



Additional Assessment Materials

Summer 2021

Pearson Edexcel GCE in Chemistry 9CH0

Resource Set 1 - Topic Group 2

Topics included:

Topic 8: Energetics I

Topic 9: Kinetics I

Topic 10: Equilibrium I

Topic 11: Equilibrium II

Topic 12: Acid-base Equilibria

Topic 13: Energetics II

Topic 16: Kinetics II

(Public release version)

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Additional Assessment Materials, Summer 2021

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General guidance to Additional Assessment Materials for use in 2021

Context

- Additional Assessment Materials are being produced for GCSE, AS and A levels (with the exception of Art and Design).
- The Additional Assessment Materials presented in this booklet are an **optional** part of the range of evidence teachers may use when deciding on a candidate's grade.
- 2021 Additional Assessment Materials have been drawn from previous examination materials, namely past papers.
- Additional Assessment Materials have come from past papers both published (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidate.

Purpose

- The purpose of this resource is to provide qualification-specific sets/groups of questions covering the knowledge, skills and understanding relevant to this Pearson qualification.
- This document should be used in conjunction with the mapping guidance which will map content and/or skills covered within each set of questions.
- These materials are only intended to support the summer 2021 series.

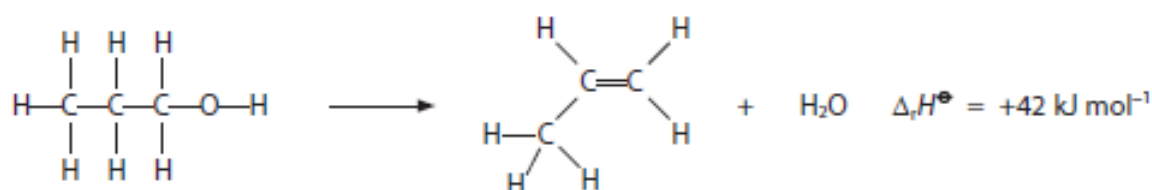
5 This question is about enthalpy changes and entropy changes.

(a) Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?

(1)

- A $4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$
- B $4\text{Al(s)} + 6\text{O(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$
- C $2\text{Al(s)} + 1\frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{Al}_2\text{O}_3\text{(s)}$
- D $2\text{Al(s)} + 3\text{O(g)} \rightarrow \text{Al}_2\text{O}_3\text{(s)}$

(b) Propan-1-ol is dehydrated to form propene.

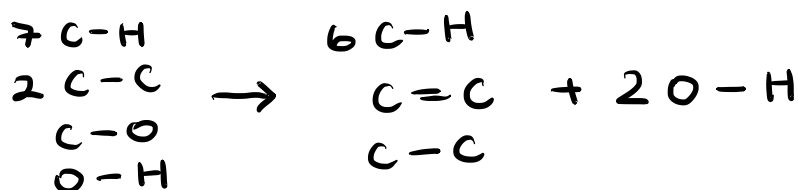


The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)



$$7 \times 413 + 2 \times 347 + x + 464 \rightarrow 6 \times 413 + 612 + 347 + 2 \times 464$$

$$4229 + x \rightarrow 4365$$

$$\Delta_f H^\ominus = \Delta_f H^\ominus (\text{products}) - \Delta_f H^\ominus (\text{reactants})$$

$$42 = 4365 - 4229 - x$$

$$42 = 136 - x$$

$$x = 94$$

$$\boxed{\text{C-O} : 94 \text{ kJ mol}^{-1}}$$

(c) Which reaction has a negative value for ΔS_{system} ?

(1)

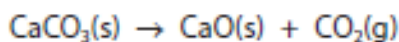
- A $2\text{Cu(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CuO(s)}$
 B $2\text{H}_2\text{O}_2\text{(l)} \rightarrow 2\text{H}_2\text{O(l)} + \text{O}_2\text{(g)}$
 C $\text{MgCO}_3\text{(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$
 D $\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$

(d) What is the expression for ΔS_{total} ?

(1)

- A $\Delta S_{\text{surroundings}} + \frac{\Delta H}{T}$
 B $\Delta S_{\text{surroundings}} - \frac{\Delta H}{T}$
 C $\Delta S_{\text{system}} + \frac{\Delta H}{T}$
 D $\Delta S_{\text{system}} - \frac{\Delta H}{T}$
- $\Delta S_{\text{total}} = -\frac{\Delta H}{T} + \Delta S_{\text{system}}$

(e) Calcium carbonate decomposes on heating.



$$\Delta_r H = +178 \text{ kJ mol}^{-1}$$

$$\Delta S_{\text{system}} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$$

Show, by calculating the value for the free energy change, ΔG , that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

$$\Delta G = \Delta H - T\Delta S \quad 165 = 0.165 \text{ kJ mol}^{-1} \text{ K}^{-1} \quad (3)$$

$$= 178 - 298 \times 0.165$$

$$= 178 - 49.17 = 128.83 \text{ kJ} > 0 \quad \therefore \text{not feasible at 298K}$$

9 This is a question about buffer solutions.

(a) A buffer solution always

(1)

- A keeps the pH less than 7.
- B contains equimolar amounts of acid and its conjugate base.
- C keeps the pH constant if small quantities of acid or base are added.
- D resists changes in pH if small quantities of acid or base are added.

(b) A buffer solution with a pH of 3.90 is required.

Calculate the mass, in grams, of sodium ethanoate that should be added to 50.0 cm^3 of an ethanoic acid solution of concentration $0.800 \text{ mol dm}^{-3}$ to form this buffer solution.

Give your answer to an appropriate number of significant figures.

$[K_a \text{ for ethanoic acid} = 1.74 \times 10^{-5} \text{ mol dm}^{-3}]$

(5)

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

$$\text{pH} = 3.90$$

$$[\text{H}^+] = 10^{-3.90} \\ = 1.2589 \times 10^{-4}$$

$$1.74 \times 10^{-5} = \frac{[\text{CH}_3\text{COO}^-] \times 1.2589 \times 10^{-4}}{0.800}$$

$$[\text{CH}_3\text{COO}^-] = 0.11057$$



$$= 82$$

$$\text{mole of } \text{CH}_3\text{COONa} = \frac{50 \times 0.11057}{1000}$$

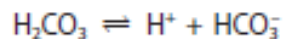
$$5.5285 \times 10^{-3} = \frac{\text{mass}}{82}$$

$$= 5.5285 \times 10^{-3}$$

$$\text{mass} = 0.4533 \text{ g}$$

$$\approx 0.453 \text{ g}$$

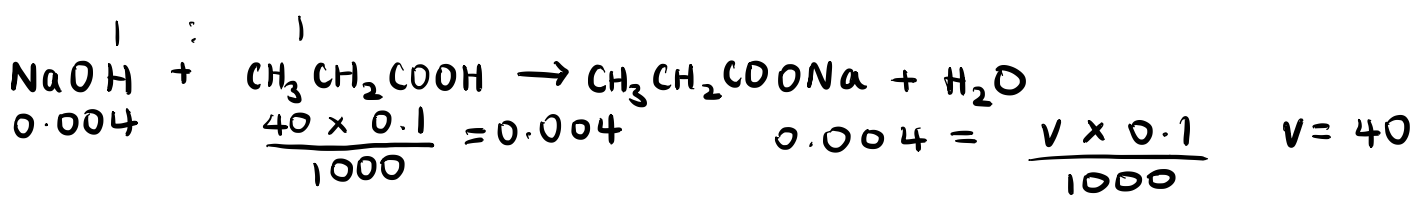
(c) One of the systems controlling the pH of blood is the carbonic acid-hydrogencarbonate buffer system.



Explain how this buffer system helps to control the pH of blood when extra carbon dioxide is present due to strenuous exercise.

(3)

The extra carbon dioxide dissolves in blood and forms carbonic acid by reacting with a base, water. This increases carbonic acid and H^+ levels ^{decreasing pH of blood.} The lungs remove excess carbonic acid (thus CO_2) ^{by} increasing the breathing rate. This lowers the level of carbonic acid shifting the equilibrium towards left hand side to resist change. Hence, it will promote H^+ and HCO_3^- to bind and form H_2CO_3 . As H^+ are getting used up, its concentration decreases increasing blood pH back to normal.



(d) A weak acid-strong base titration curve can be used to demonstrate buffer action.

- (i) Draw a titration curve for the addition of 100 cm^3 of sodium hydroxide solution of concentration $0.100 \text{ mol dm}^{-3}$ to 40.0 cm^3 of propanoic acid solution of concentration $0.100 \text{ mol dm}^{-3}$ which has a pH of 3.0.

Show the part of the curve that demonstrates buffer action.

(4)

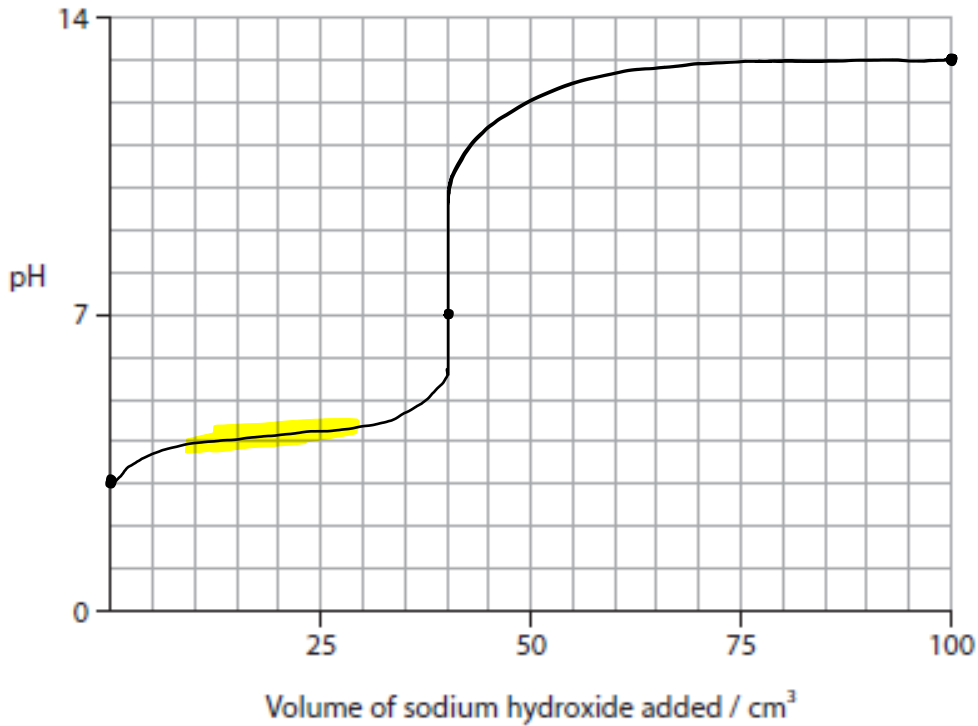
$$\text{pOH} = -\log 0.1$$

$$= 1$$

$$\text{pH} = 14 - 1$$

$$= 13$$

Buffer action



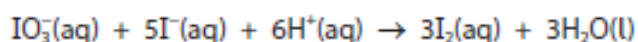
- (ii) Describe, without calculation, how you would use your curve to determine the value of K_a for propanoic acid.

(2)

pH equals to pka when half of the volume of sodium hydroxide required to completely neutralise the weak acid or reach equivalence point (so half of $40 \text{ cm}^3 = 20 \text{ cm}^3$). Hence read off the pH value when 20 cm^3 of sodium hydroxide is added.

9 This question is about the reaction kinetics of an 'iodine clock' reaction.

One example of an 'iodine clock' reaction that involves the iodate(V) ions and iodide ions in acidic solution is



(a) State why the order of reaction with respect to iodide ions cannot be five, even though 5 mol of iodide ions are shown in the equation.

(1)

Because the order of reaction is about the relationship between the rate and the reactant concentration,

✓ not the number of moles. So for order of reaction to be

5, when the concentration of iodide increases by a double (x2), the rate of reaction should increase by a factor of 2⁵.

(b) A series of experiments was carried out by a student to determine the order of reaction with respect to iodate(V) ions. The concentrations of the iodide ions and the acid were in large excess and the volume of the iodate(V) solution was varied.

The total volume of the reaction mixture was kept constant by the addition of suitable volumes of deionised water.

The following results were obtained:

Experiment Number	1	2	3	4	5	6
Volume of iodate(V) solution / cm ³	10.0	7.0	5.0	3.0	2.0	1.0
Time (t) / s	180	260	357	606	900	800
(1000/t) / s ⁻¹	5.56	3.85	2.80	1.65	1.11	1.25

(i) In experiment 6, the student forgot to add deionised water to keep the total volume the same for each experiment.

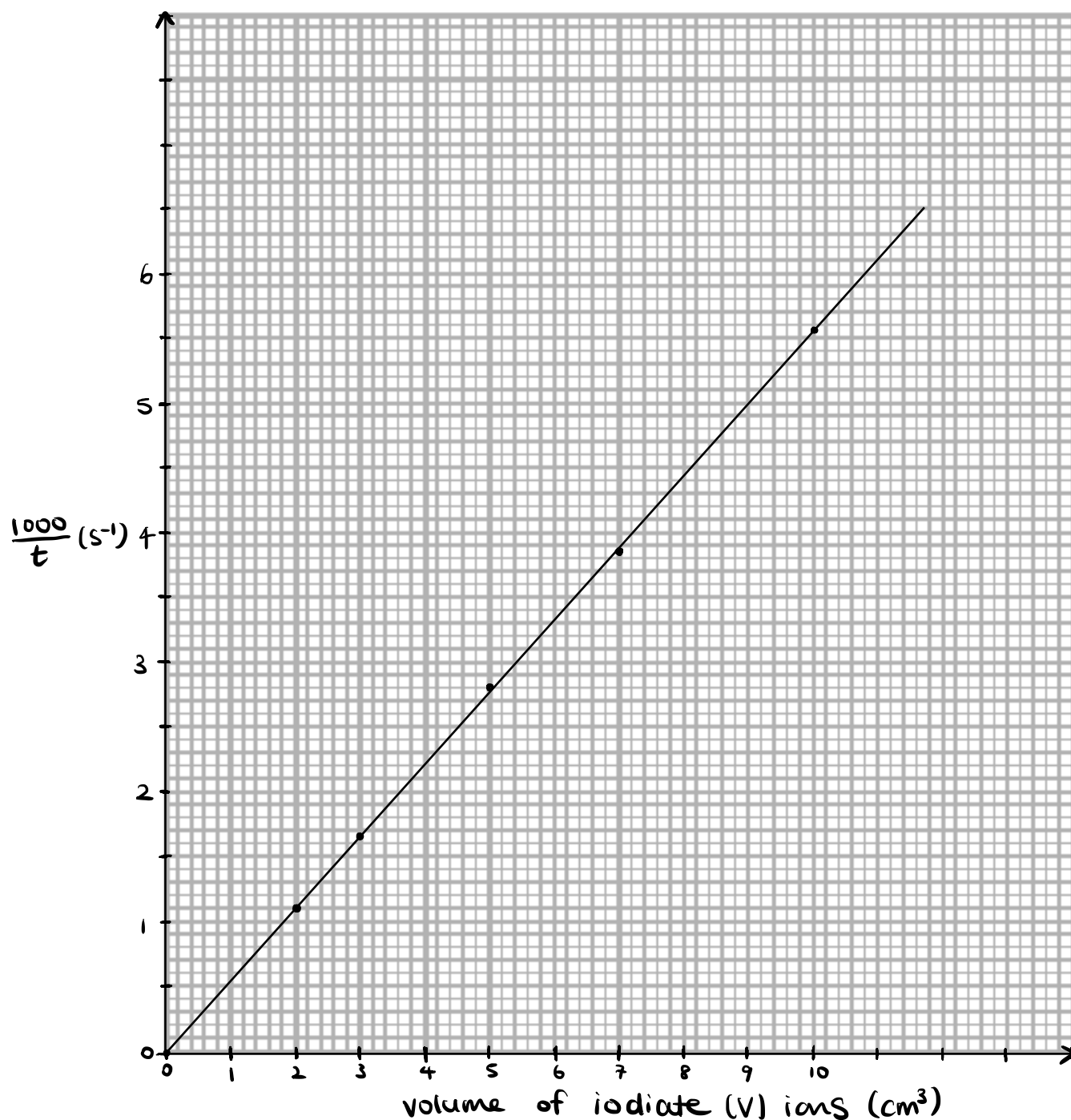
State why the total volume should be kept the same.

(1)

To ensure only one variable, concentration, is changing so that it is a fair test. Any change in time taken / rate of reaction is only due to the concentration (the change in volume of iodate solution).

(ii) Complete the table and use the results from experiments 1, 2, 3, 4 and 5 to plot a graph of $1000/t$ against volume of iodate(V) ions.

(4)



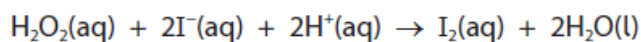
(iii) Deduce the order of reaction with respect to the iodate(V) ions. Justify your answer.

(2)

The order of reaction is 1 because the graph is a straight line (volume has a uniform effect on the time or rate). When volume increases by a double (5cm^3 to 10cm^3), the $1000/t$ increased by a double nearly (2.80 to 5.56)

- (c) A different version of the 'iodine clock' reaction involves mixing hydrogen peroxide with aqueous solutions of potassium iodide, sodium thiosulfate and starch.

The main reaction is



The reaction is first order with respect to hydrogen peroxide and iodide ions but zero order with respect to hydrogen ions.

- (i) In one experiment, the following data were obtained:

Reactants	Initial concentration / mol dm ⁻³
H ₂ O ₂ (aq)	1.50 × 10 ⁻³
I ⁻ (aq)	2.10 × 10 ⁻³
H ⁺ (aq)	2.10 × 10 ⁻³

$$\text{Initial rate} = 1.24 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$$

Write the rate equation and hence deduce the value of the rate constant, k , from these data. Include units and give your answer to an appropriate number of significant figures.

$$\text{rate} = k[\text{H}_2\text{O}_2][\text{I}^-] \quad (2)$$

$$1.24 \times 10^{-3} = k \times 1.50 \times 10^{-3} \times 2.10 \times 10^{-3}$$

$$1.24 \times 10^{-3} = k \times 3.15 \times 10^{-6}$$

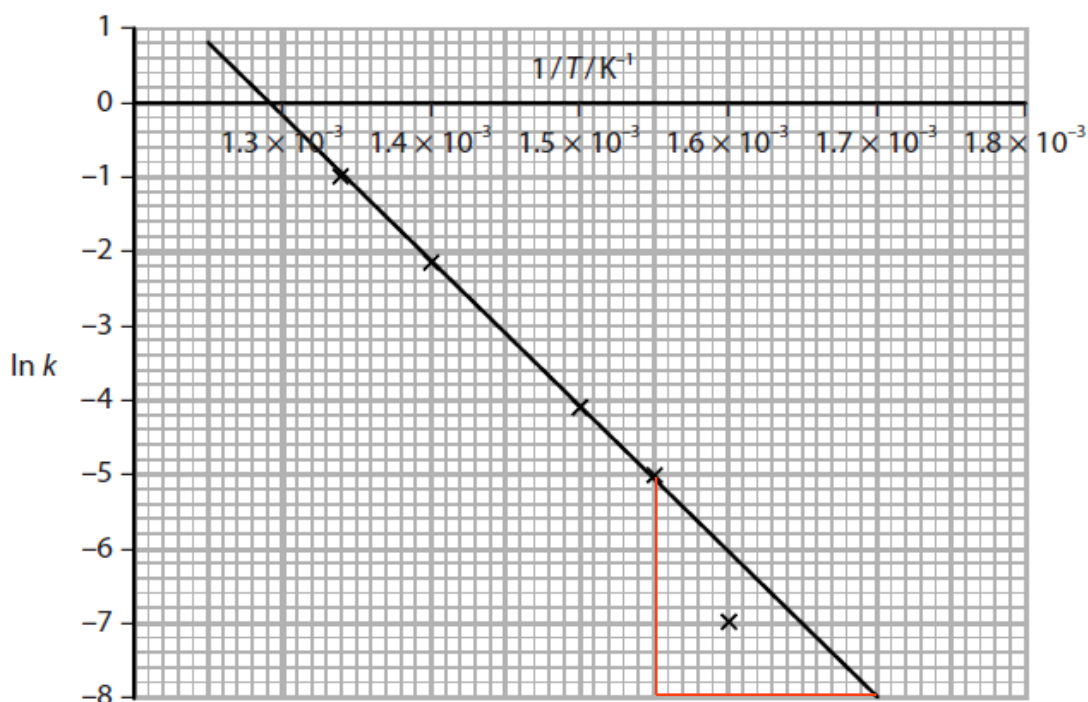
$$k = 393.65 \approx \boxed{394 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}}$$

- (ii) Explain the purpose of the starch present in the reaction mixture when starch is neither in the rate equation, nor in the reaction equation.

(2)

Starch is used as an indicator for iodine. If iodine is formed, the colour would change from colourless to blueblack indicating the presence of iodine.

- (d) Another 'iodine clock' reaction produced data that enabled the following graph of $\ln k$ against $1/T$ to be drawn.



- (i) The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \left[\frac{1}{T} \right] + \text{constant}$$

From the gradient of the graph, determine the activation energy, E_a , for this reaction.

Include a sign and units in your answer.

$$\text{gradient} = \frac{-8 - (-5)}{1.7 \times 10^{-3} - 1.55 \times 10^{-3}} = -20000 \quad (3)$$

$$-\frac{E_a}{R} = -20000 \quad E_a = 166200 \text{ J mol}^{-1}$$

\swarrow 8.31

$$= \boxed{+166.2 \text{ kJ mol}^{-1}}$$

- (ii) Give a reason for the point at $\ln k = -7$ not being included in the line drawn on the graph.

(1)

Because it does not fit the trend. It is an anomaly.

Total for Test = 40 marks