PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 9: KINETICS I

SCORE	PERCENTAGE
/189	%

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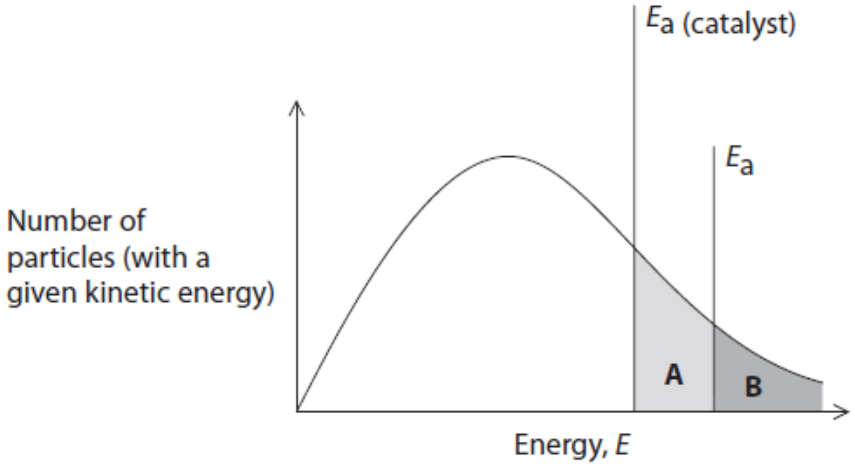
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Q1.

This is a question about catalytic converters in car exhaust systems.

Which area in the Maxwell-Boltzmann distribution diagram represents the **increase** in the number of particles with sufficient energy to react in the presence of a catalyst?



(1)

☒ **A** area A

☒ **B** area B

☒ **C** area A − area B

☒ **D** area A + area B

(Total for question = 1 mark)

Q2.

The gas phase reaction between hydrogen and iodine is reversible.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2+\sqrt{K_c}}$$

In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.

The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.

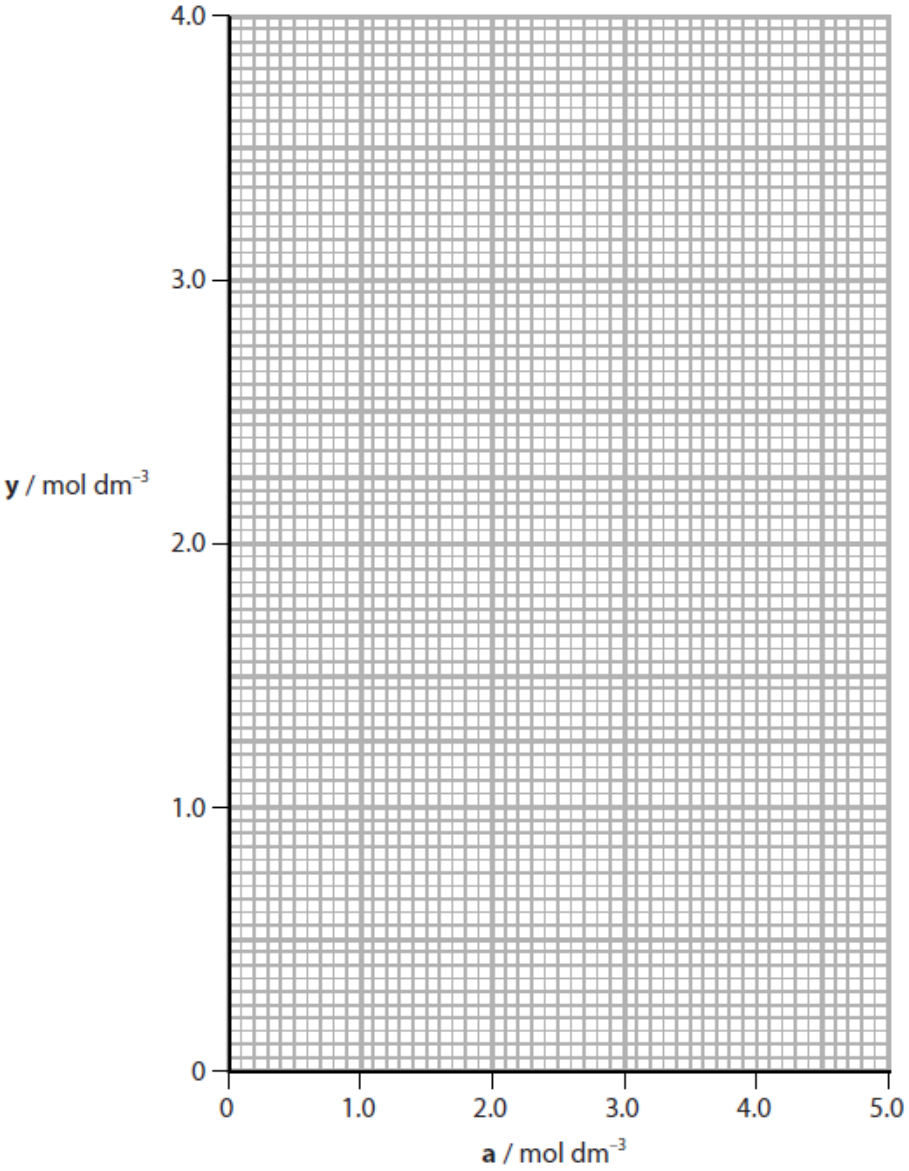
(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	$[I_2]_{eq}$ / mol dm^{-3}	y / mol dm^{-3}
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	
4.90	1.15	3.75

(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.

Show your working on the graph.

(2)

(iv) Use your answer to (b)(iii) and the expression $\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2+\sqrt{K_c}}$ to calculate the value of K_c.

(2)

(c) Identify a safety issue associated with this experiment.

(1)

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(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

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(e) The equation for the reaction between hydrogen and iodine is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

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(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

(1)

(Total for question = 16 marks)

Q3.

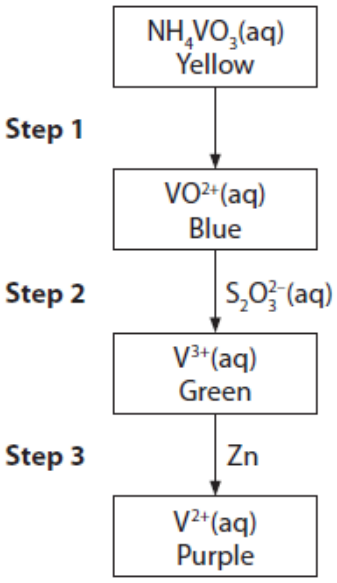
The element vanadium exists in a variety of oxidation numbers in its compounds.

(a) Calculate the oxidation number of vanadium in the compound NH_4VO_3.

(1)

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(b) NH_4VO_3 forms VO_2^+ in solution and can be reduced stepwise to form the ion, $V^{2+}(aq)$.



(i) Use the Data Booklet to give a suitable reducing agent for **Step 1** in order to only produce the blue solution.

(1)

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(ii) Give a possible reason why the reducing agent you choose may not be suitable.

(1)

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(iii) Explain what you would see during **Step 1**.

(2)

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(iv) Justify the choice of reducing agent for **Step 2**.
Write an equation for the reaction. State symbols are not required.

(2)

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Q4.

The compound sulfuryl chloride is a colourless liquid with the formula SO_2Cl_2.

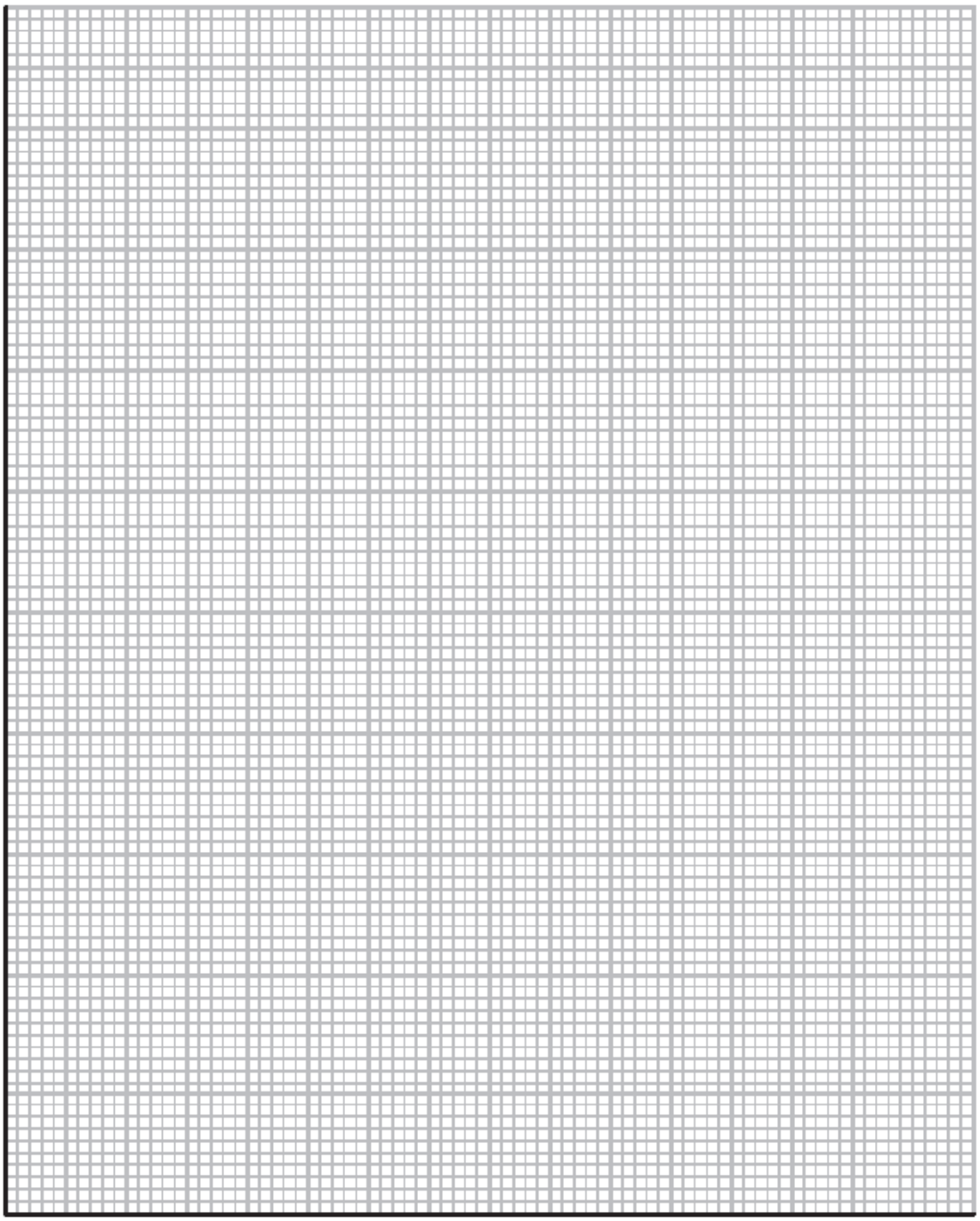
It decomposes at room temperature to form sulfur dioxide and chlorine.

The rate of the decomposition of SO_2Cl_2 can be investigated by monitoring the concentration of SO_2Cl_2 as the reaction proceeds. The data in the table were collected from such a reaction.

Time / s	$[SO_2Cl_2]$ / mol dm^{-3}
0	0.500
1000	0.370
2000	0.290
3000	0.200
4000	0.150
5000	0.110
6000	0.090
7000	0.060
8000	0.040

(i) Plot a graph of these results.

(3)



(ii) Determine the order of reaction with respect to SO_2Cl_2 and hence write the rate equation for the reaction.
Show on your graph how you arrived at your answer.

(3)

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(iii) Use your graph to find the rate of reaction when the concentration of SO_2Cl_2 is 0.200 mol dm^{-3}.

Hence calculate the rate constant, *k*, to an appropriate number of significant figures. Include units in your answer.

(4)

(b) Write a possible two-step mechanism for the reaction that is consistent with your rate equation and clearly identify the rate-determining step.

(2)

(Total for question = 12 marks)

Q5.

This question is about the kinetics of chemical reactions.

Catalysts are sometimes used in reactions.

(i) Explain how a catalyst affects the rate of a reaction.

(3)

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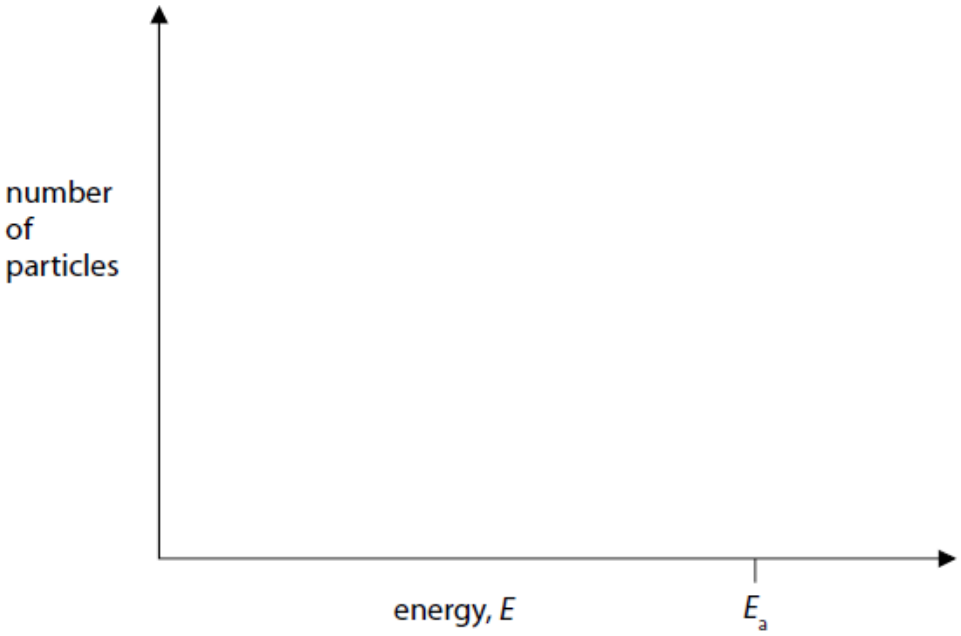
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(ii) Draw and label lines on the axes to show how an increase in temperature affects the number of particles with $E > E_a$.

(2)



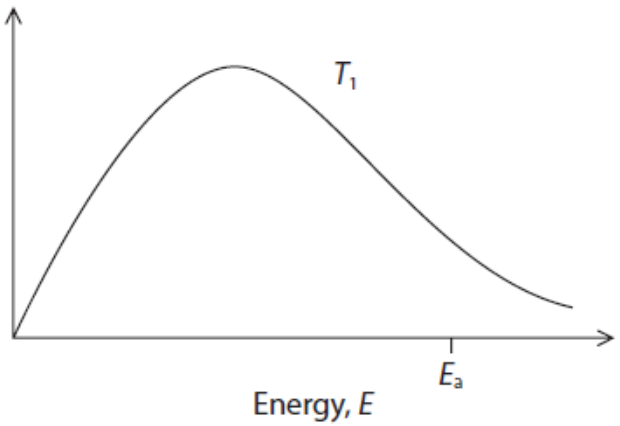
Q6.

This question is about the effect of temperature on the rate of decomposition of nitrogen(V) oxide.

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

The diagram shows the Maxwell-Boltzmann distribution of molecular energies for nitrogen(V) oxide at a temperature T_1.

E_a is the activation energy of this reaction.



(i) Give the label for the vertical axis.

(1)

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(ii) Draw a second curve on the same set of axes for the same gas at a **lower** temperature, T_2.

(2)

(iii) Explain, in terms of collisions and energy, why lowering the temperature decreases the rate of reaction.

(2)

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(iv) A catalyst is added to the gas.

Label the diagram above with the symbol E_{cat} to show a possible activation energy for the reaction in the presence of a catalyst.

(1)

(Total for question = 6 marks)

Q7.

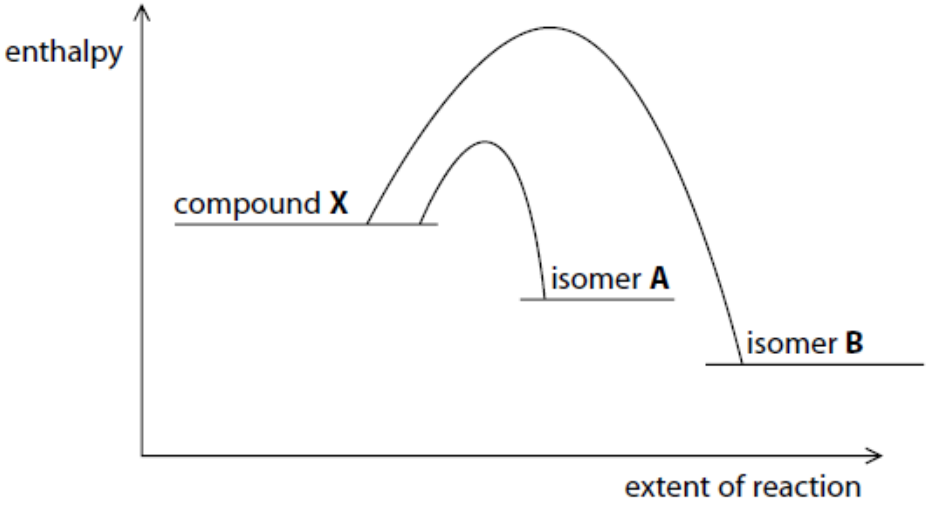
This question is about the effect of changes in temperature on reactions.

* Compound **X** reacted reversibly with concentrated sulfuric acid to form two isomers, **A** and **B**.

$$\text{compound } \mathbf{X} + H_2SO_4(\text{conc.}) \rightleftharpoons \text{isomer } \mathbf{A} + \text{isomer } \mathbf{B}$$

At 40°C, approximately 95% of the product was isomer **A**. At 160 °C, the product contained approximately 85% of isomer **B**.

The diagram shows the reaction profiles for the formation of the two isomers.



Use the information to comment on the different yields of isomer **A** and isomer **B** at different temperatures.

(6)

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Q8.

This question is about the decomposition of hydrogen iodide.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

The decomposition of hydrogen iodide is catalysed by the heterogeneous catalyst platinum.

(a) State the meaning of the term heterogeneous.

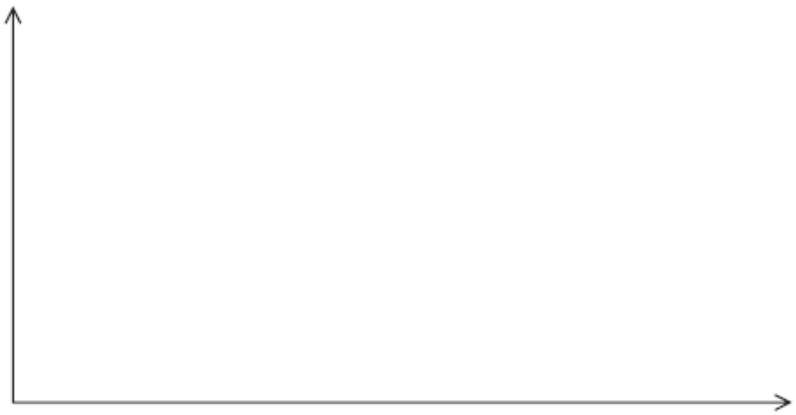
(1)

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(b) (i) Label the axes and draw a curve to show the Maxwell-Boltzmann distribution of molecular energies in a gas. Mark on your graph a suitable value for the activation energy, E_a , for the reaction.

(3)



(ii) Use the Maxwell-Boltzmann distribution to explain why a catalyst increases the rate of a reaction.

(3)

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Q9.

The solid compound V_2O_5 is used as a heterogenous catalyst in industry to speed up the reaction between oxygen and sulfur dioxide gas.

The reaction has two stages:

Stage 1 $SO_2(g) + V_2O_5(s) \rightarrow SO_3(g) + 2VO_2(s)$

Stage 2 $2VO_2(s) + ½O_2(g) \rightarrow V_2O_5(s)$

(i) Write the equation for the overall reaction. State symbols are not required.

(1)

*(ii) Explain the catalytic behaviour of V_2O_5 in this reaction.

(6)

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Q10.

This question is about how catalysts work.

Gaseous reactants attach to the catalytic surface by the process of

(1)

☒ **A** absorption

☒ **B** activation

☒ **C** adsorption

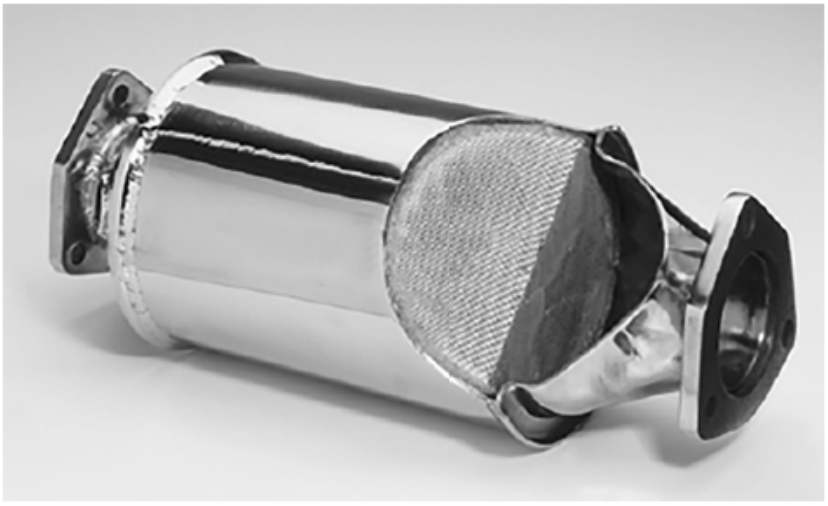
☒ **D** desorption

(Total for question = 1 mark)

Q11.

This question is about how catalysts work.

Catalytic converters of car exhaust systems have internal honeycomb structures as shown.



Explain why the honeycomb structure is used in a car exhaust system.

(2)

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(Total for question = 2 marks)

Q12.

This question is about transition metals.

Manganate(VII) ions, MnO_4^-, react with ethanedioate ions in acid solution.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The reaction starts slowly, the rate of reaction then increases, before it decreases again.

Explain this sequence.

(3)

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(Total for question = 3 marks)

Q13.

This question is about the identification of a Group 2 carbonate.

A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

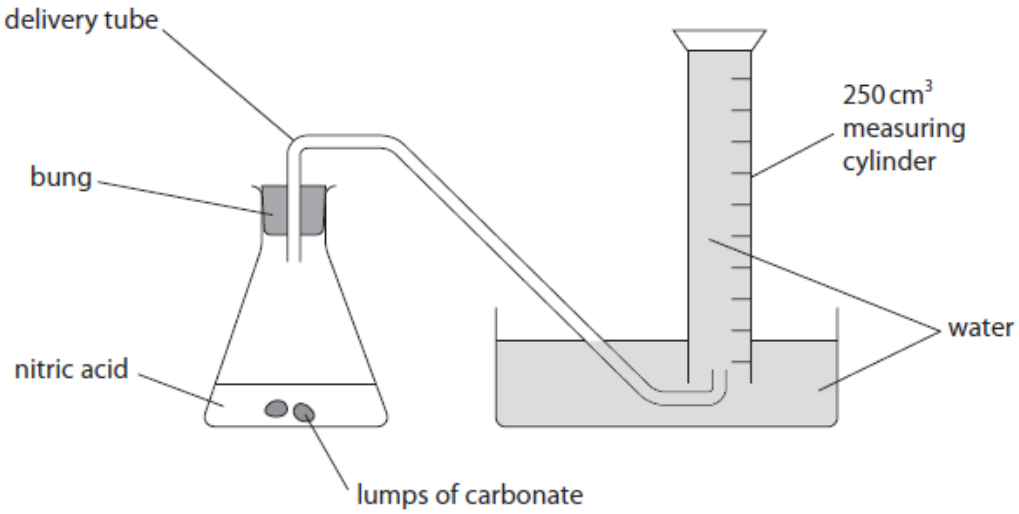
The chemistry teacher tried to identify the carbonate with the help of three students.
The three students worked under identical conditions and shared the same weighing balance.

Student **1** recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate

reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student **1** set up the apparatus shown below.



- Student **1** weighed out some of the Group 2 carbonate and added it to a 250 cm^3 conical flask.
- Student **1** then added 100 cm^3 of 0.200 mol dm^{-3} nitric acid to the conical flask and replaced the bung.
- Student **1** measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student **1** obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	.....
Volume of acid used	/ cm^3	100
Volume of gas collected	/ cm^3	225

Table 1

(a) Complete Table 1 to show the mass of the carbonate used.

(1)

(b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p.

(1)

(c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal.

(4)

(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.

Student **2** made no errors in their measurements or calculations but obtained a value for the molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.

(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

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(ii) It was later discovered that Student **2** had used 110 cm^3 of 0.200 mol dm^{-3} dilute nitric acid, instead of 100 cm^3 of 0.200 mol dm^{-3} dilute nitric acid.

Give a reason why this mistake would **not** have affected Student **2**'s result.

No calculation is required.

(1)

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(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.

Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

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(e) Student **3** suggested a different experiment.

Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.

Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.

Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3, where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)

(f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

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(g) Student **3** noticed that on heating the test tube some solid was lost.

Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

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(Total for question = 18 marks)

Q14.

Nitrogen monoxide and chlorine react together to form nitrosyl chloride.

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

The rate equation for the formation of nitrosyl chloride is

Rate = $k[NO]^2[Cl_2]$

(i) Complete the table by adding the missing values.

Experiment	[NO] / mol dm^{-3}	[Cl_2] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.122	0.241	1.09×10^{-2}
2		0.482	8.72×10^{-2}
3	0.366		4.91×10^{-2}

(2)

(ii) Calculate the rate constant, *k*, using data from Experiment 1.

Include units with your answer.

(3)

(iii) Explain how using a catalyst increases the rate constant, *k*.

(2)

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(iv) The heterogeneous catalyst palladium was suggested for use in this reaction.

Explain how impurities in the gaseous reactants could make the catalyst less effective.

(3)

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(Total for question = 10 marks)

Q15.

This question is about the kinetics of chemical reactions.

A reaction between iodine and propanone, in the presence of hydrogen ions, has the rate equation:

$$\text{rate} = k[CH_3COCH_3][H^+]$$

(i) Give the overall order of the reaction.

(1)

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(ii) Explain, in terms of collision theory, why increasing the concentration of propanone changes the rate of reaction.

(2)

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Q16.

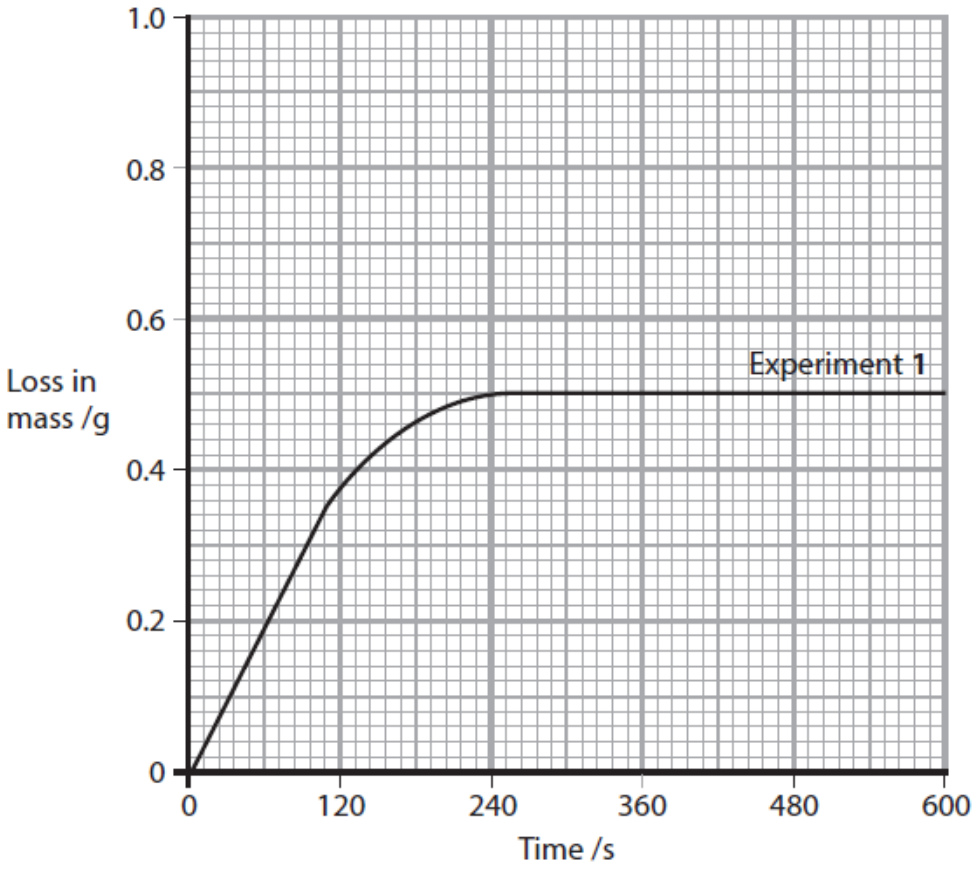
A series of experiments was carried out to investigate the factors which affect the rate of reaction between calcium carbonate and dilute hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

- 50.0 cm^3 of hydrochloric acid was added to 10 g of calcium carbonate (an excess) in a conical flask placed on an electronic balance.
- The loss in mass of the flask and its contents was recorded every 30 seconds for 10 minutes.
- The experiment was repeated using different sized pieces of calcium carbonate, a different concentration of hydrochloric acid or a different temperature.

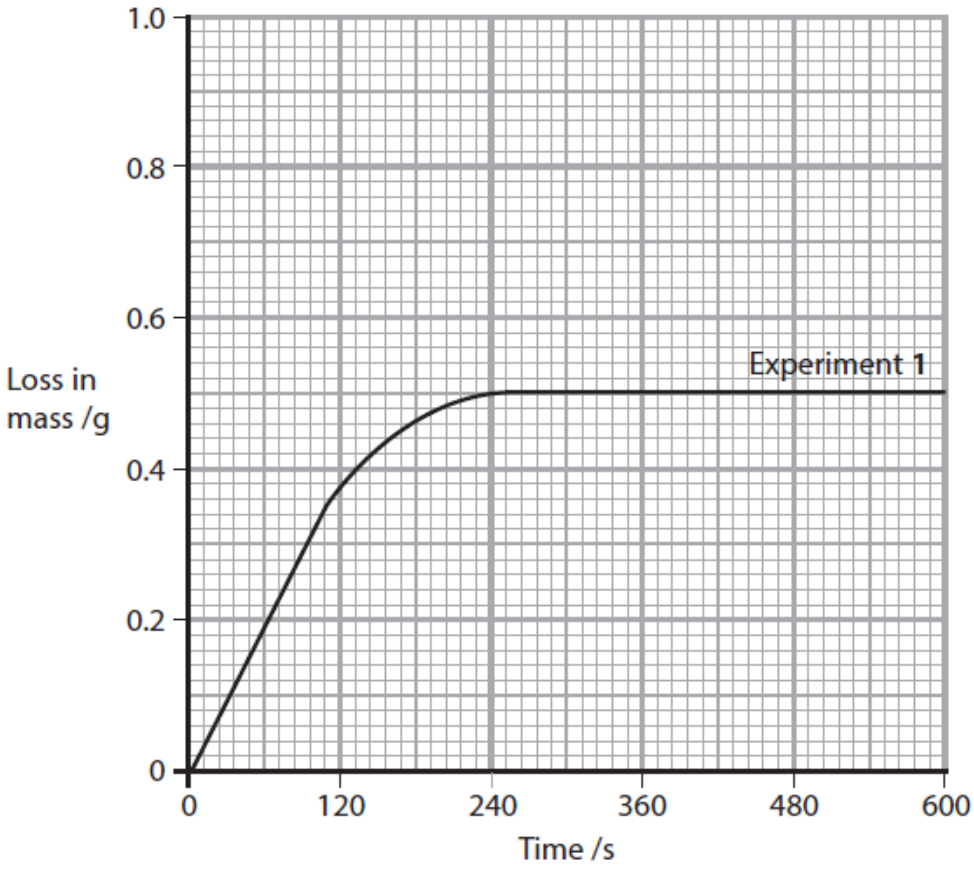
Experiment	Size of calcium carbonate	Concentration of hydrochloric acid / mol dm^{-3}	Temperature /°C
1	small pieces	0.50	20
2	small pieces	0.50	60
3	one large piece	0.50	20
4	small pieces	1.00	20

The results of Experiment **1** are shown on the graph.



Determine the initial rate of reaction for Experiment **1**.
You must show your working on the graph.
Include units in your answer.

(3)



Initial rate of reaction .....

(Total for question = 3 marks)

Q17.

Bromate(V) ions, BrO_3^-, oxidize bromide ions, Br^-, in the presence of dilute acid, H^+, as shown in the equation below.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

Three experiments were carried out using different initial concentrations of the three reactants.

The initial rate of reaction was calculated for each experiment.

The results are shown in the table below.

Experiment number	$[BrO_3^-(aq)]$ / mol dm^{-3}	$[Br^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	Initial rate of reaction / mol dm^{-3} s^{-1}
1	0.050	0.25	0.30	1.68×10^{-5}
2	0.050	0.25	0.60	6.72×10^{-5}
3	0.15	0.50	0.30	1.01×10^{-4}

*(a) (i) This reaction is first order with respect to $BrO_3^-(aq)$. State, with reasons, including appropriate experiment numbers, the order of reaction with respect to

(5)

$H^+(aq)$

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$Br^-(aq)$

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(ii) Write the rate equation for the reaction.

(1)

(iii) Use the data from experiment 1 and your answer to (a)(ii) to calculate the value of the rate constant. Include units in your answer.

(3)

(b) What evidence suggests that this reaction proceeds by more than one step?

(1)

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(c) The initial rate of reaction was obtained from measurements of the concentration of bromine at regular time intervals. How is the **initial** rate of formation of bromine calculated from a concentration-time graph?

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(Total for question = 12 marks)

Q18. The ionic equation for the reaction of ammonium peroxodisulfate (persulfate), $(NH_4)_2S_2O_8$, with potassium iodide, KI, is

$$S^2O^{82-}(aq) + 2I^-(aq) \rightarrow 2SO_4{}^{2-}(aq) + I_2(aq)$$

(a) In a series of experiments to determine the rate equation for this reaction, 10 cm^3 of 0.0050 mol dm^{-3} sodium thiosulfate was mixed with 20 cm^3 of $(NH_4)_2S_2O_8$ solution and 5 drops of starch solution. 20 cm^3 of KI solution was added with mixing and the time taken for the solution to darken was noted. The initial concentrations of the $(NH_4)_2S_2O_8$ and KI solutions and the times for the mixture to darken are shown below.

Experiment Number	Initial concentration / mol dm^{-3}		Time for solution to darken / s
	$S_2O_8^{2-}$	I^-	
1	0.10	0.20	35
2	0.05	0.20	69
3	0.10	0.10	70

(i) Explain the purpose of the sodium thiosulfate solution.

(2)

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(ii) Use the data in the table to deduce the rate equation for the reaction between $S_2O_8^{2-}$ and I^- ions. Explain, by referring to the data, how you arrived at your answer.

(3)

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(b) A further experiment was carried out to confirm the order of the reaction with respect to iodide ions. $(NH_4)_2S_2O_8$ was mixed with KI to form a solution in which the initial concentration of $(NH_4)_2S_2O_8$ was 2.0 mol dm^{-3} and that of KI was 0.025 mol dm^{-3}. The concentration of iodine was measured at various times until the reaction was complete.

(i) Outline a method, **not** involving sampling the mixture, which would be suitable for measuring the iodine concentrations in this experiment. Experimental details are not required but you should state how you would use your measurements to obtain iodine concentrations.

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(ii) Explain why the initial concentration of $(NH_4)_2S_2O_8$ is much higher than that of KI.

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(iii) State how the initial rate of reaction may be obtained from the results of this type of experiment.

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(iv) In such an experiment a student calculated the initial rate of reaction to be 8.75×10^{-5} mol dm^{-3} s^{-1}. Use this value, the initial concentrations in (b) and the rate equation that you obtained in (a)(ii), to calculate the rate constant for this reaction. Include units in your answer.

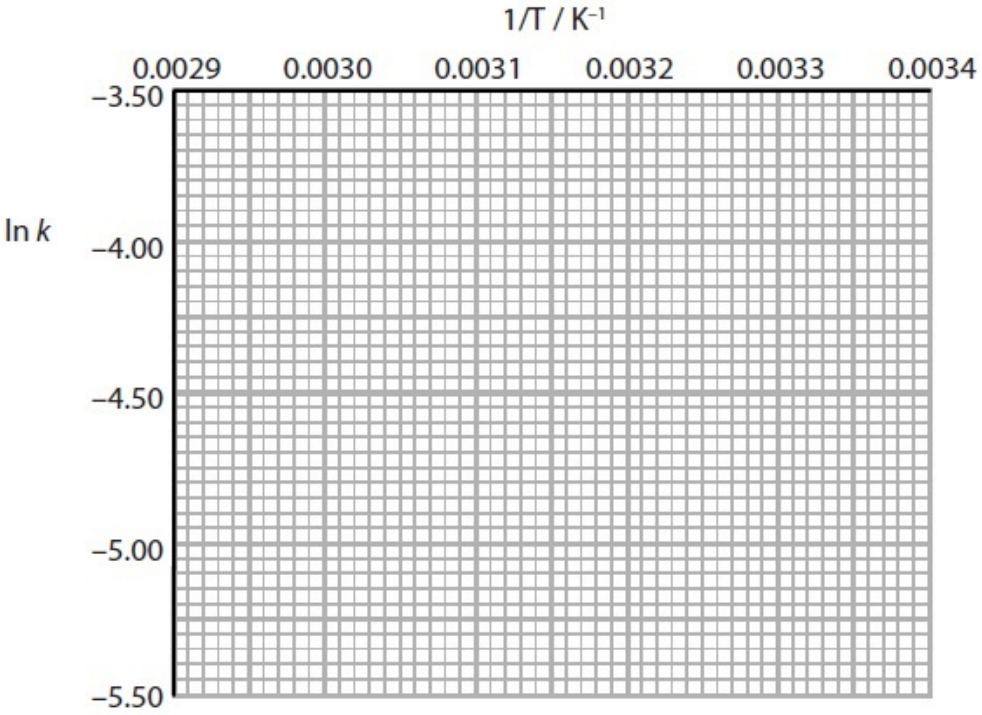
(2)

(c) Using the method outlined in (b), the rate constant for this reaction was determined at various temperatures. The data from these experiments are shown in the table below. Note that none of the temperatures corresponds to that used in (b) and that the rate constant is given in appropriate units.

Temperature T / K	Rate constant k	ln k	1/T / K^{-1}
300	0.00513	–5.27	0.00333
310	0.00833	–4.79	0.00323
320	0.0128	–4.36	0.00313
330	0.0201	–3.91	0.00303
340	0.0301	–3.50	0.00294

(i) Use the data in the table to plot a graph of ln k (on the y axis) against 1/T (on the x axis) and draw a best fit line through the points.

(2)



(ii) Determine the gradient of the best fit line in (c)(i) and use this value to calculate the activation energy, E_a, of the reaction, stating the units.

(4)

The rate constant of a reaction, k, is related to the temperature, T, by the expression

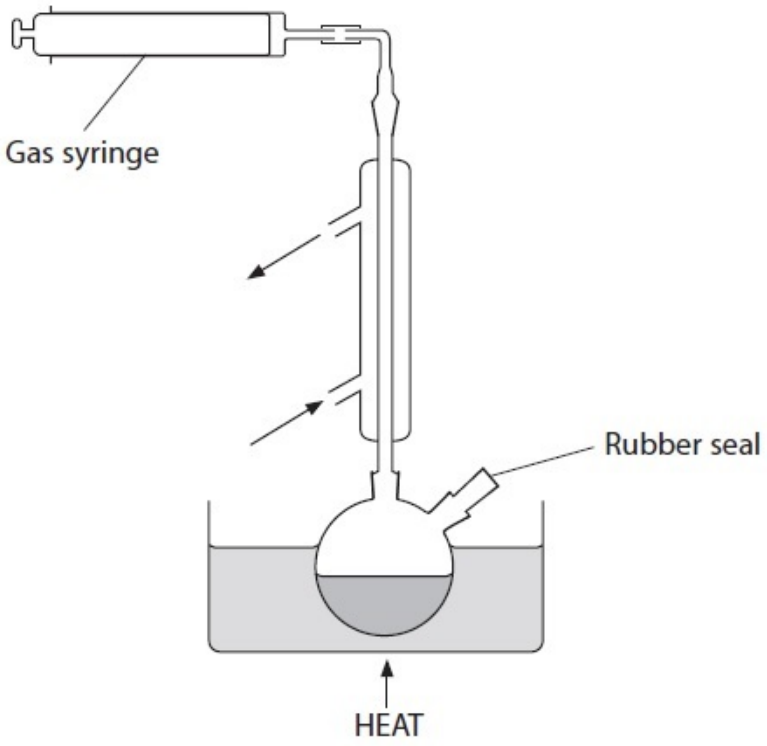
$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \qquad R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

(Total for Question = 19 marks)

Q19. This question is about the elimination of hydrogen bromide from bromoalkanes by reaction with alcoholic potassium hydroxide.

$$C_4H_9Br + KOH \rightarrow C_4H_8 + KBr + H_2O$$

To investigate the kinetics of this reaction the following apparatus was used:



A solution of concentrated potassium hydroxide in ethanol was refluxed and the gas syringe connected as shown.

0.6 cm^3 of 1-bromobutane was added to the solution with a hypodermic syringe through a rubber seal.

A stop clock was started and the volume of gas, V_t, measured at 2 minute intervals, for 12 minutes. When there was no further evolution of gas the volume of gas, V_{final}, was 76.5 cm^3.

(a) (i) Calculate the number of moles of 1-bromobutane used. You will need the values of the density and molar mass of 1-bromobutane from your Data booklet.

(2)

(ii) Calculate the maximum volume of gaseous but-1-ene, in cm^3, that could form.

[Molar volume of a gas 24 000 cm^3 under reaction conditions]

Suggest **two** reasons why this volume is unlikely to form.

(3)

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(b) The results obtained are shown in the table below.

Time t/min	Volume of but-1-ene V_t/cm^3	$(V_{final} - V_t)$/cm^3
0	0	76.5
2	31.5	45.0
4	51.0	25.5
6	62.5	14.0
8	68.5	8.0
10	72.0	4.5
12	74.0	2.5

(i) Explain why a large excess of potassium hydroxide is used in this experiment.

(1)

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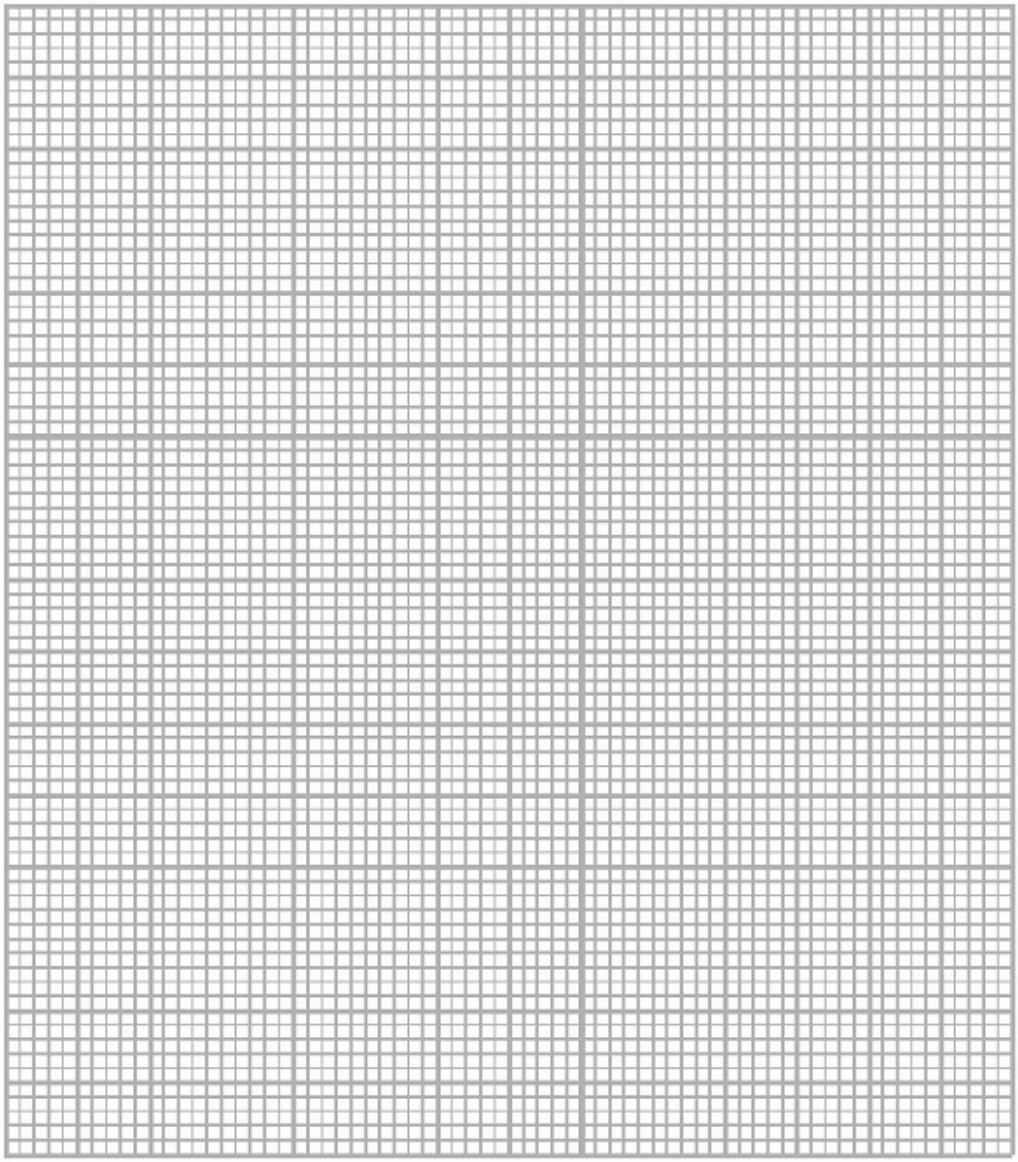
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(ii) Plot a graph of $(V_{final} - V_t)$/cm^3 against t/min.

(3)



(iii) Suggest why the value of ($V_{final} - V_t$) was plotted on your graph.

(1)

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(iv) Measure two successive half lives from your graph.

(2)

First half life
..... min

Second half life
..... min

(v) Deduce the order of reaction with respect to 1-bromobutane.

Justify your answer.

(2)

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(c) In another experiment, an excess of 1-bromobutane is reacted with varying concentrations of hydroxide ions. The results for the initial rate of the reaction are shown in the table below.

Experiment Number	$[C_4H_9Br]$ /10^{-2} mol dm^{-3}	$[OH^-]$ /10^{-3} mol dm^{-3}	Initial rate /10^{-5} mol dm^{-3} min^{-1}
1	2.50	2.50	5.00
2	2.50	1.25	2.50
3	2.50	0.50	1.00

(i) Deduce the order of reaction with respect to hydroxide ions. Justify your answer using the data in the table.

(2)

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(ii) Write the rate equation for the reaction using your answers to parts (b)(v) and (c)(i).

(1)

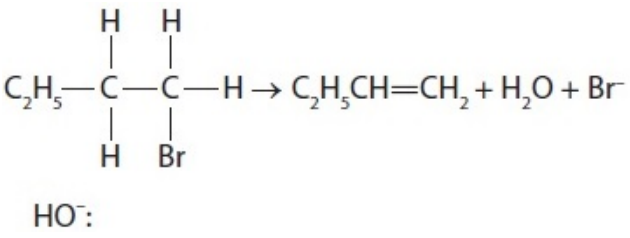
(iii) Give the units of the rate constant.

(1)

*(iv) It is suggested that the reaction begins with the slow attack by a hydroxide ion on a hydrogen atom in the 1-bromobutane, as shown below.

Complete the electron pair movement for this reaction using curly arrows and explain why this step is consistent with the rate equation for the reaction you have given in (c)(ii).

(3)



HO^-:

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(Total for Question = 21 marks)

Q20.

* An excess of magnesium was added to 100 cm^3 of 0.0540 mol dm^{-3} HCl(aq).
The same mass of magnesium, from the same sample, was added to 100 cm^3 of 0.0540 mol dm^{-3} HCOOH(aq).

Both reactions were carried out at the same temperature.
Compare and contrast the total volume of hydrogen evolved, and the rate at which it will be evolved, in the two reactions.

(6)

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Q21.

Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, NaN_3, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide.

State symbols are not required.

(1)

(ii) In the reaction in (i), a typical airbag is inflated by about 67 dm^3 of gas.

Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.

For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

(4)

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$\ldots\ldots Na + \ldots\ldots KNO_3 \rightarrow \ldots\ldots K_2O + \ldots\ldots Na_2O + \ldots\ldots N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

(3)

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(c) The third reaction in the airbag is between the metal oxides and silicon dioxide.

State the type of reaction taking place and justify why this reaction is necessary.

(3)

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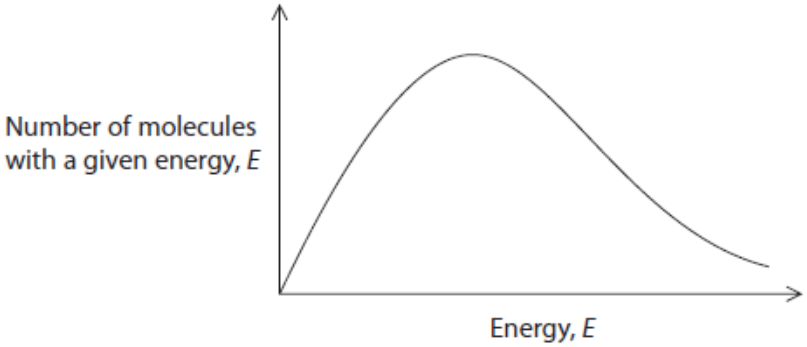
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(d) The Maxwell-Boltzmann distribution diagram shows the molecular energies for the gaseous system immediately after the airbag has been deployed.



What is the change in shape of the curve when the airbag **cools**?

(1)

☒ **A** the peak would shift to the left and be higher

☒ **B** the peak would shift to the left and be lower

☒ **C** the peak would shift to the right and be higher

☒ **D** the peak would shift to the right and be lower

(Total for question = 12 marks)

Q22.

The kinetics of the fast reaction below were investigated in a series of experiments.

$$\mathbf{A} + \mathbf{B} \xrightarrow{\text{catalyst } \mathbf{X}} \mathbf{C} + \mathbf{D} \qquad \Delta H \text{ is negative}$$

(a) Outline a titrimetric method that could be used to measure the change in concentration of compound **A** with time. Compound **A** is an alkali, whereas compounds **B**, **C** and **D** are neutral.

(3)

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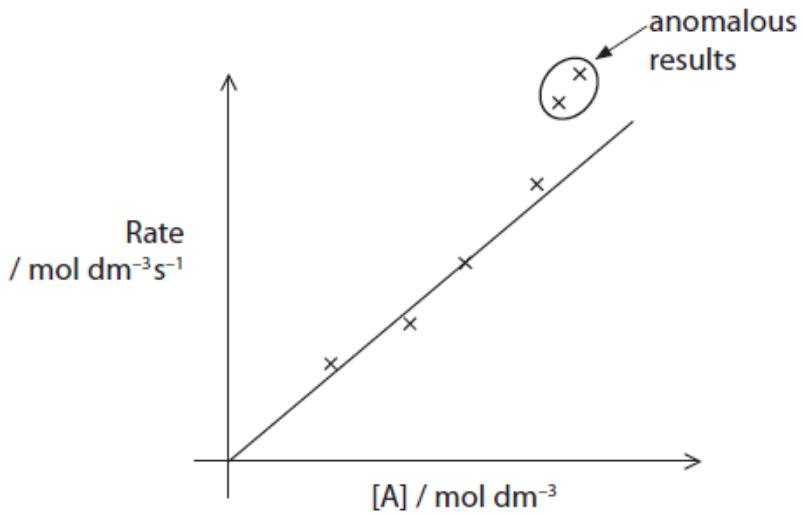
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(b) The rate of the reaction was measured at several different concentrations of **A**, in the presence of a large excess of compound **B** and a constant amount of catalyst **X**, to find the order of reaction with respect to **A**. The results are shown on the graph below.



(i) Explain how the graph confirms that the reaction is first order with respect to **A**.

(1)

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(ii) Suggest an explanation, other than human error, for the two anomalous results circled on the graph.

(3)

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(c) In a second series of experiments, further data were collected using an initial rates method. These results are summarised in the table below.

Experiment	Initial concentration / mol dm^{-3}			Initial rate / mol dm^{-3} s^{-1}
	A	**B**	**X**	
1	0.020	0.005	0.500	2.1×10^{-3}
2	0.040	0.005	0.500	4.2×10^{-3}
3	0.060	0.010	0.500	6.3×10^{-3}
4	0.080	0.010	0.250	4.2×10^{-3}