WJEC Chemistry AS-Level

2.2: Rates of Reaction

Detailed Notes

English Specification

Collision Theory

Chemical reactions occur when particles of substances **collide**. For a reaction to occur successfully, these collisions must have energy greater than or equal to the **activation energy** of the reaction and the particle **orientation** must be correct.

Changing Reaction Conditions

The conditions can be changed to increase the likelihood of a collision occurring with **sufficient energy** to react, in order to **increase the rate of reaction**.

1. **Temperature**
   When a substance is heated, **thermal energy** is transferred to it. This energy is converted to **kinetic energy** and the molecules of the substance move faster and further. Increased movement of the molecules means collisions would occur more often and with greater energy. As a result, **more collisions** have energy greater than the activation energy and **result in a reaction**.
   Therefore increasing the reaction temperature will **increase the rate of reaction** as more collisions of greater energy occur in a given time.

2. **Concentration and Pressure**
   When the concentration of a sample is increased, **more molecules** of substance occur in the same volume so they are packed closer together. Therefore, collisions between molecules become **more likely** and the chances of a collision occurring with energy greater than the activation energy increases. As a result, the rate of reaction increases. Increasing **pressure** has a similar effect as molecules are **packed closer together** into a smaller volume.

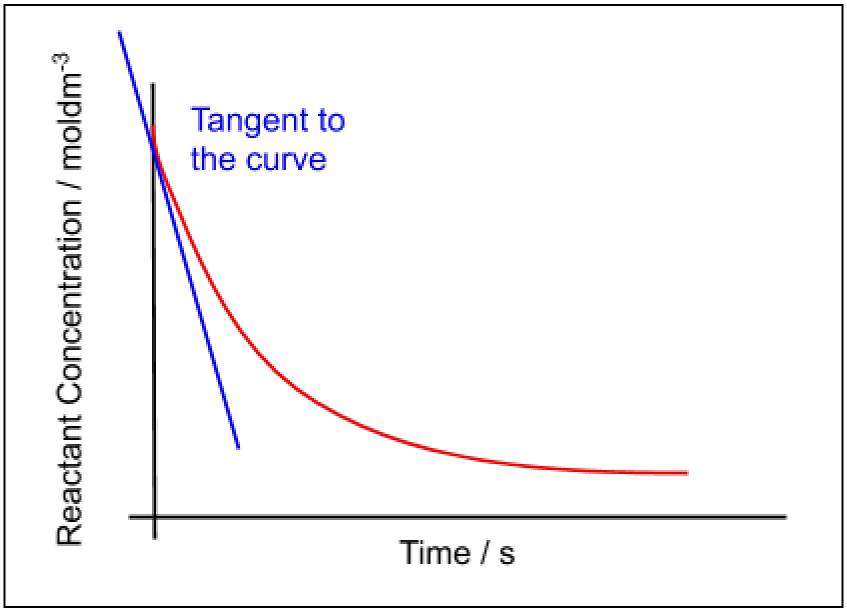
3. **Catalysts**
   A catalyst is a substance that **increases the rate of reaction** without being used up in the reaction. It works by providing an **alternative reaction path** that requires a lower activation energy for the reaction to occur.

Calculating Rates

Rates of reaction can be monitored **experimentally** by observing changes in volume or concentration change of products or reactants. The rate at a given point in a reaction can be found using a **graph** of experimental concentration data.

A concentration-time graph can be used to find the rate by drawing a **tangent** to the curve at **t=0**. The tangent is drawn at this point as it is the only time in the reaction where the exact concentration is known.

Example:

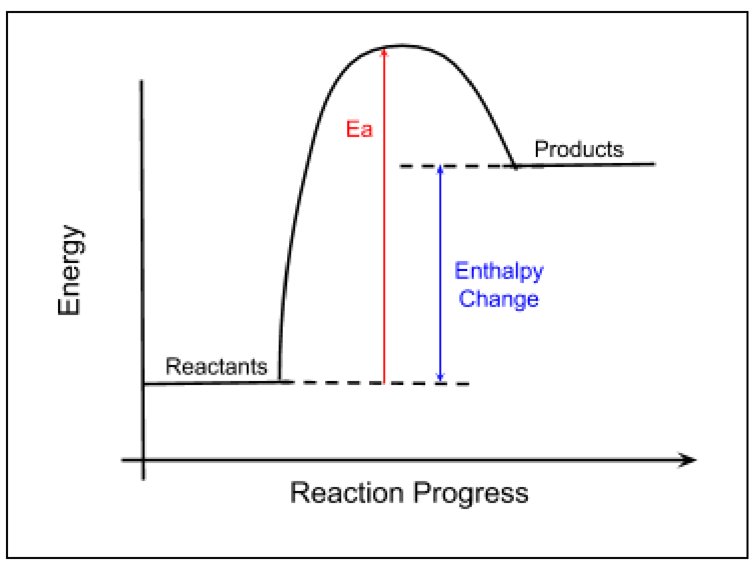


This method can then be repeated at **varying concentrations** to get a set of data for concentration and rate of reaction. This helps to identify the **relationship** between reactant concentration and rate.

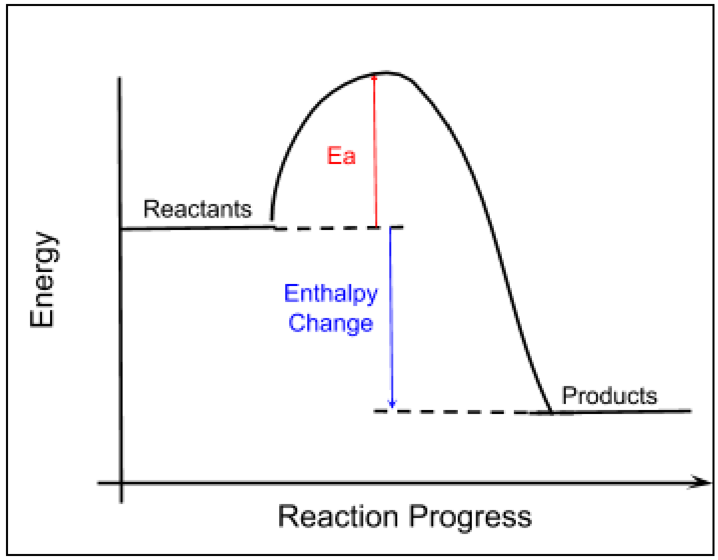
Energy Profiles

These are a way of representing energy changes in a reaction and help to identify them as **endothermic or exothermic**. The reactants and products are shown as a line on an axis of energy against reaction progress (time).

For an **endothermic** reaction, more energy is required to break bonds, so the overall energy change is **positive**.



For an **exothermic** reaction, more energy is released in bond making, so the overall energy change is **negative**.



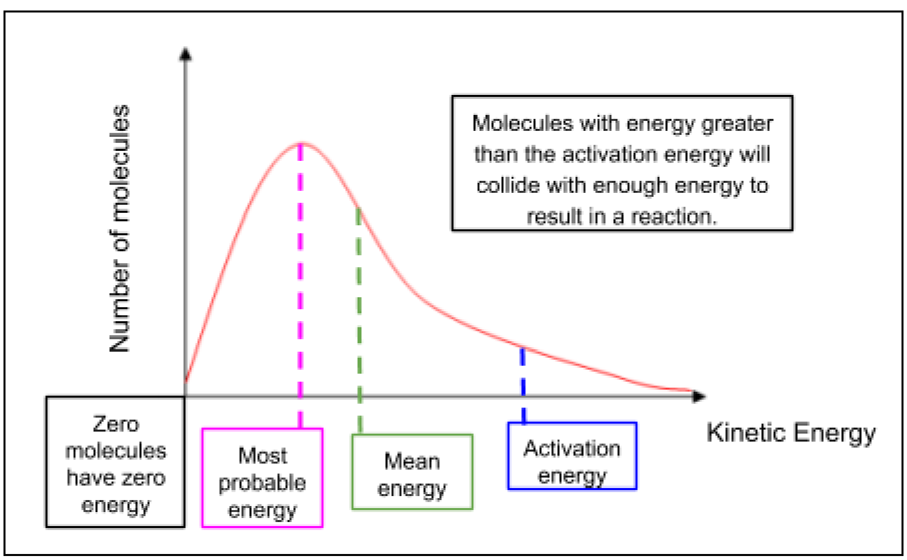
Activation Energy

This is the **minimum** amount of energy required for a reaction to take place. In accordance with collision theory, for a reaction to occur successfully, particles must collide with energy greater than or equal to the activation energy.

It is shown on energy profiles as **Ea** and is where the **peak of the energy curve** occurs.

The Maxwell-Boltzmann Distribution

Not all molecules in a substance have the same amount of energy. Their energies are distributed in a graph called the **Maxwell-Boltzmann distribution**:

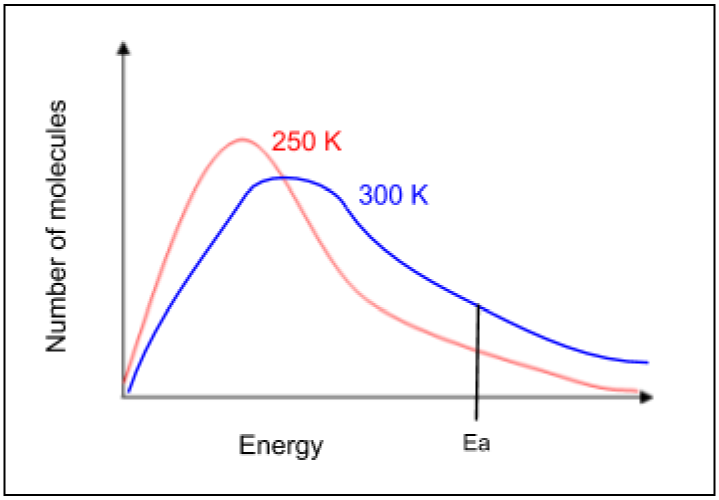


The total **area under the curve** represents the **total number of molecules** in the sample, therefore it must remain constant.

Changing Reaction Conditions

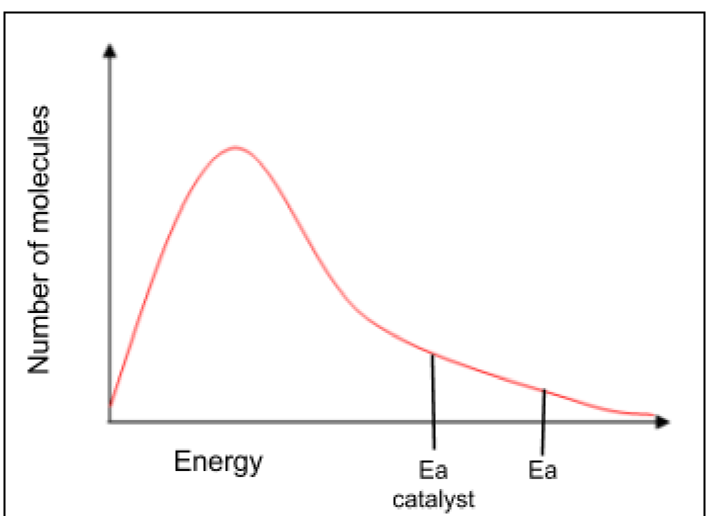
Changing the reaction conditions will **alter the shape** of the curve so that the number of particles with energy greater than the activation energy is different.

1. **Temperature**
   The Maxwell-Boltzmann distribution at an **increased** temperature **shifts to the right** so that a greater proportion of molecules have energy greater than or equal to the activation energy.



2. **Concentration**
   The Maxwell-Boltzmann distribution **has a greater area under the curve** when concentration **increases**, as there are more particles and therefore a greater number of particles with energy greater than the Ea.

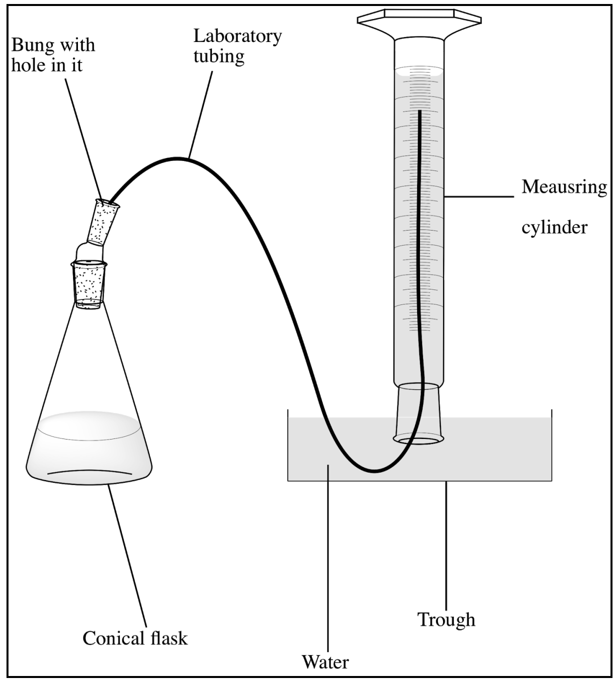
3. **Catalysts**
   In the presence of a catalyst, the Maxwell-Boltzmann distribution curve is **unchanged** in shape but the **position of the activation energy is shifted to the left**. This means that a greater proportion of molecules have energy greater than Ea, so more reactions occur.



Measuring Rates

Gas Collection

In this experimental method, a **gaseous product** is collected and the **volume** produced is monitored over a given time period.



From this, a graph of volume over time can be produced. By changing the concentration or temperature of the reactants, multiple graphs can be produced and used to analyse the effect on the rate of reaction.

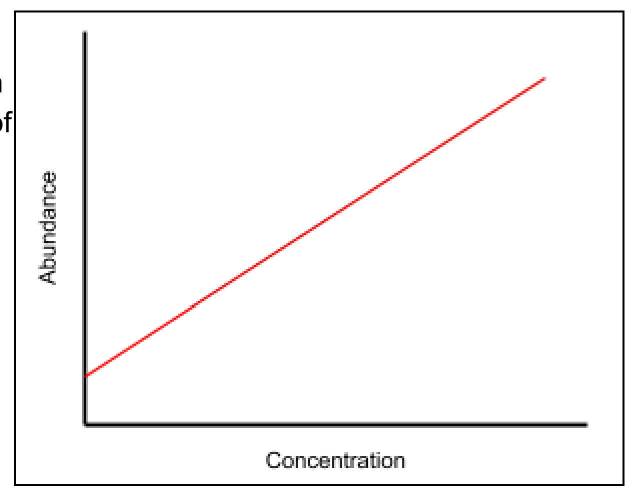
'Iodine Clock' Method

This method consists of **colour changing reactions** that involve iodine. Two colourless solutions are mixed and, after a short wait, the liquid turns a shade of dark blue due to the formation of a starch complex. The time it takes for the solution to change colour can be measured at different temperatures to investigate the effect on rate of reaction.

Colourimetry

This is an analytical technique that uses the **absorption of visible light** to determine the **concentration** of coloured ions by measuring **absorbance**.

A **calibration graph** is produced by measuring solutions of known concentrations which can then be used to calibrate the **calorimeter** on a graph of relative absorbance against concentration. This graph can then be used to determine the concentration of an unknown substance.



Colourimetry can also be used in rate investigations as it allows concentration of a species to be monitored over time. The rate at which this change occurs is an **indicator of reaction rate**.