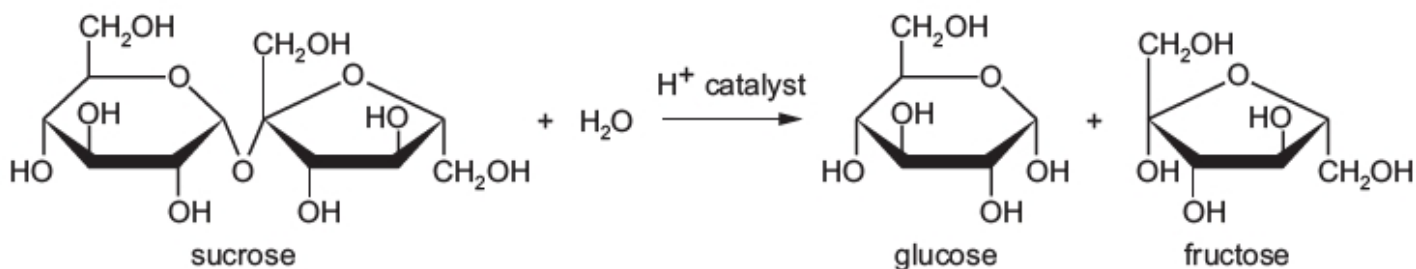
- (g) State and explain what the values of the two half-lives suggest about the order of reaction with respect to $[C_6H_5N_2^+(aq)]$.

.....

..... [1]

[Total: 18]

- 2 Sucrose, $C_{12}H_{22}O_{11}$, is a naturally occurring sugar found in sugarcane and many fruits. It can be hydrolysed in acidic solution to give glucose and fructose. All three molecules are chiral and will rotate the plane of polarised light. The degree of rotation is known as the **optical rotation**, α .



In the presence of excess water, the reaction can be considered to be first order with respect to sucrose concentration.

The progress of the reaction can be monitored using a polarimeter, which measures the optical rotation, α , of the solution. The more concentrated the solution, the greater the optical rotation of the solution.

The concentration of sucrose at time t can be represented as $(\alpha - \alpha_{\text{final}})$, where α_{final} is the optical rotation of the solution after 6 hours.

The mathematical relationship is given by the following equation.

$$\log_{10}(\alpha - \alpha_{\text{final}}) = A - \frac{kt}{2.30}$$

A is a constant.

k is the rate constant.

- (a) The experimentally determined values of optical rotation during the hydrolysis of sucrose at 298 K are recorded below.

Process the results to allow you to plot a graph of $\log_{10}(\alpha - \alpha_{\text{final}})$ against time, t .

Calculate $(\alpha - \alpha_{\text{final}})$ and record it to 1 decimal place.

Calculate $\log_{10}(\alpha - \alpha_{\text{final}})$ and record it to 2 decimal places.

time / s	optical rotation, α	$(\alpha - \alpha_{\text{final}})$	$\log_{10}(\alpha - \alpha_{\text{final}})$
0	39.9		
300	29.1		
600	21.3		
900	15.5		
1200	10.6		
1500	6.2		
1800	2.4		
2100	-0.3		
2400	-2.5		
2700	-4.5		

α_{final}	-12.0
-------------------------	-------

[2]

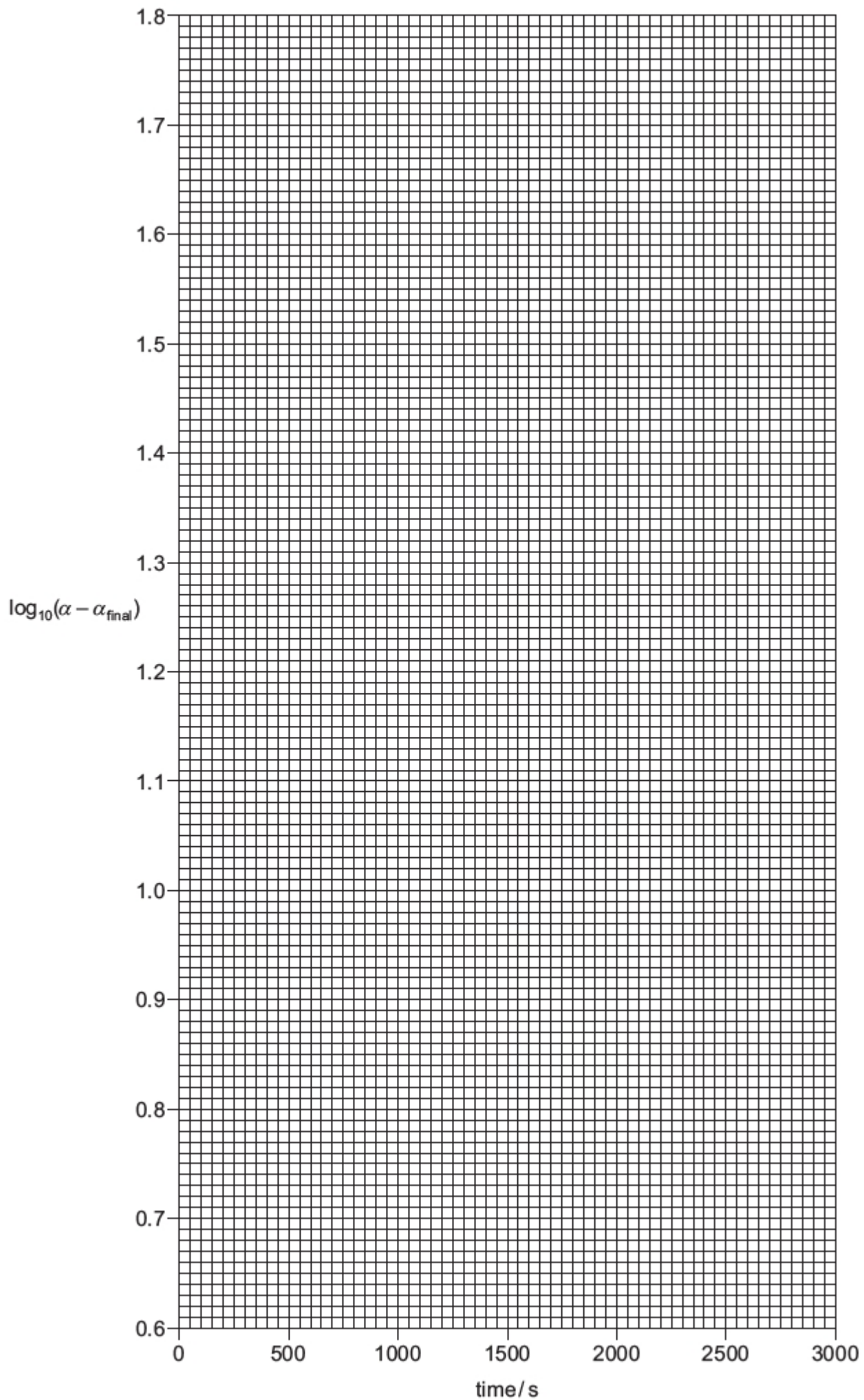
- (b) (i) Plot a graph on the grid on page 9 to show how $\log_{10}(\alpha - \alpha_{\text{final}})$ varies with time, t . Use a cross (x) to plot each data point. Draw the line of best fit.

[2]

- (ii) State and explain whether the results and your graph confirm the relationship $\log_{10}(\alpha - \alpha_{\text{final}}) = A - \frac{kt}{2.30}$.

.....

 [1]



- (c) (i) Determine the gradient of the graph.
 State the co-ordinates of both points you used for your calculation.
 Record the value of the gradient to **three significant figures**.

co-ordinates 1 co-ordinates 2

gradient = s⁻¹
 [2]

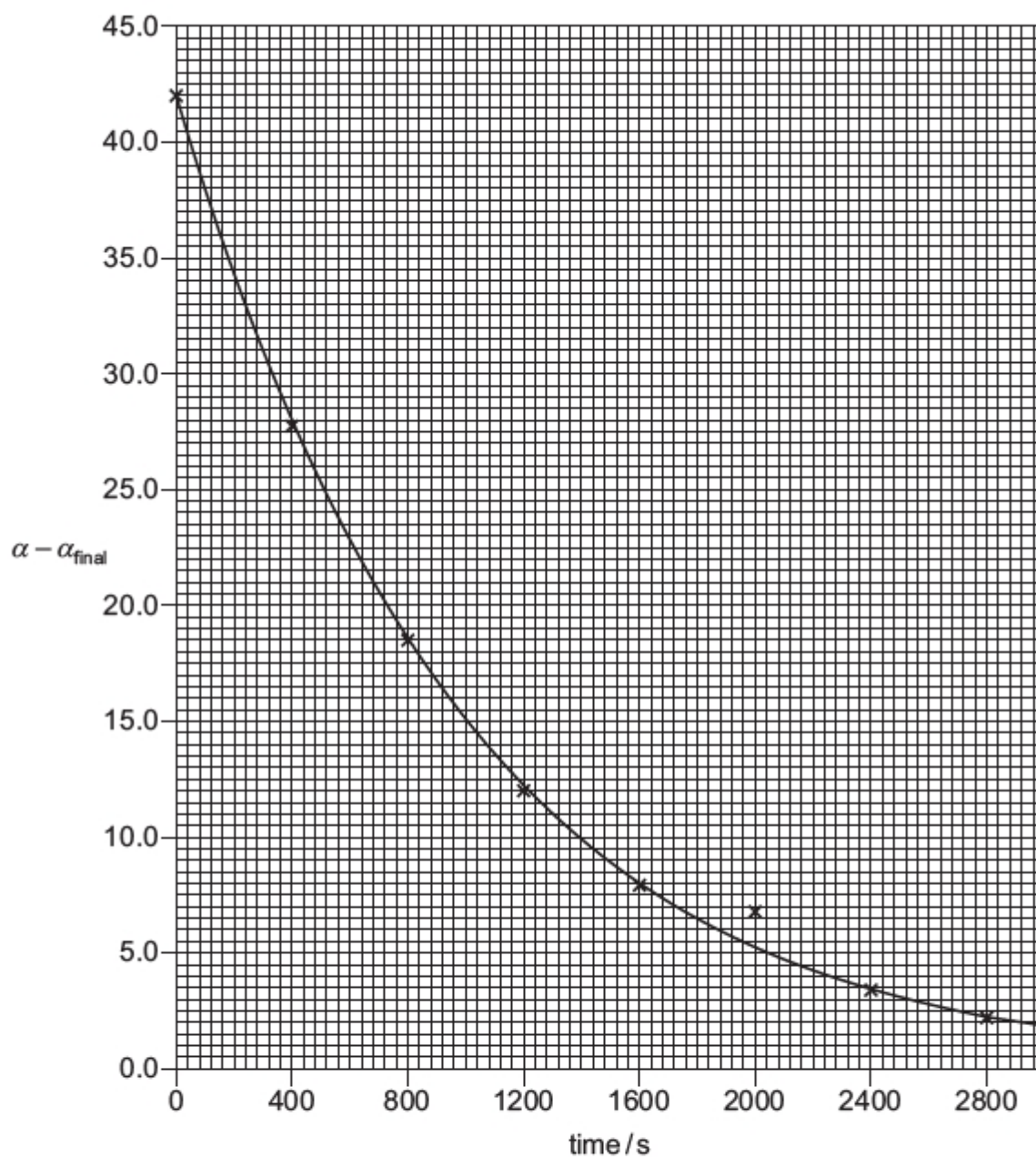
- (ii) Use the gradient value to calculate a value for k in the expression shown.

$$\log_{10}(\alpha - \alpha_{\text{final}}) = A - \frac{kt}{2.30}$$

[2]



- (d) The graph below shows the results obtained from a second hydrolysis of sucrose reaction performed at a different temperature.



- (i) The point at time = 2000 s is considered to be anomalous. Suggest what caused the anomaly.

.....

.....

..... [1]

- (ii) Use the graph to determine the half-life, $t_{1/2}$, of this reaction.
State the co-ordinates of both points you used in your calculation.

co-ordinates 1 co-ordinates 2

half-life = s [2]

- (iii) For a first-order reaction, the following relationship exists.

$$\text{half-life, } t_{1/2} = \frac{0.693}{k'}$$

Use this relationship and your answer to (ii) to determine k' , the rate constant for this second hydrolysis reaction.

If you have been unable to determine the half-life of the reaction in (ii), you may use the value $t_{1/2} = 500$ s, though this is not the correct answer.

$k' = \dots\dots\dots \text{ s}^{-1}$ [1]

- (iv) State whether the temperature of the second reaction was higher or lower than that of the first.

Explain your answer with reference to the answers you obtained in (c)(ii) and (d)(iii).

If you have been unable to calculate a value for k in (c)(ii), you may use the value $k = 8.00 \times 10^{-4}$, though this is not the correct answer.

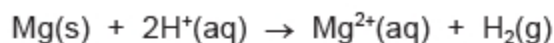
.....
.....
..... [1]

- (v) Would the value of the half-life change if the reaction were repeated with twice the initial concentration of sucrose? Give a reason for your answer.

.....
.....
..... [1]

[Total: 15]

- 2 Activation energy, E_A , is the minimum energy with which particles must collide so that a reaction occurs. The activation energy for the reaction of magnesium with aqueous hydrogen ions can be determined in the laboratory.



A magnesium strip is placed in dilute hydrochloric acid and the time taken (t), in seconds, for the magnesium to disappear is measured. The initial rate of reaction is calculated as $\frac{1}{\text{time}} \left(\frac{1}{t} \right)$.

If the experiment is repeated at several different temperatures then the following mathematical relationship can be used to calculate E_A .

$$\log_{10} \left(\frac{1}{t} \right) = \frac{-E_A}{0.0191} \times \left(\frac{1}{T} \right)$$

T is the temperature measured in K.

$\frac{1}{t}$ is the initial rate of reaction in s^{-1} .

A graph of $\log_{10} \left(\frac{1}{t} \right)$ against $\frac{1}{T}$ can be plotted.

Experimental procedure

1. 25 cm^3 of dilute hydrochloric acid is added to a boiling tube.
2. The boiling tube is placed in a water bath until the dilute hydrochloric acid reaches a constant temperature. This temperature is recorded.
3. A magnesium strip of mass 0.10 g is added to the boiling tube, the mixture stirred and the time taken for the magnesium to disappear is recorded.
4. The temperature of the water bath is changed and the experiment is repeated.



- (a) The results of this experiment, carried out at different temperatures, are recorded in the table below.

Process the results to calculate the reciprocal of temperature $\left(\frac{1}{T}\right)$ and $\log_{10}\left(\frac{1}{t}\right)$. The first value of $\frac{1}{T}$ has been done for you.

Record $\frac{1}{T}$ in **standard form** to **three** significant figures.

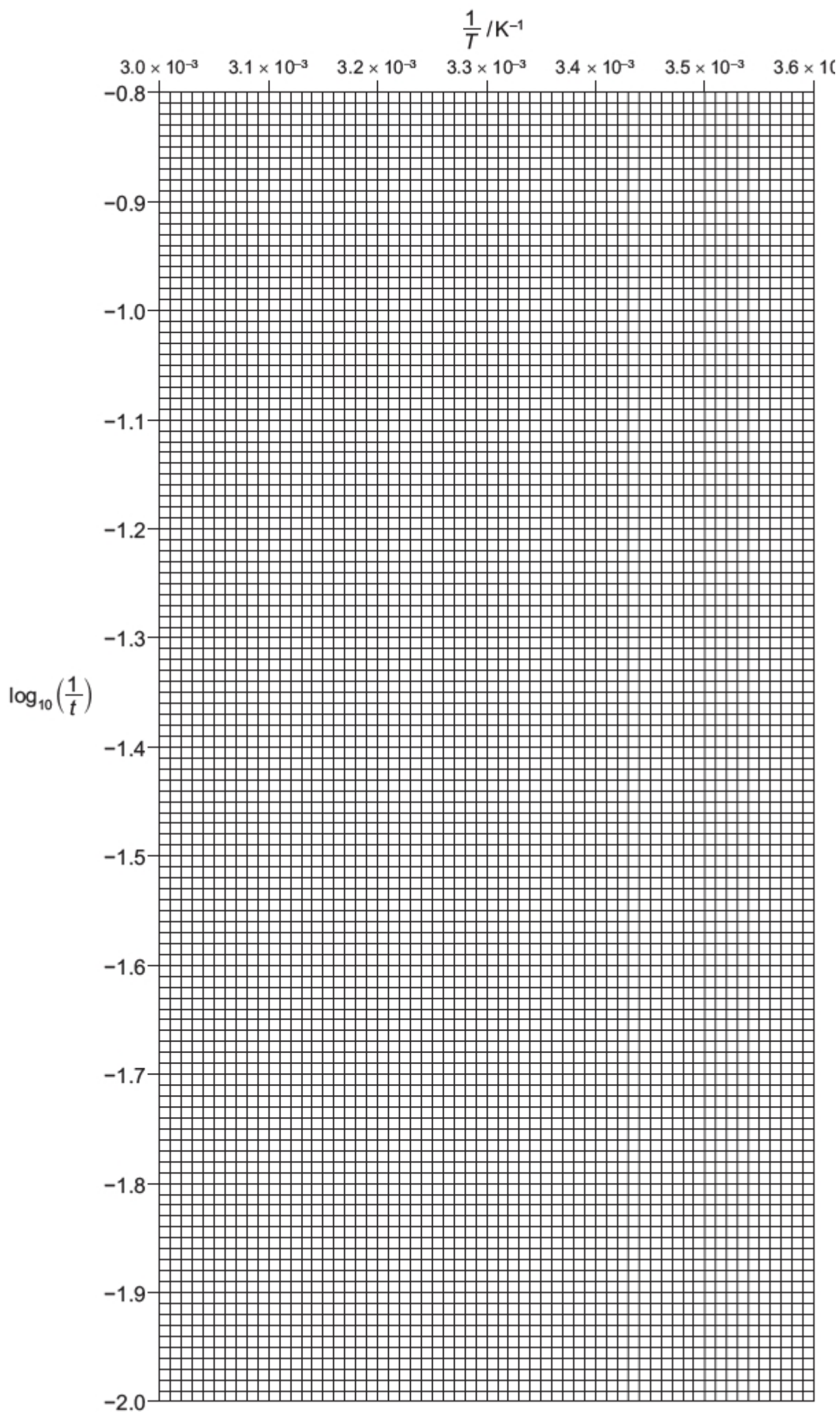
Record $\log_{10}\left(\frac{1}{t}\right)$ to **two** decimal places. You should expect $\log_{10}\left(\frac{1}{t}\right)$ to be negative.

temperature / $^{\circ}\text{C}$	time, t/s	temperature, T/K	$\frac{1}{T}/\text{K}^{-1}$	$\frac{1}{t}/\text{s}^{-1}$	$\log_{10}\left(\frac{1}{t}\right)$
15	83	288	3.47×10^{-3}	1.20×10^{-2}	
20	58	293		1.72×10^{-2}	
27	36	300		2.78×10^{-2}	
30	28	303		3.57×10^{-2}	
34	18	307		5.56×10^{-2}	
38	19	311		5.26×10^{-2}	
40	15	313		6.67×10^{-2}	
43	12	316		8.33×10^{-2}	
48	9	321		1.11×10^{-1}	
55	8	328		1.25×10^{-1}	

[3]

- (b) Plot a graph on the grid on page 7 to show the relationship between $\log_{10}\left(\frac{1}{t}\right)$ and $\frac{1}{T}$.
Use a cross (x) to plot each data point.
Draw a line of best fit.

[2]



- (c) On your graph, circle the two points you consider to be the most anomalous. Label each one with a different letter. Explain what may have caused each of the anomalies you have identified, giving a different reason each time.
Make it clear in your answer to which point you are referring.

.....

.....

.....

..... [2]

- (d) (i) Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation.
Record the value of the gradient to **three** significant figures.

co-ordinates 1

co-ordinates 2

gradient = [2]

- (ii) Use your gradient from (i) and the mathematical relationship on page 5 to calculate the activation energy, E_A , in kJ mol^{-1} .
Include a sign in your answer.

$E_A = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

- (e) State whether you consider the results to be reliable. Explain your answer.

.....

.....

..... [1]

- (f)** Student X commented that data collected at higher temperatures in the experiment may be less accurate than that collected at lower temperatures.

State whether student X is correct. Explain why.

.....

.....

..... [1]

- (g)** If the magnesium strip is not stirred it floats to the surface of the hydrochloric acid.

State how this will affect the reaction time. Explain why.

.....

.....

..... [1]

- (h)** The experiment in **(a)** is repeated using dilute ethanoic acid instead of dilute hydrochloric acid. The concentration of both acids is equal. The same temperatures are used as in **(a)**.

State the effect this change in acid will have on the initial rate values. Give a reason for this.

.....

.....

..... [1]

[Total: 15]

1 Propanone, CH_3COCH_3 , is an organic liquid which is soluble in water.

Aqueous propanone reacts with aqueous iodine. The reaction is catalysed by $\text{H}^+(\text{aq})$ ions.



The order of reaction with respect to iodine can be determined experimentally.

An experiment is carried out using the following solutions.

- solution **A**, 25.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ CH}_3\text{COCH}_3(\text{aq})$
- solution **B**, 25.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4(\text{aq})$
- solution **C**, 50.0 cm^3 of $0.200 \text{ mol dm}^{-3} \text{ I}_2(\text{aq})$

The solutions are mixed to start the reaction. At certain time intervals, a 10.0 cm^3 portion of the mixture is withdrawn and transferred to a conical flask containing excess sodium hydrogencarbonate, $\text{NaHCO}_3(\text{aq})$. This prevents any further significant reaction taking place by removing the $\text{H}^+(\text{aq})$ ions. The concentration of unreacted $\text{I}_2(\text{aq})$ in each 10.0 cm^3 portion of the mixture can then be determined by titration with aqueous thiosulfate ions, $\text{S}_2\text{O}_3^{2-}(\text{aq})$.

- (a) State the size and type of apparatus needed to prepare a suitable volume of a standard solution of $1.00 \text{ mol dm}^{-3} \text{ CH}_3\text{COCH}_3(\text{aq})$ from liquid propanone.

Calculate the mass of propanone needed to prepare this standard solution.

[A_r: C, 12.0; H, 1.0; O, 16.0]

apparatus

mass of propanone g
[3]

(b) Solutions **A**, **B** and **C** need to be added in a specific order and the clock started as the third solution is added.

(i) Suggest the best order of adding the solutions.

1

2

3

[1]

(ii) Explain your choice.

.....

..... [1]

(c) Each 10.0 cm^3 portion of mixture removed from the main reaction is added to a separate solution of sodium hydrogencarbonate, $\text{NaHCO}_3(\text{aq})$, in a conical flask to remove $\text{H}^+(\text{aq})$ ions.

(i) Which piece of apparatus should be used to transfer each 10.0 cm^3 portion of mixture to the conical flask?

..... [1]

(ii) Suggest **two** reasons why $\text{NaHCO}_3(\text{aq})$ is preferred to $\text{NaOH}(\text{aq})$ as the reagent used to remove $\text{H}^+(\text{aq})$ ions.

reason 1

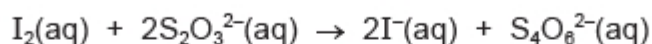
.....

reason 2

.....

[2]

- (d) The unreacted iodine in each 10.0 cm^3 portion of the mixture is titrated against 0.100 mol dm^{-3} aqueous thiosulfate ions, $\text{S}_2\text{O}_3^{2-}(\text{aq})$, to determine the concentration of $\text{I}_2(\text{aq})$ in the mixture at the time that the 10.0 cm^3 portion was withdrawn.



- (i) A 10.0 cm^3 portion of mixture is removed at time = 0. This is before any of the 0.200 mol dm^{-3} $\text{I}_2(\text{aq})$ had reacted.

Calculate the volume of 0.100 mol dm^{-3} $\text{S}_2\text{O}_3^{2-}(\text{aq})$ needed to react with the iodine present in this 10.0 cm^3 portion of mixture.

volume 0.100 mol dm^{-3} $\text{S}_2\text{O}_3^{2-}(\text{aq})$ = cm^3 [3]

- (ii) Suggest the name of a suitable indicator to use in the titration and state its colour change.

indicator

colour change

[2]

- (e) State **two** variables which must be recorded in this experiment.

For each variable, state the units.

variable 1 units

variable 2 units

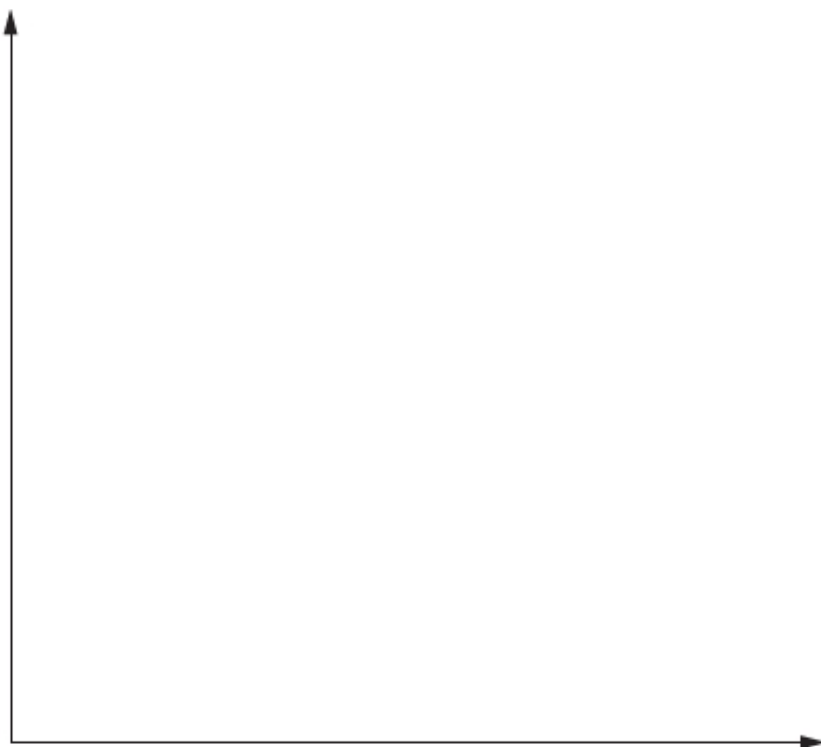
[2]

- (f) State **one** other variable which must be controlled in this experiment.

..... [1]

(g) The order of reaction with respect to iodine is expected to be first order.

(i) Use the axes below to draw a sketch graph of how the concentration of iodine changes during the experiment. Label both axes.



[2]

(ii) How could the graph be used to prove that the order of reaction with respect to iodine is first order?

.....

.....

..... [1]

(h) A student suggested that the temperature at which the experiment was carried out would affect the order of reaction with respect to iodine.

State if the student was correct and explain your answer.

.....

..... [1]

[Total: 20]

- 2 In aqueous solution, glucose can be slowly hydrolysed. The reaction appears to be first-order with respect to the glucose. As the hydrolysis proceeds, samples of the glucose solution can be analysed at regular intervals and the concentrations recorded.
If the reaction is first-order, the following equation can be used to verify this.

$$\log_{10} a - \log_{10} (a-x) = kt$$

where a is the initial concentration of glucose, x is the decrease in the concentration of the glucose, $a-x$ is the glucose concentration at any time t and k is a constant.

A plot of $\log_{10}(a-x)$ against time will be linear for a first-order reaction and the slope will be equal to $-k$.

- (a) The experimentally determined values of such a hydrolysis experiment carried out at 298 K are recorded below.

You should use a value of $1.000 \text{ mol dm}^{-3}$ for a .

Process the results in the table to enable you to plot a graph of $\log_{10}(a-x)$ against time t .

Record these values to **three significant figures** in the additional columns of the table.

Label the columns you use. For each column you use, include units where appropriate and an expression to show how your values are calculated.

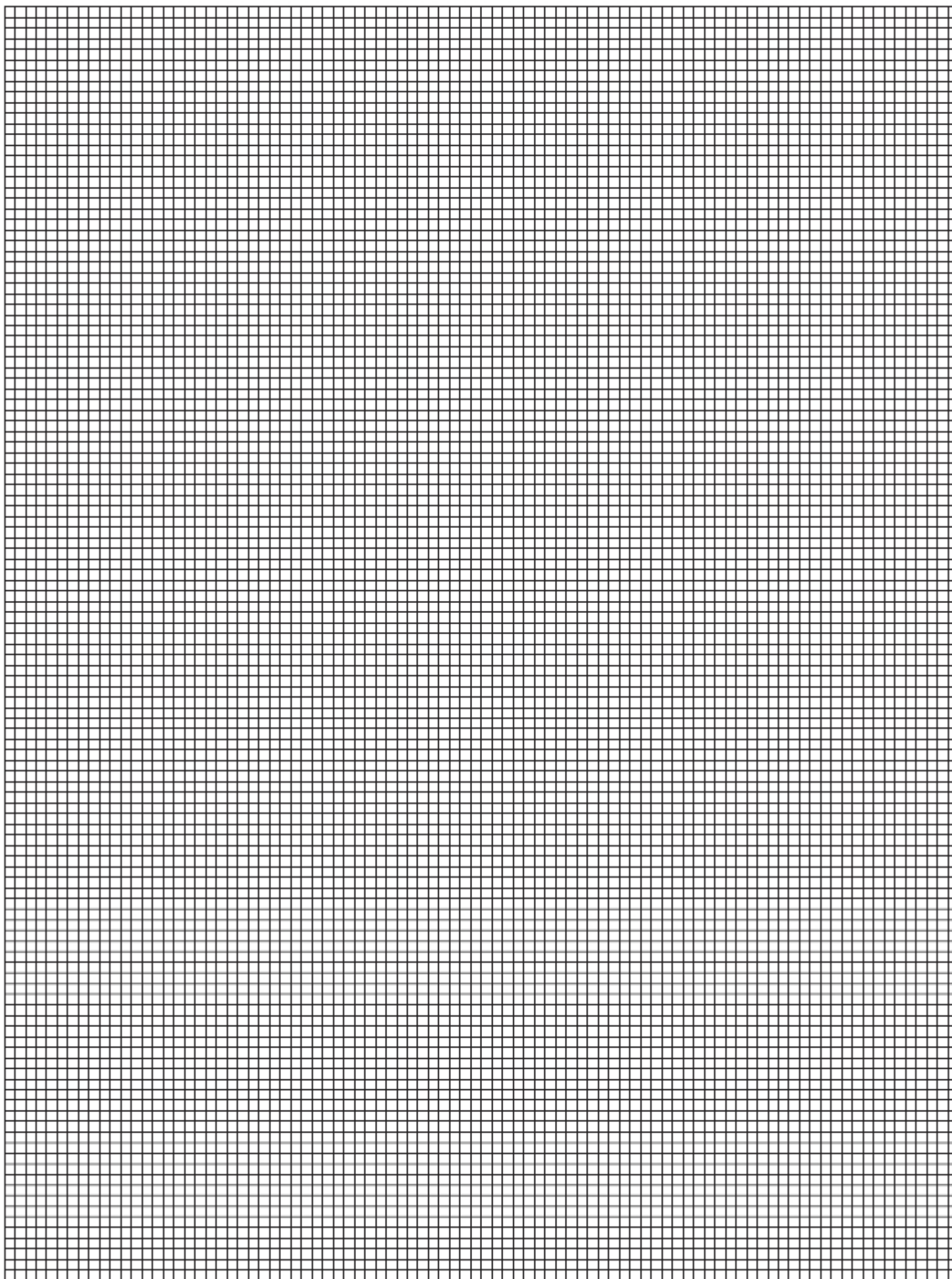
You may use the column headings A to D in these expressions (e.g. A-B).

A	B	C	D
time / min	decrease in the glucose concentration / mol dm^{-3}		
0	0.000		
30	0.101		
60	0.193		
100	0.259		
130	0.370		
180	0.469		
210	0.551		
240	0.573		
270	0.617		
300	0.655		

[2]



- (b) Present the data calculated in (a) in graphical form. Draw the line of best fit. In plotting this graph, it is necessary to show an origin for both axes. Remember that the values of $\log_{10}(a-x)$ are negative.



- (c) Circle and label on the graph in (b) any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous clearly indicating which point(s) you are describing.

.....

.....

.....

..... [3]

- (d) Comment on the reliability of the data provided in (a).

.....

.....

..... [1]

- (e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the intercepts were used in the calculation of the slope.
Record the value of the slope to **three significant figures** with appropriate units.

[3]

- (f) Do the results and your graph confirm the relationship $\log_{10} a - \log_{10} (a-x) = kt$?
Explain your answer.

[1]

- (g) On your graph, draw another line to show how an increase in temperature would affect your results.

[2]

[Total: 15]

- 2 Chemical reactions occur more rapidly as the temperature of the reaction mixture increases. The mathematical relationship that summarises this is

$$\log_{10} (\text{rate of reaction}) = \frac{-E_A}{19T}$$

where E_A is the **activation energy** of the reaction and T is the **absolute temperature** in Kelvin and the **rate of reaction** can be taken as the reciprocal of the time taken in seconds (1/time).

An experiment was carried out to investigate this relationship using dilute hydrochloric acid and aqueous sodium thiosulfate.

- 20 cm³ of dilute hydrochloric acid was placed in a boiling tube contained in a water bath.
- 20 cm³ of aqueous sodium thiosulfate was added to the dilute hydrochloric acid, while stirring and a stopwatch started.
- The temperature of the water bath was recorded.
- After a period of time the liquid became cloudy (opaque) due to the formation of a precipitate of sulfur.
- As soon as this cloudiness (opacity) appeared the time was recorded.
- The temperature of the water bath was raised and the whole experiment repeated.

- (a) The results of several such experiments are recorded below.

Process the results in the table to calculate $\log_{10} (\text{rate of reaction})$, the reciprocal of the absolute temperature (1/T) and the 'rate of reaction' (1/time). You should expect the values of $\log_{10} (\text{rate of reaction})$ to be negative.

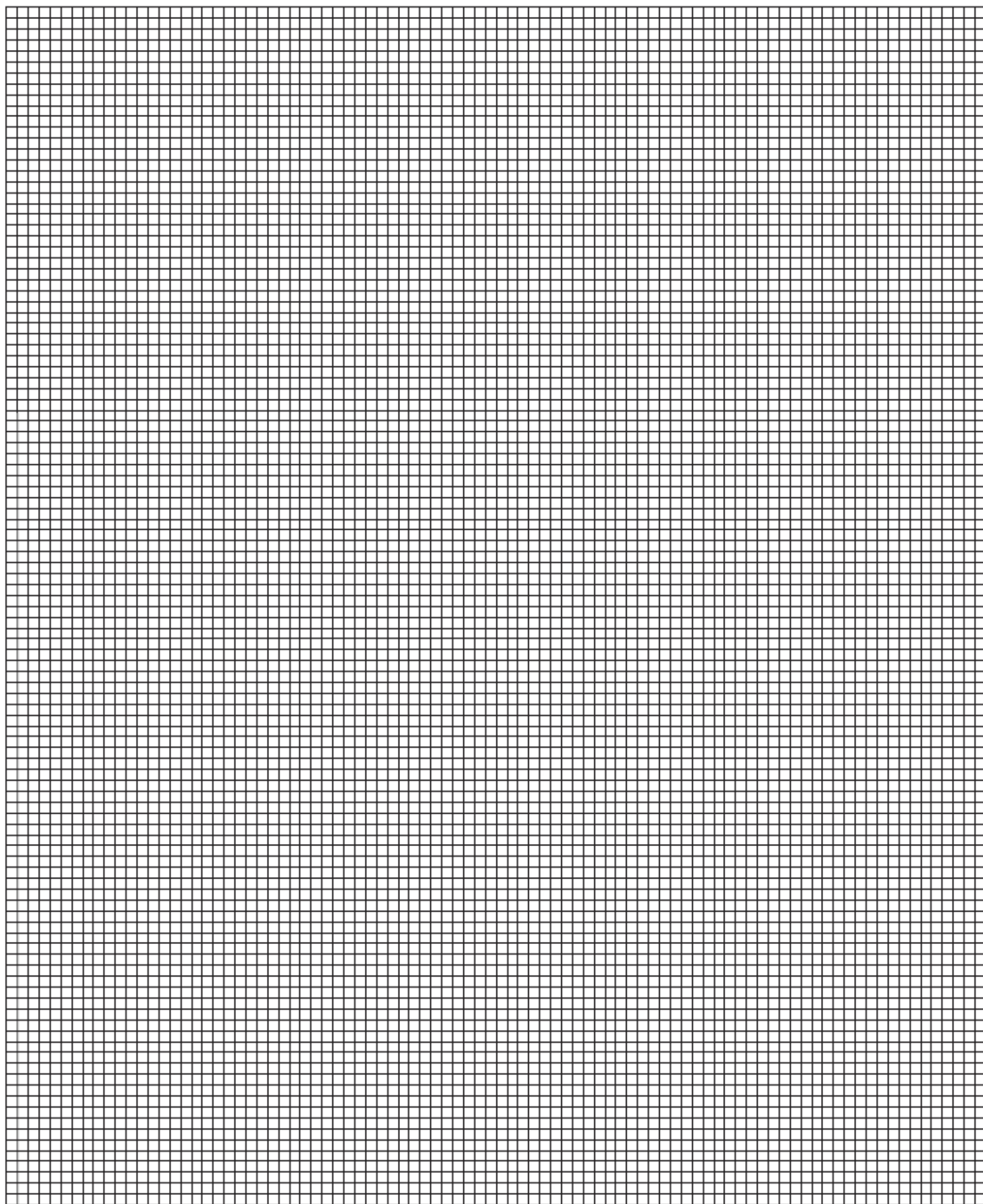
Record these values to **three significant figures** in the additional columns of the table.

Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to F for these expressions (e.g. A–B). [3]

A	B	C	D	E	F
temperature / °C	absolute temperature / K	time / s			
20.0	293	60.3			
30.0	303	46.8			
40.0	313	41.6			
45.0	318	31.6			
50.0	323	28.8			
55.0	328	25.1			
60.0	333	21.0			
65.0	338	20.4			
70.0	343	18.1			
80.0	353	15.1			

- (b) Plot a graph to show the relationship between $\log_{10}$ (rate of reaction) and the reciprocal of the absolute temperature. You are reminded that the values for $\log_{10}$ (rate of reaction) are negative.
Draw the line of best fit.



[3]

- (c) Circle and label on the graph any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous, clearly stating which point you are describing.

[3]

- (d) Comment on whether the results obtained can be considered as reliable.

[1]

- (e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the values from the intercepts were used in the calculation of the slope.

[2]

- (f) Using the value of the slope of your graph calculated in (f) calculate a value for the activation energy, E_A . Correct use of the equation will produce an answer in kJ mol^{-1} .

[1]



- (g) By considering the movement of particles in the reaction explain why the rate of reaction increases with increasing temperature.

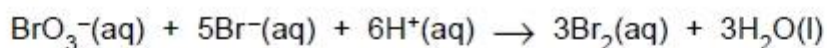
[2]

[Total: 15]

Q# 90/ ALvl Chemistry/2004/w/TZ 1/ Paper 5/Q# 1/www.SmashingScience.org :o)

EXPERIMENT Required, no longer needed from 2007 onwards.

- 1 In the presence of hydrogen ions, H^+ , bromate(V) ions, BrO_3^- , oxidise bromide ions, Br^- , to bromine, Br_2 .



The reaction is relatively slow and can be followed by adding aqueous phenol and the indicator methyl orange to the reaction mixture.

As bromine is formed it reacts rapidly with the phenol present until the latter is used up. The free bromine now in solution bleaches the methyl orange indicator. The reaction is timed from the mixing of the solutions until the colour of the indicator is lost.

You are to investigate how the rate of reaction depends on the concentrations of bromate(V), bromide and hydrogen ions.

FB 1 is aqueous phenol containing methyl orange indicator.

FB 2 is aqueous potassium bromide, KBr .

FB 3 is aqueous potassium bromate(V), KBrO_3 .

FB 4 is 0.50 mol dm^{-3} sulphuric acid, H_2SO_4 .

You will also require a supply of distilled water.

- (a) Fill the burette labelled **FB 1** with the phenol/indicator solution, **FB 1**, and the burette labelled **FB 4** with the sulphuric acid, **FB 4**.

Experiment 1

Run 20 cm^3 of **FB 1** from the burette into the conical flask.

Use measuring cylinder **A** to add 50 cm^3 of **FB 2** to the flask.

From the second burette, run into the flask 20 cm^3 of **FB 4**.

Use measuring cylinder **B** to measure 50 cm^3 of **FB 3**.

Pour the **FB 3** from the measuring cylinder into the flask and at the same time start the stop-clock or note the time on a clock.

Swirl the flask to ensure a uniform solution and place the flask on the white tile. Stop the clock or note the time when the colour of the indicator just disappears to leave a colourless solution. Record the time, to the nearest second, in Table 1.1 at the top of page 3.

Experiment 2

Empty and rinse the flask used in *Experiment 1*. Shake out as much of the rinse water as possible or dry the flask using a paper towel.

Repeat the experiment using the volumes of solution shown in Table 1.1 for *Experiment 2*.

It is important that measuring cylinder **A** is only used for potassium bromide solution, **FB 2**, and water, and measuring cylinder **B** only for potassium bromate solution, **FB 3**.

Experiments 3 and 4

Repeat the experiment using the volumes of solution shown in Table 1.1 for each of these experiments and complete the table.

Table 1.1

Expt	in flask				in measuring cylinder	time /s	rate (1000/time) /s ⁻¹ x 10 ³
	volume of FB 1 (phenol) /cm ³	volume of FB 2 (KBr) /cm ³	volume of FB 4 (H ₂ SO ₄) /cm ³	volume of water /cm ³	volume of FB 3 (KBrO ₃) /cm ³		
1	20	50	20	0	50		
2	20	50	20	10	40		
3	20	30	20	20	50		
4	20	30	40	0	50		

[1] + [10]

(b) Why is the total volume used in each experiment kept constant?

.....[1]

Processing of results

- (c) How is the rate of reaction affected by changing the concentration of BrO_3^- ion?

Use, **in calculations**, the experimental data from *Experiment 1* and *Experiment 2* to suggest the order of reaction with respect to the bromate(V) ion, BrO_3^- .

[3]

- (d) How is the rate of reaction affected by changing the concentration of Br^- ions?

Use, **in calculations**, the experimental data from *Experiment 1* and *Experiment 3* to suggest the order of reaction with respect to the bromide ion, Br^- .

[3]

- (e) How is the rate of reaction affected by changing the concentration of H^+ ions?

Use, **in calculations**, selected experimental data from a *pair of experiments* to suggest the order of reaction with respect to the hydrogen ion, H^+ .

Which *pair of experiments* have you selected?

.....

Calculations

[2]

Q# 79/ ALVl Chemistry/2022/w/TZ 1/ Paper 5/Q# 3/www.SmashingScience.org :o)

3(a)(i)	description of a (clock) method to measure the time taken for a particular amount of product (Br_2) to be produced	1
3(a)(ii)	X = 1, Y = 1 and Z = 2 all 3 correct = ✓✓ 2 correct = ✓ 1 or 0 correct = ×	2
3(b)	burette	1
3(c)	(changing) the temperature (of the reagents) will affect the rate of reaction (so it must be kept constant)	1
3(d)	M1: measure (a volume of) 1 mol dm^{-3} sulfuric acid using a <u>burette</u> into a <u>volumetric flask</u> AND make up to the (calibration) mark with <u>distilled water</u>	1
	M2: $(0.15 \times a) \text{ cm}^3$ of 1 mol dm^{-3} sulfuric acid is measured to make up a cm^3 (of the diluted solution)	1

Q# 80/ ALVl Chemistry/2022/s/TZ 1/ Paper 5/Q# 2/www.SmashingScience.org :o)

2(a)(i)	thermostatically controlled water bath	1																														
2(a)(ii)	flammable substance(s) are used (in the experiment)	1																														
2(b)(i)	(50 cm^3) burette	1																														
2(b)(ii)	10(.00) cm^3 (volumetric) pipette	1																														
2(c)	reduces the reaction rate (of hydrolysis reaction) OR quenches the reaction	1																														
2(d)	volume of sodium hydroxide (solution used in titration)	1																														
2(e)(i)	<table border="1"> <thead> <tr> <th>time / s</th><th>titre, V_t / cm^3</th><th>$V_{\text{final}} - V_t / \text{cm}^3$</th></tr> </thead> <tbody> <tr><td>60</td><td>1.25</td><td>46.00</td></tr> <tr><td>300</td><td>7.75</td><td>39.50</td></tr> <tr><td>600</td><td>17.75</td><td>29.50</td></tr> <tr><td>900</td><td>20.00</td><td>27.25</td></tr> <tr><td>1200</td><td>24.25</td><td>23.00</td></tr> <tr><td>1500</td><td>28.40</td><td>18.85</td></tr> <tr><td>1800</td><td>31.15</td><td>16.10</td></tr> <tr><td>2700</td><td>38.00</td><td>9.25</td></tr> <tr><td>Final</td><td>47.25</td><td>(0.00)</td></tr> </tbody> </table>	time / s	titre, V_t / cm^3	$V_{\text{final}} - V_t / \text{cm}^3$	60	1.25	46.00	300	7.75	39.50	600	17.75	29.50	900	20.00	27.25	1200	24.25	23.00	1500	28.40	18.85	1800	31.15	16.10	2700	38.00	9.25	Final	47.25	(0.00)	1
time / s	titre, V_t / cm^3	$V_{\text{final}} - V_t / \text{cm}^3$																														
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1800	31.15	16.10																														
2700	38.00	9.25																														
Final	47.25	(0.00)																														
2(e)(ii)	concentration of the 2-bromo-2-methylpropane	1																														
2(e)(iii)	M1 all points plotted correctly M2 smooth curve of best fit line drawn passing close to all points except anomaly	2																														
2(e)(iv)	M1 selects the point most anomalous to the plotted line of best fit (point at 600, 29.5 expected) M2 reaction was not effectively quenched	2																														
2(e)(v)	M1 correctly placed construction lines shown on the graph to determine at least one half-life correctly OR both co-ordinates from line of best fit correctly recorded in the form (x,y) for either first $t_{1/2}$ OR second $t_{1/2}$ M2 two sets of co-ordinates from line of best fit correctly recorded for first $t_{1/2}$ AND second $t_{1/2}$ in the form (x,y) M3 two half-lives correctly calculated from listed co-ordinates (expected value: 1159 s)	3																														
2(e)(vi)	first order AND half-lives are constant (within experimental error)	1																														

2(a)	M1 Addition of solid and acid must not lead to initial escape of gas from sealed system or produce excess volume measurement leading to a false volume reading e.g. Adding acid to solid already in the flask or vice versa. M2 Allow any leakproof apparatus capable of delivering a sample of gas into one collection vessel over water. M3 A vertical inverted measuring cylinder or burette filled with water positioned to collect the gas (via delivery tube).	3													
2(b)(i)	<table><tr><td>$V_{\text{final}} - V_i / \text{cm}^3$</td></tr><tr><td>93</td></tr><tr><td>71</td></tr><tr><td>56</td></tr><tr><td>43</td></tr><tr><td>32</td></tr><tr><td>25</td></tr><tr><td>18</td></tr><tr><td>15</td></tr><tr><td>14</td></tr><tr><td>6</td></tr><tr><td>3</td></tr><tr><td>0</td></tr></table> 93, 71, 56, 43, 32, 25, 18, 15, 14, 6, 3, 0	$V_{\text{final}} - V_i / \text{cm}^3$	93	71	56	43	32	25	18	15	14	6	3	0	1
$V_{\text{final}} - V_i / \text{cm}^3$															
93															
71															
56															
43															
32															
25															
18															
15															
14															
6															
3															
0															
2(b)(ii)	M1 Selects and labels appropriate linear scales for axes AND All points plotted correctly AND covering at least half of the grid for each axis. M2 Smooth curve of best fit line drawn going through most points.	2													
2(b)(iii)	The point at 240 s.	1													
2(b)(iv)	The volume of gas may have been read before 240 .	1													
2(b)(v)	M1 Suitable construction lines shown on the graph. M2: Two half-lives read correctly from graph AND mean half-life calculated using values read correctly from graph. (Likely to be approx. 78 s)	2													
2(b)(vi)	$= \frac{0.693}{\text{average } t_{1/2} \text{ calculated in 2(b)(v)}}$	1													
2(c)	The value of k would increase AND as $t_{1/2}$ would decrease.	1													
2(d)(i)	M1 Table complete with four different sets of values that would produce different concentrations, total volume = 50 cm³ AND All volumes of 2.0 mol dm⁻³ acid must be 10 cm³ or greater (to ensure an excess). M2 All concentrations correctly calculated.	2													
2(d)(ii)	time (taken for fizzing to stop)	1													
2(d)(iii)	The experiment should be repeated to identify / eliminate anomalies.	1													



GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- ☐ the specific content of the mark scheme or the generic level descriptors for the question
- ☐ the specific skills defined in the mark scheme or in the generic level descriptors for the question
- ☐ the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always whole marks (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded positively:

- ☐ marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- ☐ marks are awarded when candidates clearly demonstrate what they know and can do
- ☐ marks are not deducted for errors
- ☐ marks are not deducted for omissions
- ☐ answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

1(a)(i)	M1 moles needed $0.100 \div 250 / 1000 = 0.025(0)$ mol M2 $M1 \div 166.0 = 4.15$ g	2
1(a)(ii)	(Re)weigh the empty weighing boat (and the difference should be 4.15 g)	1
1(a)(iii)	M1 (pour using a funnel and) rinse the beaker with (distilled) water M2 add (distilled) water dropwise near the mark	2
1(b)	the solution in the burette is at the expected concentration	1
1(c)	12.50 (cm ³)	1
1(d)(i)	step 4	1
1(d)(ii)	the recorded times are repeatable / the recorded times can be duplicated / the repeated times are close to one another	1
1(d)(iii)	0.5(00)%	1
1(d)(iv)	acid is in excess	1
1(d)(v)	M1 independent: (relative) concentration of KI / (relative) concentration of I ⁻ M2 dependent: time (taken)	2

1(e)(i)	<table><tr><th>v / cm^3</th><th>$\log v$</th><th>t_{sv} / s</th><th>$(1 / t_{sv}) / \text{s}^{-1}$</th><th>$\log(1 / t_{sv})$</th></tr><tr><td>5.00</td><td>0.699</td><td>219</td><td>0.00457</td><td>-2.34</td></tr><tr><td>10.00</td><td>1.00</td><td>113</td><td>0.00885</td><td>-2.05</td></tr><tr><td>12.50</td><td>1.10</td><td>100</td><td>0.0100</td><td>-2.00</td></tr><tr><td>15.00</td><td>1.18</td><td>76.5</td><td>0.0131</td><td>-1.88</td></tr><tr><td>20.00</td><td>1.30</td><td>59.0</td><td>0.0169</td><td>-1.77</td></tr><tr><td>25.00</td><td>1.40</td><td>48.0</td><td>0.0208</td><td>-1.68</td></tr></table>	v / cm^3	$\log v$	t_{sv} / s	$(1 / t_{sv}) / \text{s}^{-1}$	$\log(1 / t_{sv})$	5.00	0.699	219	0.00457	-2.34	10.00	1.00	113	0.00885	-2.05	12.50	1.10	100	0.0100	-2.00	15.00	1.18	76.5	0.0131	-1.88	20.00	1.30	59.0	0.0169	-1.77	25.00	1.40	48.0	0.0208	-1.68	2
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	25.00	1.40	48.0	0.0208	-1.68																																
M1 column 3 and column 6 mathematically correct																																					
M2 column 3 and column 6 to 3 sf																																					

1(e)(ii)	M1 points plotted M2 line of best fit	2
1(e)(iii)	M1 correct co-ordinates M2 correct gradient (to 3 sf) M3 first order	3

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1(a)(i)	To prevent reaction with water/hydrolysis (if wet)	1
1(a)(ii)	M1 solid / ppt NaBr forms M2 Equilibrium (position) lies (well) to the right / equilibrium position shifts to RHS	2
1(b)	M1 No naked flames AND (highly) flammable M2 Perform experiment in fume cupboard AND irritant to respiratory system / may cause dizziness / drowsiness	2
1(c)(i)	mass of NaI = $0.50 \times \frac{150}{1000} \times 149.9 = 11.2 \text{ g}$ mass of propanone = $150 \times 0.79 = 118.5 \text{ g}$	2
1(c)(ii)	M1 volume of NaI varied M2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ volume (2.0 cm^3) AND total volume constant at 42.0 cm^3 AND table is complete	2
1(c)(iii)	dependent variable = time	1
1(c)(iv)	rate = $1 / \text{time}$ or $1 / t$	1
1(c)(v)	M1 (Recording / determining) the time when opaque / cross disappears M2 dilute the solution (to give a longer time)	2
1(d)	No and because rate of $\text{S}_{\text{N}}1$ is only dependent on (concentration) of the organic compound	1

Q# 84/ ALvl Chemistry/2018/s/TZ 1/ Paper 5/Q# 2/www.SmashingScience.org :o)

2(a)	Water bath/beaker of water containing thermometer around flask	1
	Controlled heat source or heater/temperature regulator	1
2(b)(i)	Moles $\text{N}_2 = 72 / 24\,000 = 0.003 \text{ moles}$ ($1 \text{ mol } \text{C}_6\text{H}_5\text{N}_2^+\text{Cl}^- \rightarrow 1 \text{ mol } \text{N}_2$)	1
	Moles $\text{C}_6\text{H}_5\text{N}_2^+$ in 1000 cm^3 solution = $0.003 \times (1000 / 200) = 1.50 \times 10^{-2} \text{ (mol)}$	1
2(b)(ii)	Graph 1: A line graph with the y-axis labeled 'vol. $\text{N}_2(\text{g}) / \text{cm}^3$' ranging from 0 to 12, and the x-axis labeled '$[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})] / \text{mol dm}^{-3}$' ranging from 0 to 0.015. The line starts at (0, 12) and ends at (0.015, 0). OR Graph 2: A line graph with the y-axis labeled 'vol. $\text{N}_2(\text{g}) / \text{cm}^3$' ranging from 0 to 12, and the x-axis labeled '$[\text{C}_6\text{H}_5\text{N}_2^+(\text{aq})] / \text{mol dm}^{-3}$' ranging from 0 to 0.015. The line starts at (0, 0) and ends at (0.015, 12).	
	Axes (label with quantity or correct unit) and values correct	1
	Straight line from axis marks OR from 0,0 over most of the axes	1

2(c)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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2(a)	Column C data correct		1
	Column D data correct and given to 2 dp		1
			2
	C	D	
	$(\alpha - \alpha_{\infty})$	$\log_{10}(\alpha - \alpha_{\infty})$	
	51.9	1.72	
	41.1	1.61	
	33.3	1.52	
	27.5	1.44	
	22.6	1.35	
	18.2	1.26	
	14.4	1.16	
	11.7	1.07	
	9.5	0.98	
	7.5	0.88	

2(b)(i)	All ten points plotted correctly Best-fit straight line drawn	1 1 2
2(b)(ii)	(Yes) most of the points are on the line OR only a few points are not on the line	1 1
2(c)(i)	Co-ordinates read and recorded correctly Correctly calculated value of the gradient given to 3sf and using the candidate's co-ordinates correctly	1 1 2
2(c)(ii)	$k = \text{candidate's gradient} \times (-2.30)$ Correct answer	1 1 2
2(d)(i)	Reading/value of α was read/taken/recorded too early	1 1
2(d)(ii)	Two co-ordinates on line correctly read and stated AND One y value must be half the other $t_{1/2}$ correctly determined from candidate's co-ordinates values provided $y_1 = y_2/2$	1 1 2
2(d)(iii)	Correctly calculated value for $k' = \frac{0.693}{t_{1/2}}$	1 1
2(d)(iv)	Second reaction took place at <u>higher</u> temperature AND because k' (second k value) is larger	1 1
2(d)(v)	No OR the half-life would not change AND half-life is independent of concentration OR the reaction is first order (with respect to sucrose)	1 1
Total:		15

Q# 86/ ALvl Chemistry/2016/s/TZ 1/ Paper 5/Q# 2/www.SmashingScience.org :o)

2 (a)	1/T/K ⁻¹	log ₁₀ (1/t)	
	3.47 × 10 ⁻³	-1.92	
	3.41 × 10 ⁻³	-1.76	
	3.33 × 10 ⁻³	-1.56	
	3.30 × 10 ⁻³	-1.45	
	3.26 × 10 ⁻³	-1.25 or -1.26	
	3.22 × 10 ⁻³	-1.28	
	3.19 × 10 ⁻³	-1.18	
	3.16 × 10 ⁻³	-1.08	
	3.12 × 10 ⁻³	-0.95	
	3.05 × 10 ⁻³	-0.90	
	Column values for 1/T correctly calculated		[1]
	Column values for log ₁₀ (1/t) correctly calculated		[1]
	3sf in 1/T AND 2 dp in log ₁₀ (1/t)		[1]

(b)	candidate's points plotted correctly from table in 2(a)	[1]
	line of best fit drawn	[1]
(c)	Two anomalies identified Reasons: Points to the left of the line: the time of disappearance was thought to be later OR the time was stopped too late (after reaction ended) OR the (hydrochloric acid) solution had not reached the temperature of the water bath OR the timer was started early OR magnesium folded up (reduced surface area) Points to the right of the line: the Mg may have been thought to have disappeared earlier than it did OR the timer was started late OR the timer was stopped too early (reaction still going)	[1]
(d) (i)	two co-ordinates in correct x, y format	[1]
	gradient calculated correctly from candidate's stated co-ordinates (the value MUST be negative unless the graph is mis-plotted) value MUST be to 3 significant figures Expected range -2500 to -3500	[1]
(ii)	$-E_A = \text{gradient} \times 0.0191$ OR $-E_A = \text{gradient} \times 0.0191$ then divide by 1000 OR correct transformations	[1]
	correct calculation and sign from candidate's gradient, gradient may be in calculation form, minimum 2 significant figures	[1]
(e)	valid answer dependent on candidate's graph, e.g. reliable because most of the points on/ close to the line OR unreliable as most points not on the line	[1]
(f)	Student X is correct; reaction time less OR reaction is faster AND percentage error / uncertainty will be greater OR greater error / uncertainty in time / data / recordings	[1]
(g)	reaction time is longer / rate slower AND some of the magnesium is not in contact (with the acid) OR less surface area for reaction (with HCl) OR only the bottom of the magnesium is reacting	[1]
(h)	initial rate lower / slower. AND the concentration of H^+ ions is lower / pH higher OR ethanoic acid less dissociated / weaker acid	[1]
		[15]

Q# 87/ ALvl Chemistry/2016/m/TZ 2/ Paper 5/Q# 1/www.SmashingScience.org :o)

question	expected answer	mark
1 (a)	M1 (apparatus mark) volumetric flask in range 25–250 cm³; M2 mol propanone = $1.00 \times (\text{flask volume} / 1000)$; e.g. mol of propanone = $1.00 \times 25 / 1000 = 0.025 \text{ mol}$ M3 M2 $\times 58.0$; e.g. $0.025 \times 58.0 = 1.45 \text{ g}$	[3]



(b) (i)	B must be added before first or second reactant	[1]
(ii)	the reactants are A and C so one of these must be mixed last; or the reaction must not start before all three substances are present;	[1]
(c) (i)	(10 cm ³) pipette	[1]
(ii)	M1 NaHCO ₃ will effervesce so when effervescence finishes it shows that all H ⁺ ions have been removed; M2 NaOH will react with I ₂ / CH ₃ COCH ₃ / reactants;	[2]
(d) (i)	M1 mol I ₂ = (10 / 100) × 0.200 × (50 / 1000) = 1.(00) × 10 ⁻³ mol; M2 mol S ₂ O ₃ ²⁻ = 2 × 1.00 × 10 ⁻³ = 2.(00) × 10 ⁻³ mol; M3 volume 0.100 mol dm ⁻³ S ₂ O ₃ ²⁻ = (1000 × 2.00 × 10 ⁻³) / 0.100 = 20(.0) cm ³ ;	[3]
(ii)	indicator = starch; colour change = blue-black to colourless;	[2]
(e)	time and units of s; volume of thiosulfate and units of cm ³ ;	[2]
(f)	temperature;	[1]
(g) (i)	M1 (labels) x-axis = time y-axis = concentration of iodine M2 curved line decreasing from left to right starting from x = 0	[2]
(ii)	idea of constant half-life: determine at least two half-lives from the graph and ensure that they are the same; or half-lives determined from the graph should be constant; or determine the gradient (rate) at different points on the graph and plot rate v. concentration to determine if the plot is linear and goes through the origin;	[1]
(h)	(incorrect and) half-life will still be constant; or temperature has no effect upon order (of reaction);	[1]

2 (a)	ACE Data	Correct log column heading as $\log C/\log(a-x)/\log(1-B)$. Calculations for the log column in the table below are correct and given to 3 sig figs. (Allow 1 error without penalty.) <table border="1" data-bbox="528 360 1342 797"> <thead> <tr> <th>A</th><th>B</th><th>C</th><th>D</th></tr> <tr> <th></th><th></th><th>$1 - B / \text{mol dm}^{-3}$</th><th>$\log C$</th></tr> </thead> <tbody> <tr><td>0</td><td>0.000</td><td>1</td><td>0</td></tr> <tr><td>30</td><td>0.101</td><td>0.899</td><td>- 0.0462</td></tr> <tr><td>60</td><td>0.193</td><td>0.807</td><td>- 0.0931</td></tr> <tr><td>100</td><td>0.259</td><td>0.741</td><td>- 0.130</td></tr> <tr><td>130</td><td>0.370</td><td>0.630</td><td>- 0.201</td></tr> <tr><td>180</td><td>0.469</td><td>0.531</td><td>- 0.275</td></tr> <tr><td>210</td><td>0.551</td><td>0.449</td><td>- 0.348</td></tr> <tr><td>240</td><td>0.573</td><td>0.427</td><td>- 0.370</td></tr> <tr><td>270</td><td>0.617</td><td>0.383</td><td>- 0.417</td></tr> <tr><td>300</td><td>0.655</td><td>0.345</td><td>- 0.462</td></tr> </tbody> </table>	A	B	C	D			$1 - B / \text{mol dm}^{-3}$	$\log C$	0	0.000	1	0	30	0.101	0.899	- 0.0462	60	0.193	0.807	- 0.0931	100	0.259	0.741	- 0.130	130	0.370	0.630	- 0.201	180	0.469	0.531	- 0.275	210	0.551	0.449	- 0.348	240	0.573	0.427	- 0.370	270	0.617	0.383	- 0.417	300	0.655	0.345	- 0.462	[1] [1]
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(b)	ACE Data	Both axes scaled from zero with x-axis labelled as 'time /min' and y-axis as $\log C$. Plotted points must cover at least half the grid in both directions. All nine points plotted correctly. (Allow tolerance of $\pm$ of $\frac{1}{2}$ small square.) Appropriate straight line drawn through the origin. (If all points do not lie on the line then the net deviation of the non-anomalous points on each side of the best fit line must be approximately the same.)	[1] [1] [1]																																																
(c)	ACE Evaluation	2 anomalous points circled at time 100 min and 210 min. $t = 100$ min – sample taken out too early OR recorded time is later than sample withdrawn. $t = 210$ min – sample taken out too late OR recorded time is earlier than sample withdrawn.	[1] [2]																																																
(d)	ACE Evaluation	Most of the points are on the line OR only a few points are not on the line OR there are only a few anomalies.	[1]																																																
(e)	ACE data	Appropriately drawn lines on the graph. Correctly read values from the graph. (If no construction lines shown, allow values from the table if graph drawn does actually go through point(s) used.) Correctly calculated value of the slope given to 3 sig figs with correct unit (min^{-1}) using the candidate's figures.	[1] [1] [1]																																																
(f)	ACE Conclusion	Statement that the relationship is justified since a straight line is produced.	[1]																																																

(g)	ACE Conclusion	Draws a straight line from the origin with a different gradient.	[1]
		Shows shorter elapsed times. (Steeper gradient)	[1]
	Total		[15]

Q# 89/ ALvl Chemistry/2011/w/TZ 1/ Paper 5/Q# 2/www.SmashingScience.org :o)

Question	Sections	Indicative material	Mark
2 (a)	ACE Data	Log ₁₀ (rate) or Log ₁₀ (1/time) or Log ₁₀ (1/t). One of these labels also serves as expression, full column no units. Accept log with no base.	[1]
		Reciprocal absolute temperature or reciprocal Kelvin temperature or 1/T (not temp etc.). One of these labels also serves as expression, full column with unit, K ⁻¹ . Don't accept 1/T × 10 ⁻³ /K ⁻¹ but /10 ⁻³ K ⁻¹ OK	[1]
		Data in both columns above to 3 sig figs and correct, allow 2 errors.	[1]
		Allow salvage mark for rate column if ALL correct. A heading of 1/time or 1/t or 1/C also serves as expression.	
(b)	ACE Data	Unambiguously labelled axes. 1/T on the x-axis and log ₁₀ (rate) on the y axis AND appropriate scaling. Ignore units unless it is the label.	[1]
		Correctly plotted points. Ecf incorrectly calculated data. All 10 points need to be plotted. Check points 3 & 7 and 1 & 10 and any others off the line.	[1]
		Line of best fit.	[1]
		Allow plot and line marks if other axes used.	
(c)	ACE Evaluation	Allow the candidate to select up to five anomalies which must include that furthest from the line.	[1]
		This mark is available if other axes used.	
		The data has two anomalies, Points 3 & 7.	
		Point 3, Timed to past opacity (not late stopping the clock alone), or solutions not equilibrated with water bath temperature or clock started early.	[1]
		Point 7, Timed to prior to opacity (not early stopping the clock alone), or clock started late.	[1]
		Give a rescue mark if both correct anomalies present but not linked to their points.	
		These last two marks not available if other axes used.	

(d)	ACE Evaluation	Either no repeats OR five or more points not on line hence unreliable OR most points on line OR points produce straight line hence reliable. This mark not available if other axes used.	[1]
(e)	ACE Data	Has construction lines on the plot. States intercept readings from them. (Could be to data points if the line and construction is to that point. Powers of 10 (e.g. $\times 10^{-3}$) must be included if necessary) then calculates the slope (around -1050). Slope is $(y_1 - y_2)/(x_1 - x_2)$. The sign of the gradient must be correct from the sign produced from the intercept calculations. Allow these marks if other axes used.	[1] [1]
(f)	ACE Conclusions	Correct calculation. Any calculation that has slope above multiplied by 19 i.e. $-E_A = \text{slope} \times 19$. Or slope = $-E_A/19$. Ignore units. Also accept that calculation subsequently divided by 1000 i.e. about 19950 or 19.95. T is not in this calculation. Allow this mark for other plots.	[1]
(g)	ACE Conclusions	Increased K.E/energy/speed. More collisions/unit time or more frequent collisions or more chance of collisions or more energetic collisions or more collisions exceeding activation energy or more successful collisions or more effective collisions. NOT just more collisions.	[1] [1]
	Total		[15]

Q# 90/ ALvl Chemistry/2004/w/TZ 1/ Paper 5/Q# 1/www.SmashingScience.org :o)

Page 1	Mark Scheme	Syllabus	Paper
	A LEVEL – NOVEMBER 2004	9701	5

1 Table of results - Table 1.1

Give one mark if all times are given to the nearest second.

Do **not** give this mark if timings are given to 0.1 or 0.01 s

Do **not** give this mark if the stop-clock has been read as minute.second e.g. 1.07

The Examiner:

Rounds all times to the nearest second if necessary, and

Converts times that are clearly in minute.second format to seconds. e.g. 1.07 becomes 67 s

(The shortest time recorded should be approaching 60 seconds).

1



Accuracy Marks

For each of the Experiments 1 - 3 a (volume x time) value is calculated.

For *Experiment 1*, the Examiner calculates (50 x time in seconds)

Record this value in the margin to the left of Table 1.1 and alongside *Experiment 1*.

For *Experiment 2*, the Examiner calculates (40 x time in seconds)

Record this value in the margin to the left of Table 1.1 and alongside *Experiment 2*.

For *Experiment 3*, the Examiner calculates (30 x time in seconds)

Record this value in the margin to the left of Table 1.1 and alongside *Experiment 3*.

Accuracy marks for reactions where the $[\text{BrO}_3^-]$ is changed

Calculate the difference between the (V x t) values for *Experiments 1 and 2*.

Calculate $\frac{\text{difference in Vt values}}{\text{larger Vt used in calculating difference}} \times 100$

Record both Vt and % difference below Table 1.1

Assign accuracy marks as follows:

Difference	Mark
Up to 4%	5
4+% to 5%	4
5+% to 6%	3
6+% to 8%	2
8+% to 10%	1
Greater than 10%	0

IT IS RECOMMENDED THAT EXAMINERS RECORD THE EXPRESSION FOR EACH % DIFFERENCE ON THE SCRIPT

5

Accuracy marks for reactions where the $[\text{Br}^-]$ is changed

Calculate the difference between the (V x t) values for *Experiments 1 and 3* and for *Experiments 2 and 3*.

For each pair of experiments – calculate

$$\frac{\text{difference in } V_t \text{ values}}{\text{larger } V_t \text{ used in calculating difference}} \times 100$$

Record V_t and % difference for each pair below Table 1.1

Assign accuracy marks as follows for the smaller of the two % differences:

Difference	Mark
Up to 5%	5
5+ to 7%	4
7+ to 10%	3
10+ to 15%	2
15+ to 20%	1
Greater than 20%	0

5

IF A SPREADSHEET IS USED TO GENERATE V_t VALUES, V_t DIFFERENCES, % DIFFERENCES AND MARKS, DOUBLE CHECK THE EXPERIMENT TIMES ENTERED FOR EACH CANDIDATE

(b) Give one mark for one of the following ideas:

Total volume is constant so that reagent volume is $\propto$ concentration of reagent

Total volume is constant so that (individual) volumes represent or are a measure of concentration

Total volume is constant so that in any pair of experiments only one concentration is varied

The concentration of phenol remains constant

1

In (c) to (e) when calculating the appropriate order of reaction from the candidate's results, allow fractional/decimal orders or the calculated order rounded to the nearest whole number.

(c) The effect on the rate of reaction when $[\text{BrO}_3^-]$ is changed

Give **one mark** for a comparison of the volumes of BrO_3^- used for Experiments 1 and 2.

Give **one mark** for a comparison of the calculated rates of reaction for Experiments 1 and 2.

Give **one mark** for linking the volume ratio to rate ratio to suggest an appropriate order of reaction.

N.B. There must be use of experimental values and calculation to gain these marks.

3

(d) The effect on the rate of reaction when $[\text{Br}^-]$ is changed

Give **one mark** for a comparison of the volumes of Br^- used for Experiments 1 and 3.

Give **one mark** for a comparison of the calculated rates of reaction for Experiments 1 and 3.

Give **one mark** for linking the volume ratio to rate ratio to suggest an appropriate order of reaction.

N.B. There must be use of experimental values and calculation to gain these marks.

3

Where candidates use compare V_t values to establish order, give 1 mark for each V_t value, correctly calculated for the appropriate experiment and 1 mark for order statement from the V_t values.

(e) The effect on the rate of reaction when $[\text{H}^+]$ is changed

Give **one mark** for selection of experiment 3 and experiment 4.

Providing experiments 3 and 4 have been selected

Give **one further mark** for a calculation that compares the volumes of acid used and also compares the calculated rates.

(Most text-books give the reaction as 2nd order with respect to acid - expect to see rate increasing x 3 when the concentration of acid is doubled.)

2

Total for Question 1 = 20