CAIE Chemistry A-level

8: Reaction Kinetics

Notes

Rate of Reaction

The rate of a reaction is expressed as **the change in concentration of a reactant or product per unit of time**.

Collision Theory

There are several factors which affect whether or not particles will react when they collide. For a successful reaction, particles must collide with the correct **orientation** and with **sufficient energy (activation energy)**.

Effect of Concentration

Increasing the concentration of reactants will increase the rate of reaction because there are more particles in the same volume so particles will collide more frequently. This means that there is a greater chance that the particles will collide at the correct orientation with sufficient energy for them to react, so there will be **more frequent successful collisions**.

Effect of Pressure

Increasing the pressure of reactants will increase the rate of reaction as there are the same number of particles in a smaller volume so particles will collide more frequently. This means that there is a greater chance that the particles will collide at the correct orientation with sufficient energy for them to react, so there will be **more frequent successful collisions**.

Measuring Rate of Reaction

There are several ways in which the rate of reaction can be measured, depending on the reaction:

- If a **precipitate** is produced, the rate could be measured by placing the reaction mixture over a black cross and timing how long it takes for the cross to disappear.
- If the reaction mixture **changes colour** during the reaction, colorimetry could be used to measure the amount of light absorbed by the mixture.
- If hydrogen ions are reacting or are produced, the **pH** could be measured using a pH probe. This method only works for large changes in hydrogen ion concentration.
- **Electrical conductivity** measurements can be taken to work out the rate of reaction. The electrical conductivity of a liquid depends on the concentration of ions so if ions are being used up, the conductivity will decrease.
- If a reaction **produces a gas,** the rate of reaction could be measured using:
    - a gas syringe to record the volume of gas produced;
    - an upturned measuring cylinder in a water trough to measure the volume of gas produced;
    - or a mass balance to measure the change in mass (mass will be lost as the gas escapes).

The rate of reaction can be calculated as follows:

Rate of reaction = (Amount of product formed or reactant used) ÷ (Time)

If you want to compare the initial rates of two reactions where the volume of gas collected is the same, it can be said that the **initial rate is inversely proportional** to the time it takes to collect the volume of gas:

Initial rate ∝ 1/t

Therefore, 1/t can be calculated and plotted as the initial rate.

Temperature and Rate

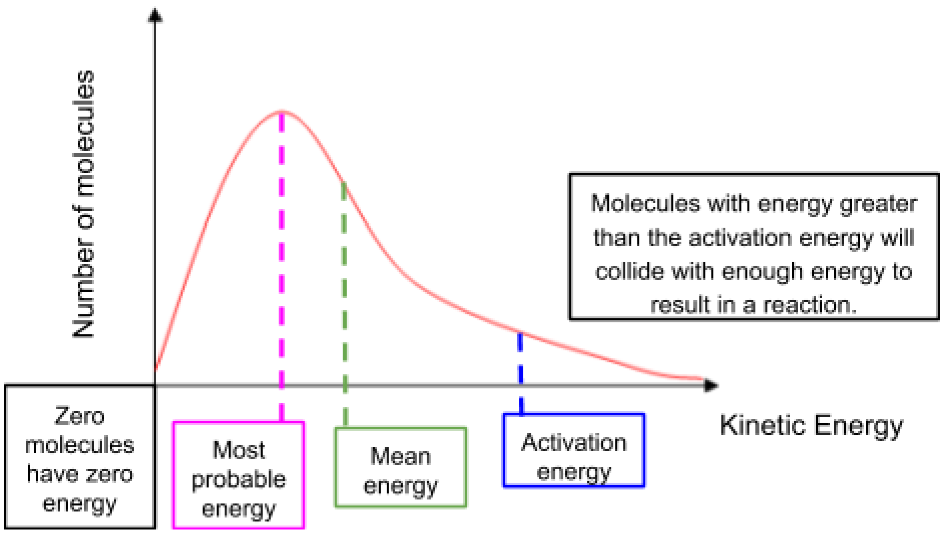
Activation Energy and the Boltzmann Distribution

The activation energy is the **minimum amount of energy** required for a reaction to occur between two colliding particles. Only particles with energy greater than or equal to the activation energy will be able to react. The particles must also collide with the **correct orientation**.

For gases, the relative energies of the particles can be plotted on a **Boltzmann distribution** graph. There are several key points to remember about Boltzmann distributions:

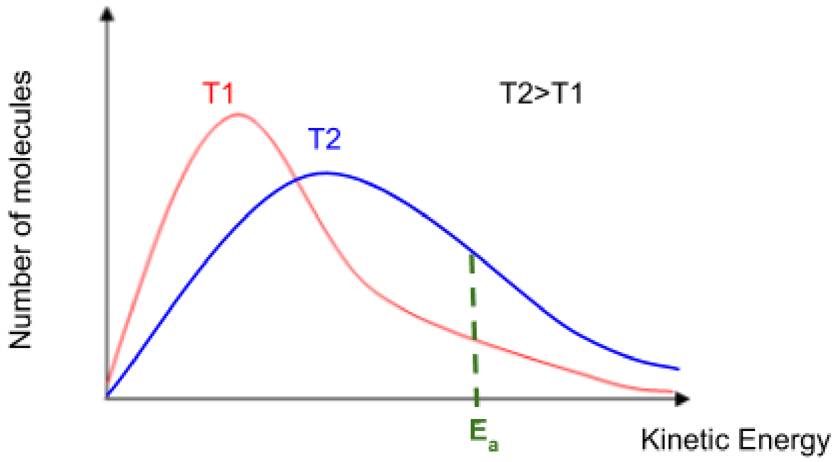
- The **area** under the curve is equal to the total number of particles present.
- No particles have **no energy**. The curve must start at (0,0).
- There is **no maximum** energy.
- Only particles with energy above the **activation energy** have sufficient energy to react when they collide.

The general shape of a **Boltzmann distribution**:



Changing Temperature

Below is a Boltzmann distribution showing the **relative energies of particles** at two different **temperatures** (T_2 is a higher temperature than T1):

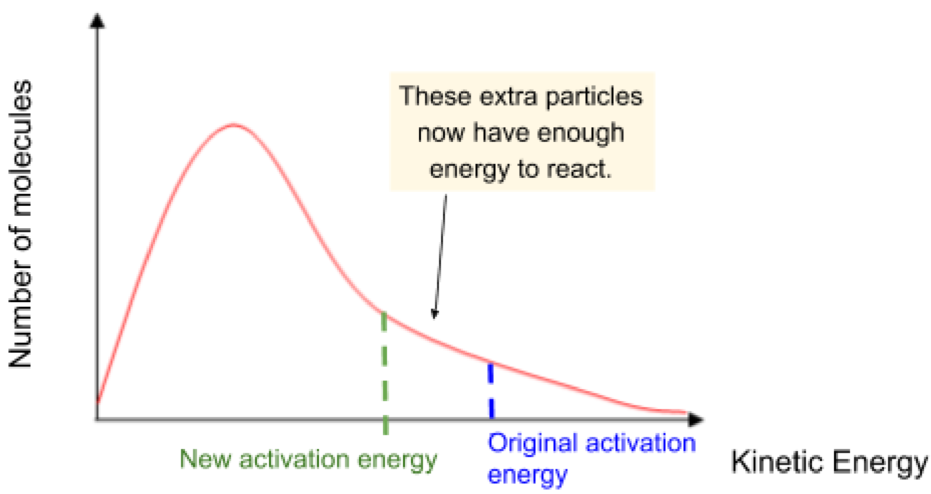


Increasing the temperature means the particles have **more kinetic energy** so there will be more collisions in the same amount of time. Also, a greater proportion of the particles will have **energy above the activation energy** (as seen in the Boltzmann distribution above), meaning more of the collisions will result in a reaction. This means there will be **more frequent successful collisions** so the rate of reaction will **increase**.

Catalysts

A catalyst is a substance which **speeds up the rate** of a reaction **without being chemically changed** at the end of the reaction. A homogeneous catalyst is in the same phase as the reactants while a heterogeneous catalyst is in a different phase to the reactants. In the presence of a catalyst, a reaction has a **different mechanism**, with a **lower activation energy**.

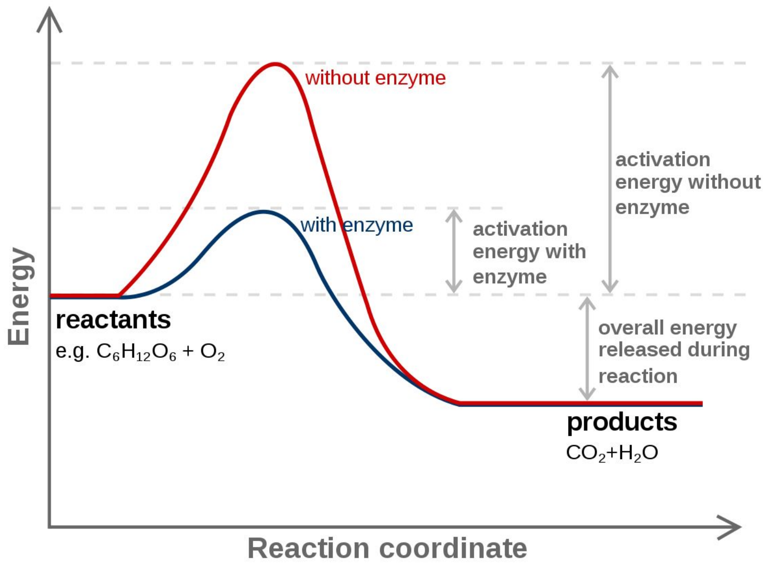
The Boltzmann distribution below shows the effect of catalysts:



Enzymes

Enzymes are **biological catalysts** made of **proteins**. They increase the rate of reactions in living cells. Enzymes are very **specific** (due to their specific shape) meaning they may only catalyse one reaction.

The following **reaction pathway diagram** shows how the enzyme catalyst reduces the activation energy of the reaction, so that the reaction is more likely to occur.



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