FACTFILE:
GCE CHEMISTRY

2.9 KINETICS

Rewarding Learning

Learning Outcomes

Students should be able to:

2.9.1 recall how factors, including concentration, pressure, temperature and catalyst, affect the rate of a chemical reaction;

2.9.2 use the collision theory and the concept of activation energy to qualitatively explain how these factors affect the reaction rate;

2.9.3 demonstrate a qualitative understanding of the Maxwell-Boltzmann distribution of molecular energies in gases and interpret curves for different temperatures and for catalysed and uncatalysed reactions;

2.9.4 relate the concept of activation energy to the Maxwell-Boltzmann distribution;

Chemical Kinetics

Reaction rate is the change of the amount of concentration (amount) of a reactant or product with respect to time.

Before a chemical reaction can occur the reacting particles must collide. After they collide, they may react. Whether they do or not depends on two factors:

1. The reacting species must approach each other in the correct orientation;
2. The reacting species must have the activation energy which is the minimum amount of energy required for the reaction to occur.

The rate of a chemical reaction can be affected by a number of factors:

- Concentration
- Temperature
- Pressure
- Catalysis

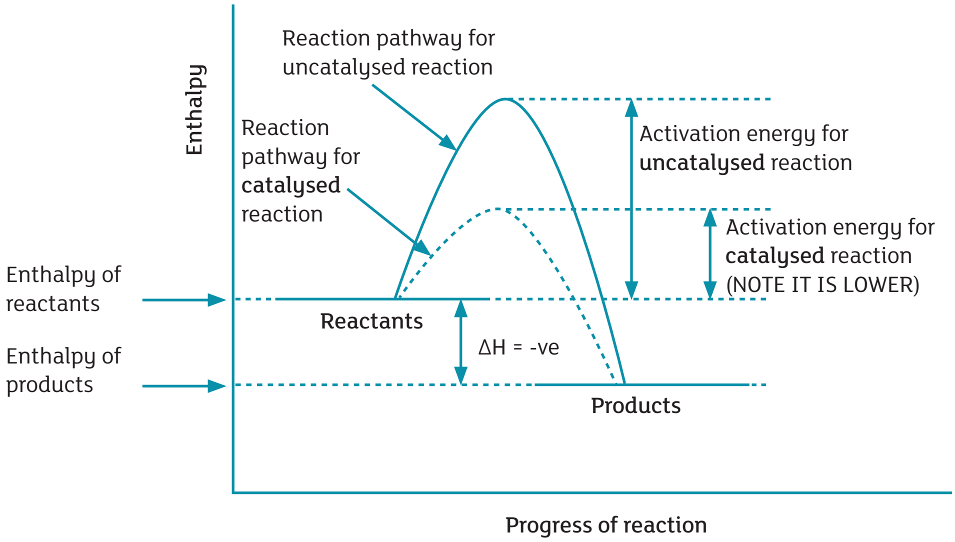
Increasing the concentration of a reactants means that there are more particles in the same volume and so more successful collisions (collisions with at least the activation energy) will occur per unit time. This leads to an increased rate of reaction.

Increasing the temperature means that the particles have more energy and so more particles have energy greater than the activation energy. This again leads to more successful collisions per unit time.

Increasing the pressure of a homogeneous gaseous reaction leads to the particles being forced into a smaller volume of space. More successful collisions will occur per unit time.

A catalyst is a substance which increases the rate of a chemical reaction but it is not used up.

Catalysts increase the rate of a chemical reaction by providing an alternative reaction pathway of lower activation energy.



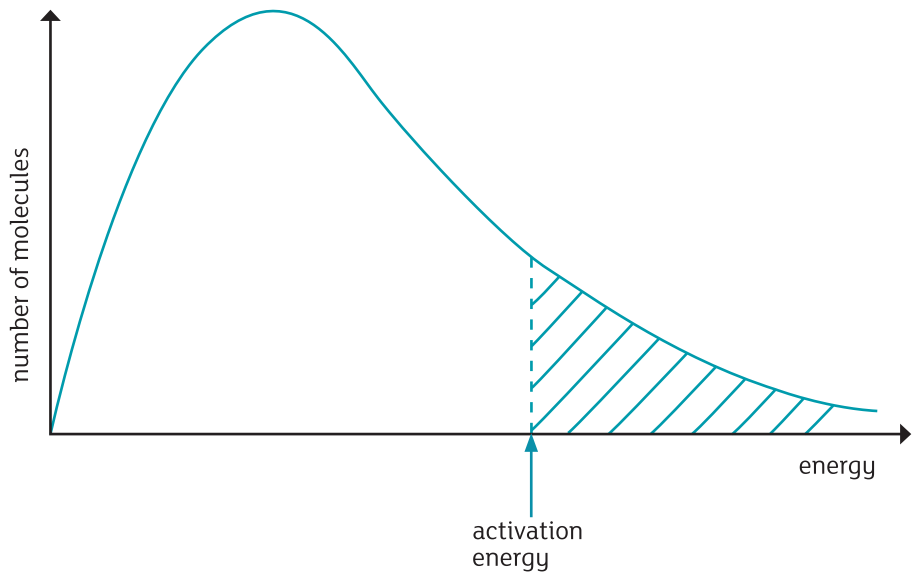
Enthalpy level diagram for an exothermic reaction

For example, consider the reaction of calcium carbonate with hydrochloric acid:

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

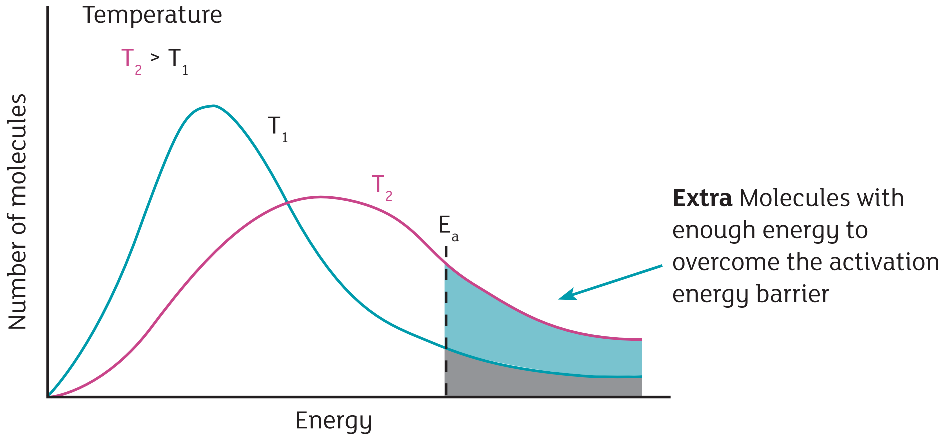
Increasing the concentration of the hydrochloric acid means there are more hydrogen ions in the same volume. This leads to an increase in collisions with the calcium carbonate and so the reaction proceeds at a faster rate. Similarly, breaking the solid calcium carbonate into smaller pieces means more of the surface is available to react with the hydrogen ions. This again leads to a faster rate of reaction.

In any system, the particles present will have a very wide range of energies. For gases, this can be shown on a graph called the **Maxwell-Boltzmann distribution** which is a plot of the number of particles having each particular amount of energy.

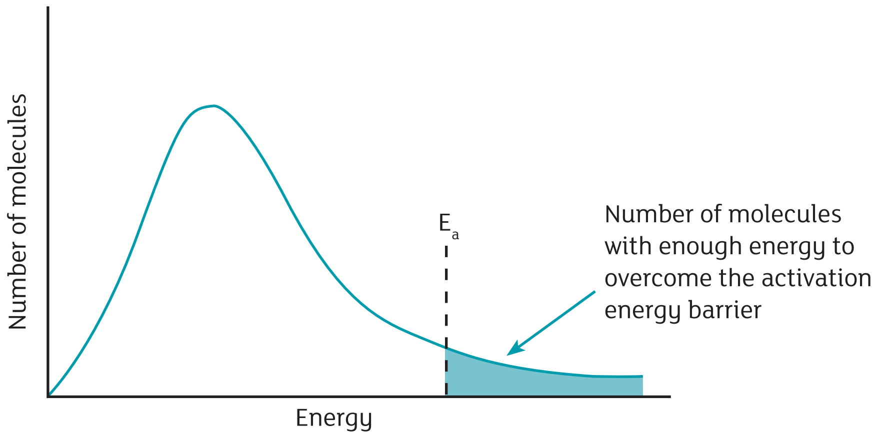


The area under the curve is a measure of the total number of particles present. For a reaction to happen, particles must collide with energies equal to or greater than the activation energy for the reaction. Notice that the large majority of the particles don't have enough energy to react when they collide.

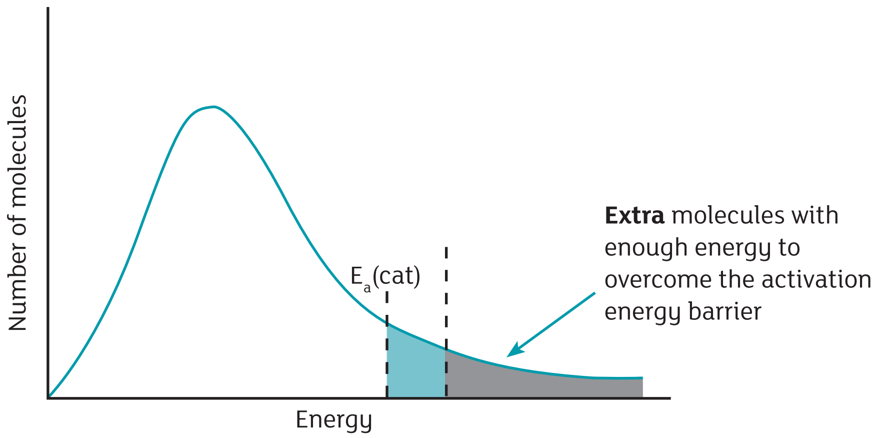
Increasing the temperature shifts the curve lower and to the right, resulting in more gas particles having energy equal or greater than the activation energy, leading to a faster reaction rate. If a catalyst is used, the position of the activation shifts to the left which has the same effect.



If a catalyst is used, the position of the activation energy on the curve shifts to the left which results in more gas particles having energy greater than or equal to the activation energy, leading to a faster reaction rate.



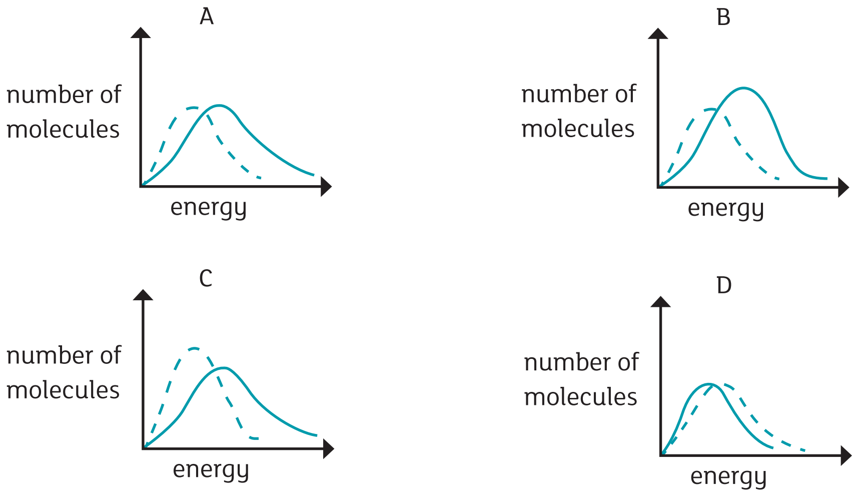
Maxwell-Boltzmann distribution showing the activation energy for the uncatalysed reaction (E_a).



Maxwell-Boltzmann distribution showing the activation energy for the catalysed reaction, E_a (cat).

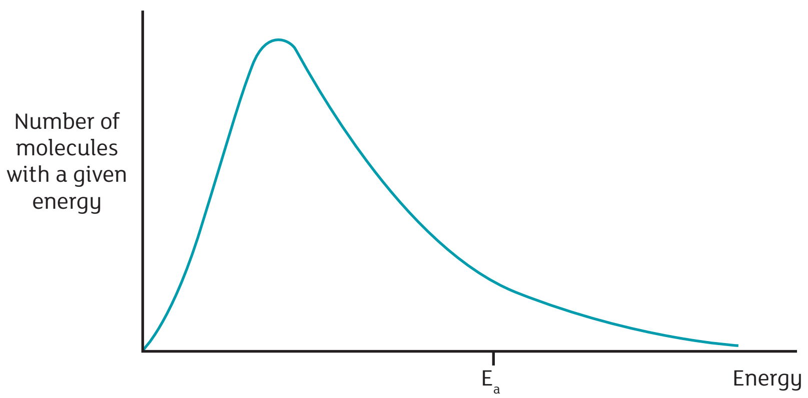
Revision Questions

1 Which one of the graphs below most accurately represents the distribution of molecular energies in a gas at 500 K if the dotted curve represents the distribution for the same gas at 300 K?



[1]

2 The diagram shows a Maxwell-Boltzmann distribution curve for a mixture of sulfur dioxide and oxygen at temperature T.
E_a = activation energy.



(a) On the diagram, sketch the distribution curve for the same mixture at a higher temperature. [2]

(b) Use these distribution curves to explain why the reaction between sulfur dioxide and oxygen is faster at the higher temperature.

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(c) Use the distribution curve to explain the role of catalyst and why the reaction between sulfur dioxide and oxygen is faster in the presence of a catalyst.

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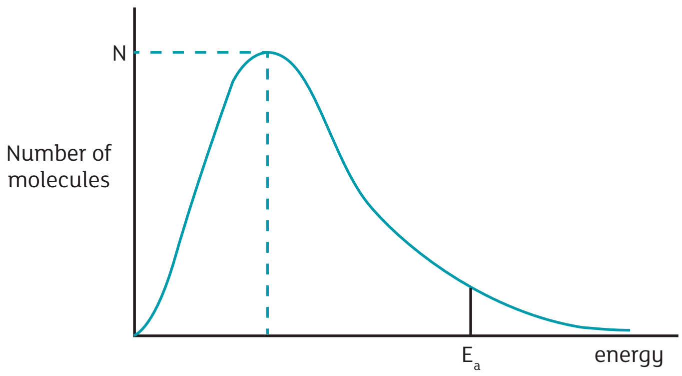
3 The Maxwell-Boltzmann distribution for a reaction mixture is shown below.
N is the number of molecules with the most probable energy and E_a is the activation energy.



Which one of the following shows the effect on E_a and on N of increasing the temperature?

	E_a	N
A.	constant	decreases
B.	constant	increases
C.	decreases	decreases
D.	decreases	increases

[1]