16.2 Activation Energy

Question Paper

Course	DP IB Chemistry
Section	16. Chemical Kinetics (HL only)
Topic	16.2 Activation Energy
Difficulty	Medium

Time allowed: 60

Score: /49

Percentage: /100

Question 1a

a)
The decomposition of hydrogen peroxide into water and oxygen occurs at a slow rate with a rate constant of $k = 6.62 \times 10^{-3}$ mol dm^{-3} s^{-1} and at a temperature of 290 K.

Using Sections 1 and 2 of the Data Booklet, calculate the activation energy, E_a, correct to three significant figures and state its units.

The constant, $A = 3.18 \times 10^{11}$ mol^{-1} dm^3.

[3 marks]

Question 1b

b)
Hydrogen peroxide decomposes to form water and oxygen as shown in the equation below.

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

The table below shows the value of the rate constant at different temperatures for a reaction.

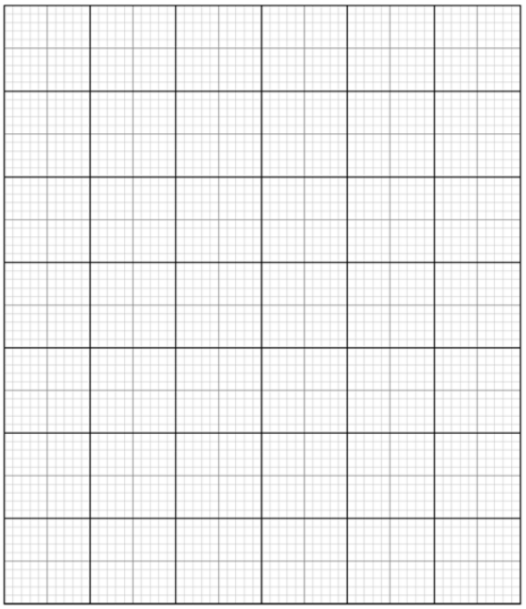
Rate constant k / s^{-1}	*ln k*	Temperature / K	$\frac{1}{T}$
0.000493		295	
0.000656		298	
0.001400		305	
0.002360		310	
0.006120		320	

Complete the table by calculating the values of *ln k* and $\frac{1}{T}$ at each temperature.

[2 marks]

Question 1c

c)
The results of the experiment can be used to calculate the activation energy, E_a. Use the results table to plot a graph of *ln k* against $\frac{1}{T}$.



[4 marks]

Question 1d

d)
Using Sections 1 and 2 of the Data Booklet and your graph, calculate a value for the activation energy, E_a, for this reaction. To gain full marks you must show all of your working.

[4 marks]

Question 2a

a)

The Arrhenius equation can be represented as $k = Ae^{-Ea/RT}$ in its exponential form.

State the effect on k of an increase in;

i) The constant, A, (frequency factor)

ii) Activation energy, E_a

iii) Temperature, T

[3 marks]

Question 2b

b)

Using Sections 1 and 2 of the Data Booklet, calculate the activation energy, E_a, of a reaction at 57°C and a rate constant of 1.30×10^{-4} mol dm^{-3} s^{-1}. The constant $A = 4.55 \times 10^{13}$.

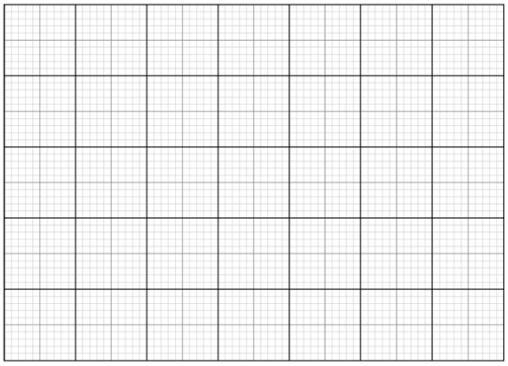
[2 marks]

Question 2c

c)
The table below shows how temperature affects the rate of reaction.

Rate constant k/s^{-1}	*ln k*	Temperature / K	$\frac{1}{T}$
2.0×10^{-5}	-10.8	278	0.00360
4.7×10^{-4}	-7.7	298	0.00336
1.7×10^{-3}	-6.4	308	0.00325
5.2×10^{-3}	-5.3	318	0.00314

Use the results to plot a labelled graph of *ln k* against $\frac{1}{T}$.



[3 marks]

Question 2d

d)
Using Sections 1 and 2 of the Data Booklet and your graph, calculate a value for the activation energy, E_a, for this reaction.

[4 marks]

Question 3a

a)
Nitrogen dioxide and ozone react according to the following equation.

$$2NO_2(g) + O_3(g) \rightarrow N_2O_5(g) + O_2(g)$$

Experimental data shows the reaction is first order with respect to NO_2 and first order with respect to O_3.

State the rate expression for the reaction.

[1 mark]

Question 3b

b)
At 30 °C, the initial rate of reaction is 3.46×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of NO_2 is 0.50 mol dm^{-3} and the initial concentration of O_3 is 0.21 mol dm^{-3}.

Calculate a value for the rate constant *k* at this temperature and state its units.

[3 marks]

Question 3c

c)
Using Sections 1 and 2 of the Data Booklet and your answer from part (b), calculate a value for the activation energy of this reaction at 30 °C.

For this reaction $\ln A = 15.8$ mol^{-1} dm^3.

[4 marks]

Question 3d

d) The relationship between the rate constant and temperature is given by the Arrhenius equation, $k = Ae^{-\frac{Ea}{RT}}$

State how temperature affects activation energy.

[1 mark]

Question 4a

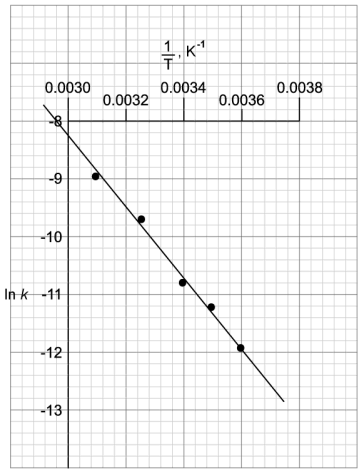
a)
A common relationship exists between temperature and rate.

What temperature change is associated with a doubling of rate?

[1 mark]

Question 4b

b) An Arrhenius plot of ln *k* against $\frac{1}{T}$ for the reaction between A (g) and B (g) at different temperatures is shown in **Figure 1** below.



The equation of the line of best fit was found to be:

$$\ln k = -6154\left(\frac{1}{T}\right) - 8.2$$

Calculate the activation energy, E_a, for the reaction between A (g) and B (g).

[2 marks]

Question 4c

c)
Define the Arrhenius constant, *A*.

[2 marks]

Question 4d

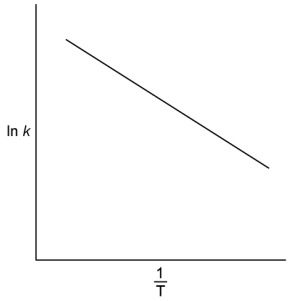
d)
Using the Arrhenius plot, calculate an approximate value for the constant, *A*.

[2 marks]

Question 5a

a)

The graph of ln *k* against $\frac{1}{T}$ for a general reaction is shown.



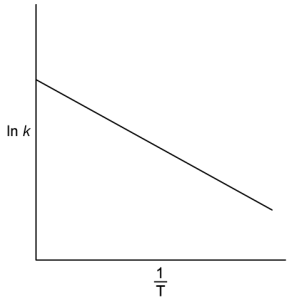
Sketch the expected line for a **different** reaction with a higher activation energy.

[1 mark]

Question 5b

b)

A graph of ln *k* against $\frac{1}{T}$ for another general reaction is shown.



Sketch the expected line for the **same** reaction with an added catalyst.

[2 marks]

Question 5c

c)
Rate constant data for the reaction of hydrogen and iodine at two different temperatures is shown in the table below.

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

Table 1

Experiment	Temperature / K	Rate constant, k / mol dm^{-3} s^{-1}
1	599	5.40×10^{-4}
2	683	2.80×10^{-2}

Using Sections 1 and 2 of the Data Booklet, calculate the activation energy, in kJ mol^{-1}, for the reaction.

[3 marks]

Question 5d

d)
Using the data from experiment 1 and Sections 1 and 2 in the Data Booklet, calculate a value for the constant, *A*.

Table 2

Experiment	Temperature / K	Rate constant, k / mol dm^{-3} s^{-1}
1	599	5.40×10^{-4}
2	683	2.80×10^{-2}

[2 marks]