A' Level Chemistry
Year 2

Unit 12: The Arrhenius Equation

Summer Examination Revision Pack

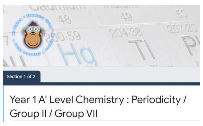
The questions in this pack should be attempted **AFTER** completing all other revision.

Grade Accelerator
Recall Definitions
Drawing Diagrams
Using Equations
Drawing Graphs

Quizlet

Quizlet Classes
Flashcard Based
Games
Tests & Quizzes
Keyword Spell Checker

Condensed Notes
Keywords & Definitions
Key Concepts
Application
Key Skills



Online Forms
Take Time to Answer
Use Paper & Calculator
Work It Out
Review Missed Marks

Use the 3 Wave Process when completing these revision packs.

1. Complete the questions without assistance
(Can't answer a question? Leave it and move on)
2. Use your notes to fill any gaps after step 1
3. Use the mark scheme to fill in any remaining gaps.

1. Having gaps after step 1 is normal, that's why we are doing revision!
2. If your notes don't help during step 2, they are not good enough!
(Change your note taking method and try to understand the problem)
3. If you don't understand why the mark scheme answer is correct, **see Andy.**

STOP If you struggle with the questions in the pack, **STOP!** and complete some more revision.

STOP If you come to a complete dead-end, **STOP!** and speak to **Andy** asap.

0 3 . 2 An equation that relates the rate constant, k, to the activation energy, E_a, and the temperature, T, is

$$\ln k = \frac{-E_a}{RT} + \ln A$$

Use this equation and your answer from Question **3.1** to calculate a value, in kJ mol^{-1}, for the activation energy of this reaction at 25 °C.

For this reaction $\ln A = 16.9$

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

(If you were unable to complete Question **3.1** you should use the value of 3.2×10^{-3} for the rate constant. This is not the correct value.)

[4 marks]

Activation energy ______________________ kJ mol^{-1}

7

Question	Answers	Mark	Additional Comments/Guidance	
03.2	$\ln k$ = $\ln 2.8 \times 10^{-2}$ (= - 3.58)	M1	M1 = ln (their k) If incorrect then award M2 and M3 only	Alternative value $\ln k = \ln 3.2 \times 10^{-3}$ = - 5.74
	E_a = RT(ln A - ln k) OR $-E_a$ = RT(ln k – ln A)	M2	if ln 16.9 used max 3 If temp used 25 max 2 Incorrect rearrangement then M1 only	
	E_a = 8.31 × 298 (16.9 + 3.58) (= 50716 J mol^{-1})	M3		E_a = 8.31 × 298 (16.9 + 5.74) (= 56076 J mol^{-1})
	E_a = 51 kJ mol^{-1}	M4	– 50.7 or -51 scores max 2	E_a = 56 kJ mol^{-1}
Total		**7**		

0 5 . 3 A second series of experiments was carried out to investigate how the rate of the reaction varies with temperature.
The results were used to obtain a value for the activation energy of the reaction, E_a

Identical amounts of reagents were mixed at different temperatures.
The time taken, *t*, for a fixed amount of bromine to be formed was measured at different temperatures.

The results are shown in **Table 3**.

Table 3

Temperature, *T* / K	$\frac{1}{T}$ **/ K^{-1}**	**Time, *t* / s**	$\frac{1}{t}$ **/ s^{-1}**	**ln $\frac{1}{t}$**
286	3.50×10^{-3}	54	1.85×10^{-2}	–3.99
295	3.39×10^{-3}	27	3.70×10^{-2}	
302		15	6.67×10^{-2}	–2.71
312	3.21×10^{-3}	8	1.25×10^{-1}	–2.08

Complete **Table 3**.

[2 marks]

0 5 . 4 The Arrhenius equation can be written as

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + C_1$$

In this experiment, the rate constant, *k*, is directly proportional to $\frac{1}{t}$

Therefore

$$\ln \frac{1}{t} = -\frac{E_a}{R}\left(\frac{1}{T}\right) + C_2$$

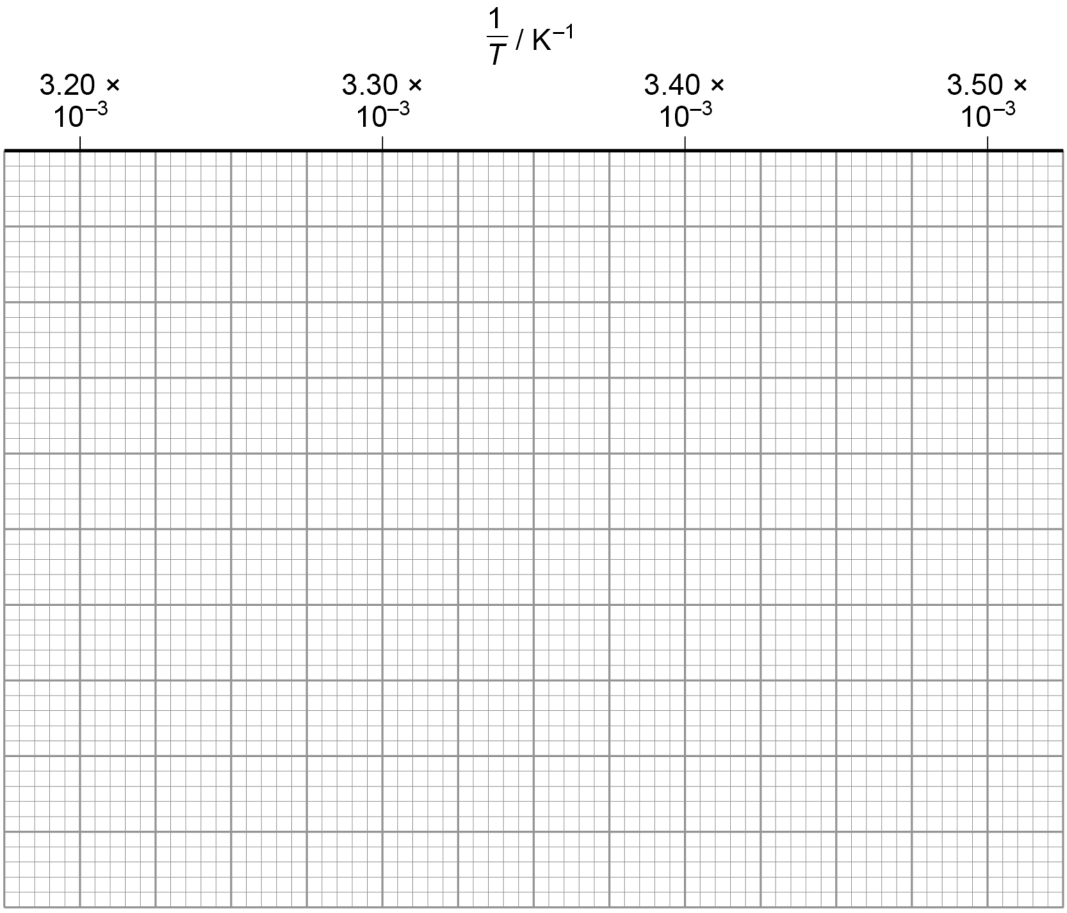
where C_1 and C_2 are constants.

Use values from **Table 3** to plot a graph of ln $\frac{1}{t}$ (y axis) against $\frac{1}{T}$ on the grid.

Use your graph to calculate a value for the activation energy, in kJ mol^{-1}, for this reaction.

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

[6 marks]



Activation energy ______________________ $kJ\ mol^{-1}$

14

Question	Answers	Mark	Additional Comments/Guidance
05.3 **G**	1/T value 3.31(1) × 10^{-3} or 0.00331(1) ln(1/t) value –3.30 or –3.297	1 1	Must be 3 sig figs or more Not allow –3.29
05.4 Can see 05.3	M1 y axis labelled with values (no units) and plotted points use over half of the axis M2 points plotted correctly (see graph below) M3 best fit straight line (minimum 3 points plotted) M4 gradient = – 6.64 × 10^3 (K) or -6640 (K) M5 E_a = M4 × 8.31 M6 = 55.2 kJ mol^{-1}	1 1 1 1 1 1	+ - one small square for line of best fit Range - 6.5 × 10^3 to - 6.8 × 10^3 or -6500 to -6800 If gradient outside range then max 4 for M1,M2,M3 and M5 Range 54.0 - 56.5
Total			14

Do not write outside the box

0 5 The rate constant, k, for a reaction varies with temperature as shown by the equation

$$k = Ae^{-E_a/RT}$$

For this reaction, at 25 °C, $k = 3.46 \times 10^{-8}\ s^{-1}$
The activation energy $E_a = 96.2\ kJ\ mol^{-1}$
The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Calculate a value for the Arrhenius constant, A, for this reaction.
Give the units for A.

[4 marks]

05 This question was pulled because it contained an error.
All students were awarded full marks for this question.

A ______________________ Units ______________________

4

Do not write outside the box

An experiment is done to investigate the rate of reaction in Question **04.2**.

0 4 . 4 During the experiment the concentration of cisplatin is measured at one-minute intervals.

Explain how graphical methods can be used to process the measured results, to confirm that the reaction is first order.

[3 marks]

In another experiment, the effect of temperature on the rate of the reaction in Question **04.2** is investigated.

Table 1 shows the results.

Table 1

Temperature T / K	$\frac{1}{T}$ / K^{-1}	**Rate constant** k / s^{-1}	**ln** k
293	0.00341	1.97×10^{-8}	–17.7
303	0.00330	8.61×10^{-8}	–16.3
313	0.00319	3.43×10^{-7}	–14.9
318		6.63×10^{-7}	
323	0.00310	1.26×10^{-6}	–13.6

0 4 . 5 Complete **Table 1**.

[2 marks]

0 4 . 6 The Arrhenius equation can be written in the form

$$\ln k = \frac{-E_a}{RT} + \ln A$$

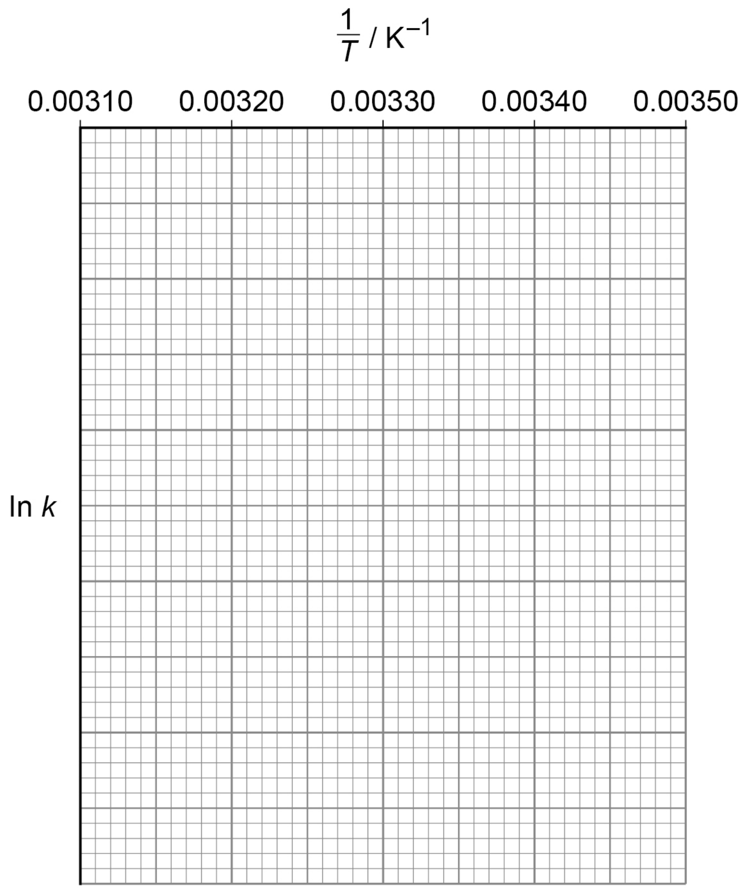
Use the data in **Table 1** to plot a graph of ln *k* against $\frac{1}{T}$ on the grid in **Figure 2**.

Calculate the activation energy, E_a, in kJ mol^{-1}

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

[5 marks]

Figure 2



E_a ______________________________ kJ mol^{-1}

Do not write outside the box

15

04.4	M1 plot concentration (y-axis) against time (x-axis) **and** take tangents / (calculate the) gradients (to calculate rates) M2 Plot rate/gradients against conc M3 straight line through origin / directly proportional confirms first order	Allow concentration-time graph NOT time-concentration graph (unless clarified in words or sketch) but mark on allow first order if rate halves/doubles when conc halves/doubles Alternatives to M2 and M3: M2 Plot a graph of log rate vs log conc M3 (Straight) line of gradient = 1 M2 measure (at least) two half-lives (in this case, tangents not required for M1) M3 constant half-life means first order M2 compare rates/gradients at different concentrations M3 first order if rate halves when conc halves	1 1 1

<table>
<tr>
<td>04.5</td>
<td>
<table>
<tr><th>temperature, T / K</th><th>$\frac{1}{T}$ / K^{-1}</th><th>rate constant, k / s^{-1}</th><th>ln k</th></tr>
<tr><td>318</td><td>0.00314</td><td>6.63×10^{-7}</td><td>–14.2</td></tr>
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</td>
<td>Allow 3.14×10^{-3}</td>
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1</td>
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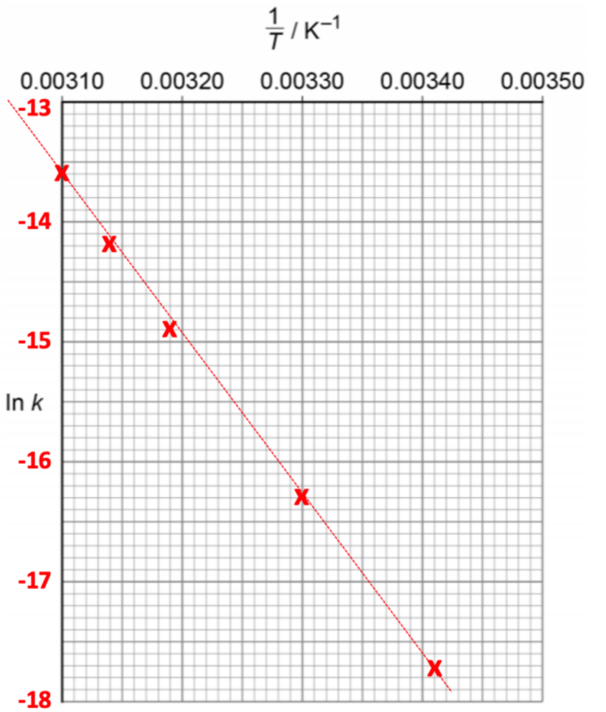
<td>04.6</td>
<td>


Gradient = –13 125
$\left(-13125 = \frac{-E_a}{R}\right)$
$E_a = 13\,125 \times 8.31 = 109\,069$
$= 109$ (kJ mol^{-1})
</td>
<td>Vertical axis with sensible scales (plotted points must take up more than half the grid)
NOT M1 if y-axis in wrong direction

all points plotted correctly (within ±0.5 small square)

Best fit straight line based on the student's data (ignoring anomalous point if relevant)

Gradient calculated within range:
12876 - 13598

Mark is for their (gradient x 8.31) and conversion into kJmol^{-1}
E_a in the range: 107 – 114 kJ mol^{-1}
NOT a negative activation energy</td>
<td>1

1

1

1

1</td>
</tr>
</table>

Do not write outside the box

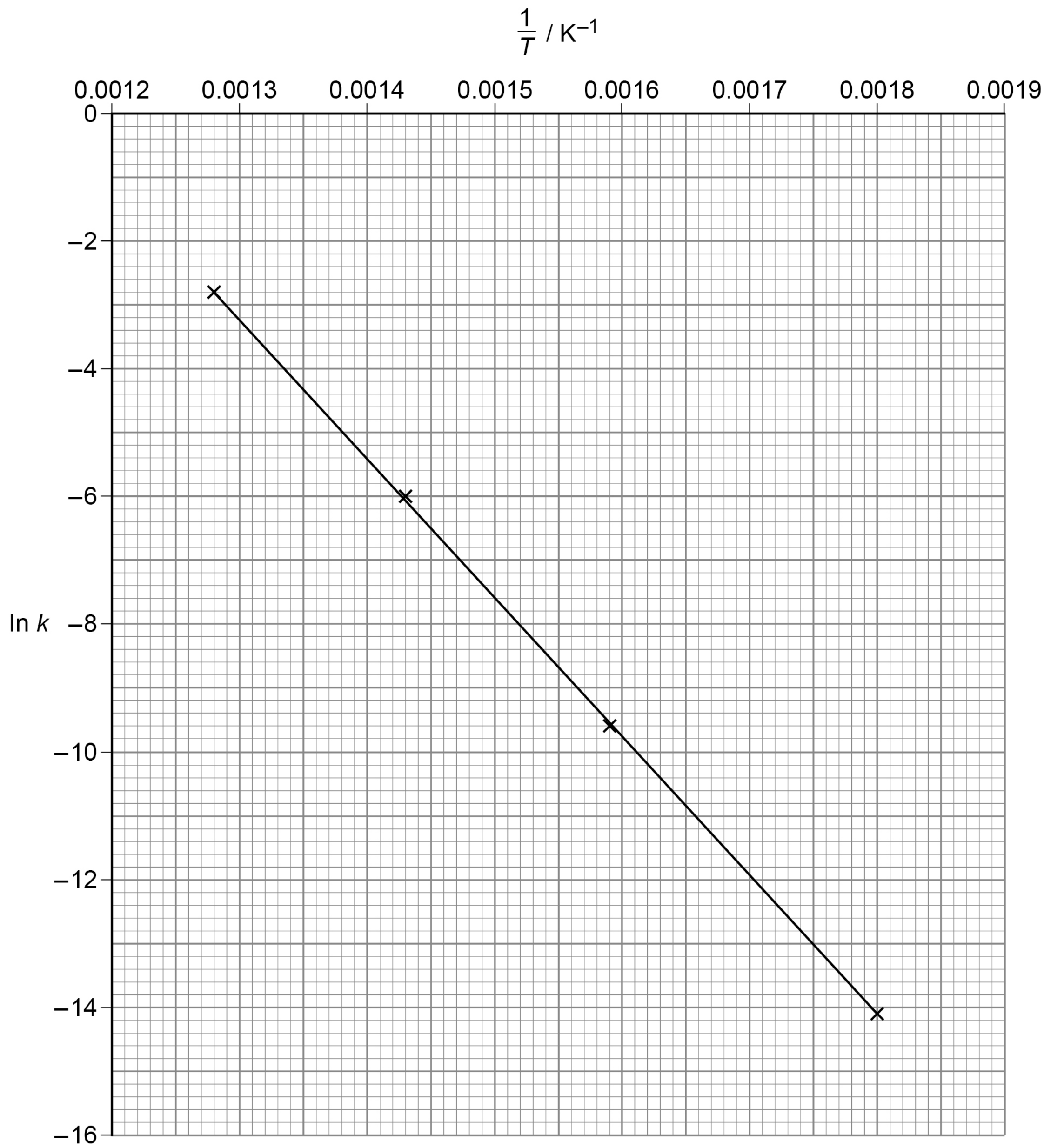
10.5 The Arrhenius equation can be written as

$$\ln k = \frac{-E_a}{RT} + \ln A$$

Figure 8 shows a graph of ln k against $\frac{1}{T}$ for the reaction

$$2\,HI(g) \rightarrow H_2(g) + I_2(g)$$

Figure 8



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Use **Figure 8** to calculate a value for the activation energy (E_a), in kJ mol^{-1}, for this reaction.

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

[3 marks]

E_a ______________________________ kJ mol^{-1}

12

END OF QUESTIONS

Question	Answers	Additional Comments/Guidelines	Mark
10.5	Gradient = (−14.1 − −2.8) / (0.00180 − 0.00128) = −11.3 / 0.00052 = −21731	Allow -21330 to -22130	M1
	Gradient = $-E_a$ / R $-E_a$ = their answer x 8.31 (= 180583 J mol^{-1})		M2
	E_a = M2 ÷ 1000 (= 181 kJ mol^{-1})		M3

Do not write outside the box

0 1 . 7 For a different reaction, **Table 2** shows the value of the rate constant at different temperatures.

Table 2

Experiment	Temperature / K	Rate constant / s^{-1}
1	$T_1 = 303$	$k_1 = 1.55 \times 10^{-5}$
2	$T_2 = 333$	$k_2 = 1.70 \times 10^{-4}$

This equation can be used to calculate the activation energy, E_a

$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Calculate the value, in kJ mol^{-1}, of the activation energy, E_a

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

[5 marks]

E_a __________________________ kJ mol^{-1}

Question	Answers	Additional Comments/Guidelines	Mark
01.7	$\ln(1.55 \times 10^{-5} / 1.70 \times 10^{-4}) = {}^{Ea}/_{R}\,({}^{1}/_{333} - {}^{1}/_{303})$ $-2.39 = {}^{Ea}/_{R}\,(-2.97 \times 10^{-4})$ ${}^{2.39 \times 8.31}/_{2.97 \times 10^{-4}} = E_a$ 66937 66.9 kJ mol^{-1}	Insertion of correct values Evaluate LHS and fraction on RHS Re-arrange for E_a Evaluate convert to kJ mol^{-1} If only k_1 and k_2 reversed this gives a negative answer for E_a Lose M1 and M5 If AE in M2 allow ECF Allow ECF from M4 to M5 for a correct unit conversion Allow range 66.3 – 67.1	M1 M2 M3 M4 M5 (5 x AO2)