



A-Level Chemistry

Maxwell-Boltzmann Curves

Question Paper

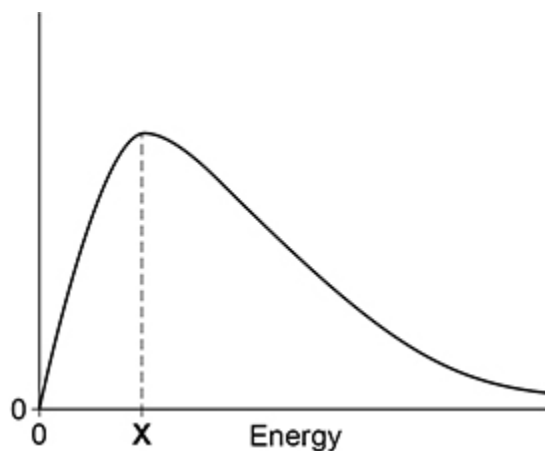
Time available: 60 minutes

Marks available: 58 marks

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1.

The figure below shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas.



(a) Label the y-axis on the figure above.

(1)

(b) State why the curve starts at the origin.

(1)

(c) State what **X** indicates on the figure above.

X indicates _____

(1)

(d) Half of the gas molecules in the sample are removed.
The remaining gas molecules are kept at the same temperature.

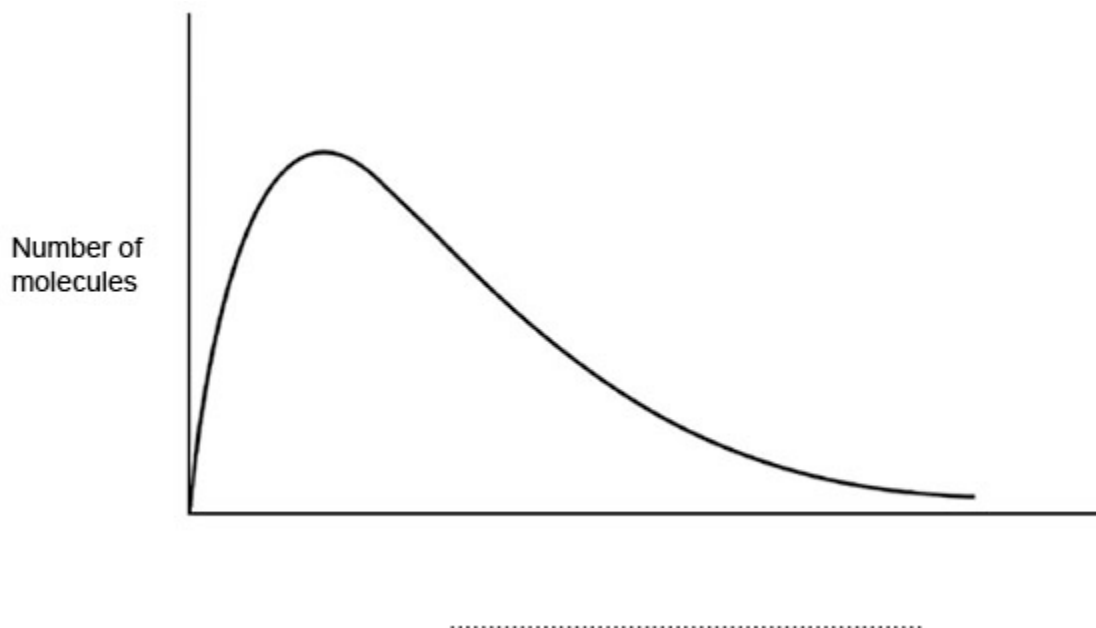
Draw the new distribution of molecular energies for the remaining gas on the figure above.

(2)

(Total 5 marks)

2.

The graph shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas at a fixed temperature.



(a) Label the horizontal axis on the graph.

(1)

(b) On the graph, sketch a distribution of molecular energies for this sample of gas at a higher temperature.

(2)

(c) This gas decomposes on heating.

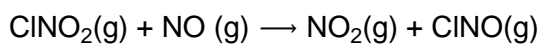
Explain why an increase in temperature increases the rate at which this gas decomposes.

(2)

(Total 5 marks)

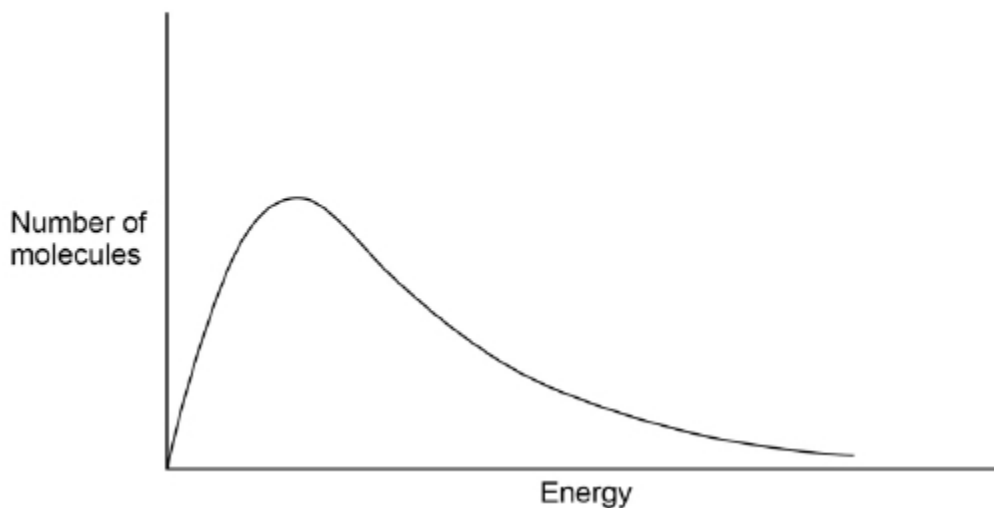
3.

Nitryl chloride reacts with nitrogen monoxide according to the equation:



The Maxwell–Boltzmann distribution curve in **Figure 1** shows the distribution of molecular energies in 1 mol of this gaseous reaction mixture (sample 1) at 320 K.

Figure 1



(a) On the same axes, draw a curve for sample 1 at a lower temperature.

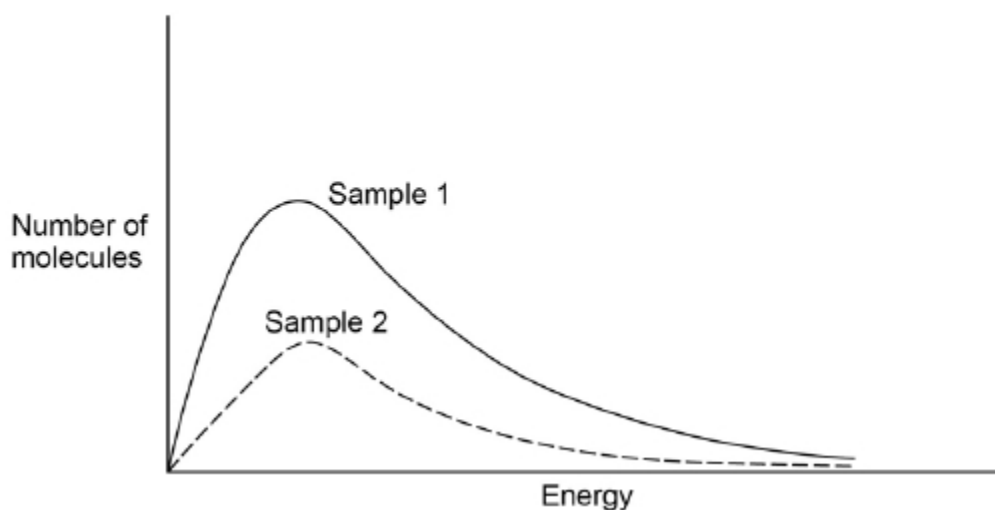
(2)

(b) Explain the effect that lowering the temperature would have on the rate of reaction.

(2)

- (c) A Maxwell–Boltzmann distribution curve was drawn for a second sample of the reaction mixture in the same reaction vessel. **Figure 2** shows the results.

Figure 2



Deduce the change that was made to the reaction conditions.

Explain the effect that this change has on the rate of reaction.

Change _____

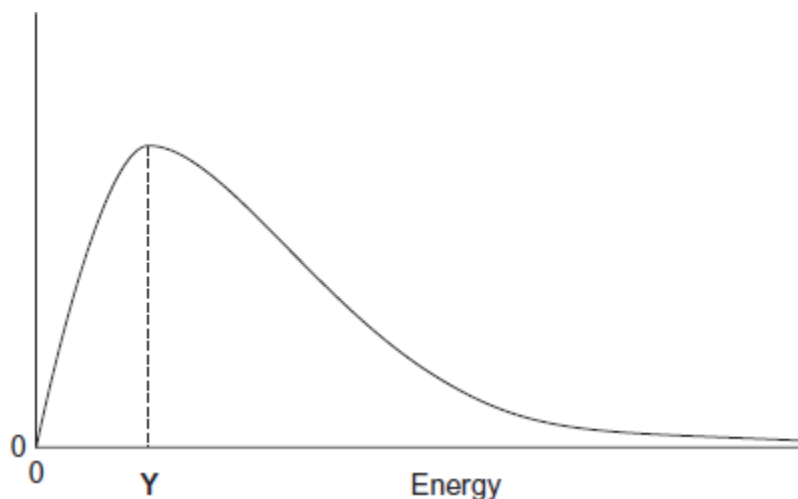
Explanation _____

(3)

(Total 7 marks)

4.

The following figure shows the Maxwell-Boltzmann distribution of molecular energies in a sample of gas at temperature T .



- (a) One of the axes is labelled.
Label the other axis.

(1)

- (b) State why the curve starts at the origin.

(1)

- (c) Which of the following, **A**, **B** or **C**, describes what the value of **Y** represents in the figure?
Write the correct letter, **A**, **B** or **C**, in the box.

- A** The energy needed for a successful collision
B The minimum energy needed for a reaction to occur
C The most probable energy

(1)

- (d) On the figure above, draw a distribution of molecular energies in this sample of gas at a **higher** temperature.

(2)

- (e) The pressure of the original sample of gas is doubled at temperature T .

State the effect, if any, of this change on the value of Y .

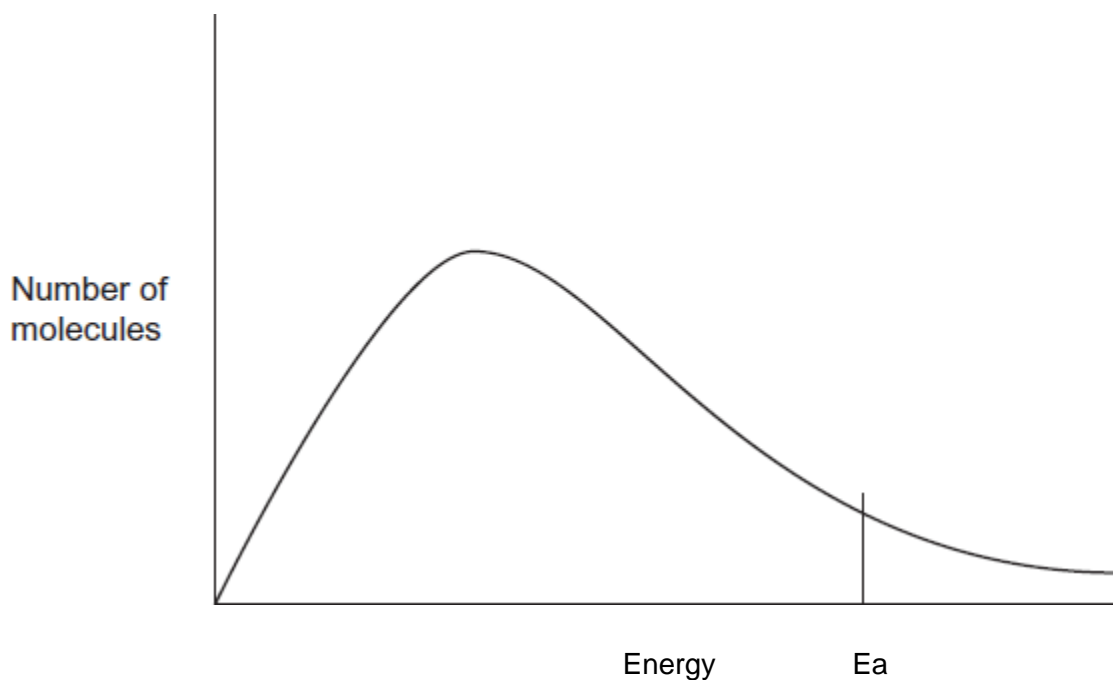
(1)

(Total 6 marks)

5.

The diagram shows the Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.

E_a is the activation energy for the decomposition of this gas.



E_{mp} is the most probable value for the energy of the molecules.

- (a) On the appropriate axis of this diagram, mark the value of E_{mp} for **this** distribution.

On this diagram, sketch a new distribution for the same sample of gas at a **lower** temperature.

(3)

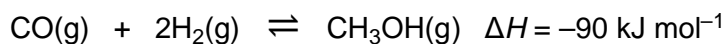
- (b) With reference to the Maxwell–Boltzmann distribution, explain why a decrease in temperature decreases the rate of decomposition of this gas.

(2)

(Total 5 marks)

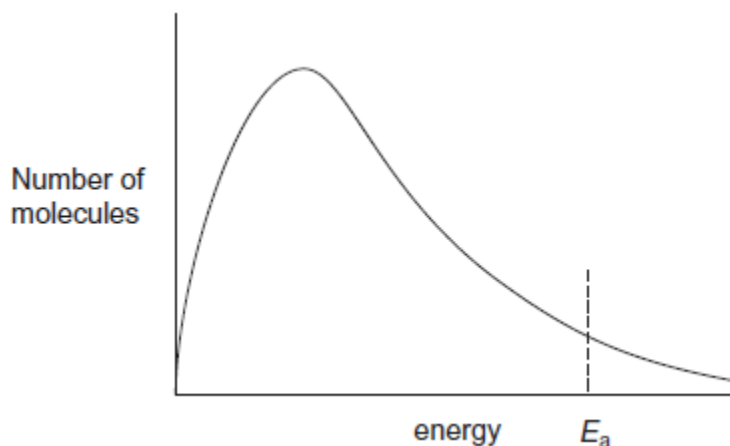
6.

Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.



The reaction is typically carried out at 300 °C and 3×10^7 Pa, in the presence of a catalyst.

- (a) The graph shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 °C.



- (i) Sketch a second curve on the graph to show the distribution of molecular energies in this mixture at a higher temperature.

(1)

- (ii) Explain with reference to both curves on the graph how a small change in temperature leads to a large change in the rate of reaction.

(2)

- (b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

- (i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

(3)

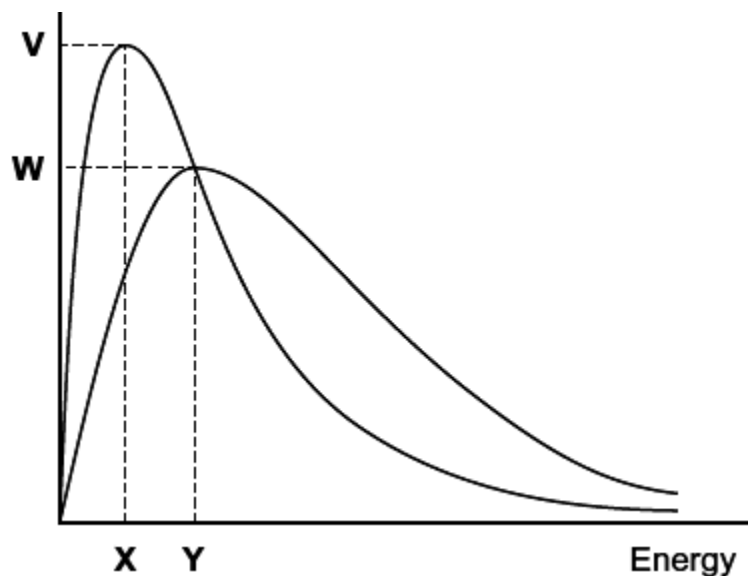
- (ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 °C rather than at a higher temperature.

(2)

(Total 8 marks)

7.

The diagram shows the Maxwell-Boltzmann distribution of molecular energies in a gas at two different temperatures.



- (a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1)

- (b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

(1)

- (c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1)

- (d) Explain what must happen for a reaction to occur between molecules of two different gases.

(2)

- (e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

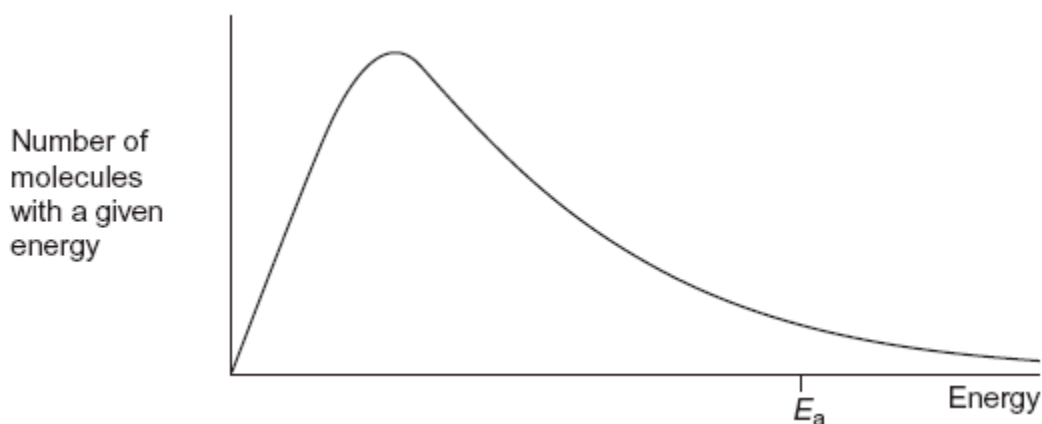
(1)

(Total 6 marks)

8.

The diagram below shows a Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.

E_a is the activation energy for the decomposition of this gas.



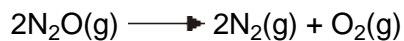
- (a) (i) On this diagram, sketch the distribution for the same sample of gas at a higher temperature.

(2)

- (ii) With reference to the Maxwell–Boltzmann distribution, explain why an increase in temperature increases the rate of a chemical reaction.

(2)

- (b) Dinitrogen oxide (N_2O) is used as a rocket fuel. The data in the table below show how the activation energy for the decomposition of dinitrogen oxide differs with different catalysts.



	$E_a / \text{kJ mol}^{-1}$
Without a catalyst	245
With a gold catalyst	121
With an iron catalyst	116
With a platinum catalyst	136

- (i) Use the data in the table to deduce which is the most effective catalyst for this decomposition.

(1)

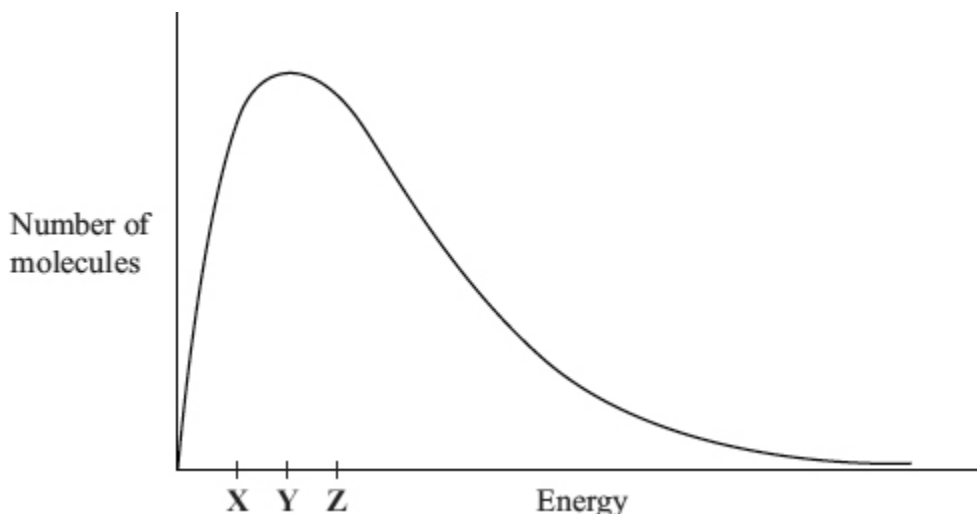
- (ii) Explain how a catalyst increases the rate of a reaction.

(2)

(Total 7 marks)

9.

The diagram below shows the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas.



- (a) (i) State which one of **X**, **Y** or **Z** best represents the mean energy of the molecules.

- (ii) Explain the process that causes some molecules in this sample to have very low energies.

(3)

- (b) On the diagram above, sketch a curve to show the distribution of molecular energies in the same sample of gas at a higher temperature.

(2)

- (c) (i) Explain why, even in a fast reaction, a very small percentage of collisions leads to a reaction.

- (ii) Other than by changing the temperature, state how the proportion of successful collisions between molecules can be increased. Explain why this method causes an increase in the proportion of successful collisions.

Method for increasing the proportion of successful collisions _____

Explanation _____

(4)

(Total 9 marks)