AQA Chemistry A-Level

3.1.9: Rate Equations

Detailed Notes

3.1.9.1 - Rate Equations

Rate of a reaction shows how fast reactants are converted into products. It depends on the **concentrations** of the reactants and a **rate constant**.
Example:

$$A + B \longrightarrow C$$

$$\text{Rate} = k[A]^m[B]^n$$

The constants ***m*** and ***n*** show the **order of the reaction** with respect to that species. This means that different species can have more of an affect on the reaction than others.

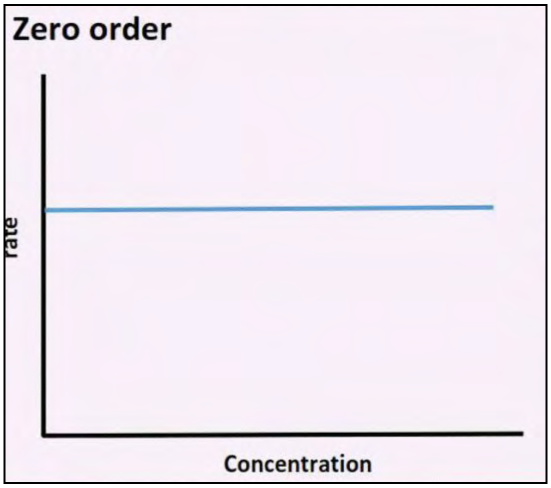
The **total order** of reaction for this chemical reaction can be found as the **sum** of the separate orders.

$$\boxed{\text{Total order} = m + n}$$

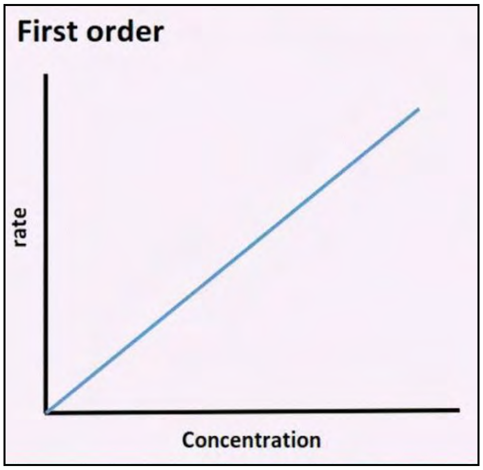
Orders of Reaction

At A2, orders of reaction go from **zero to second order**. This means that changing the concentration of reactants can have different effects on the whole reaction:

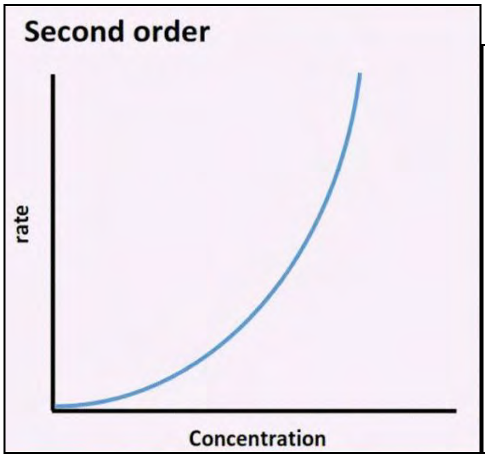
Zero Order - The concentration of this species has **no impact** on rate.
- Shown graphically as a **horizontal** line:
- **Rate = k**



First Order - The concentration of the species and rate are **directly proportional**.
- Doubling concentration doubles the rate.
- **Rate = k[A]**



Second Order - The rate is proportional to the concentration **squared**.
- Doubling the concentration will increase the rate by **four**.
- **Rate = $k[A]^2$**



Images courtesy of derekcarrsavvy-chemist.blogspot.com

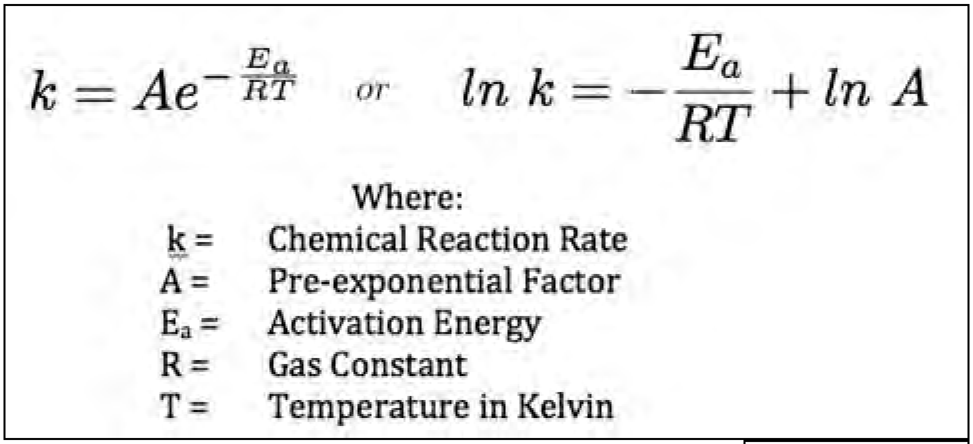
Rate Constant (k)

The rate constant for a reaction is constant when the reaction temperature is constant. It can be found by **rearranging the rate equation** for that reaction.

It has **varying units** depending on the number of species and their orders of reaction. This can be found by **substituting the units** into the rearranged equation and **cancelling**.

The Arrhenius Equation

This equation shows how the rate constant *k* and temperature are related **exponentially**:



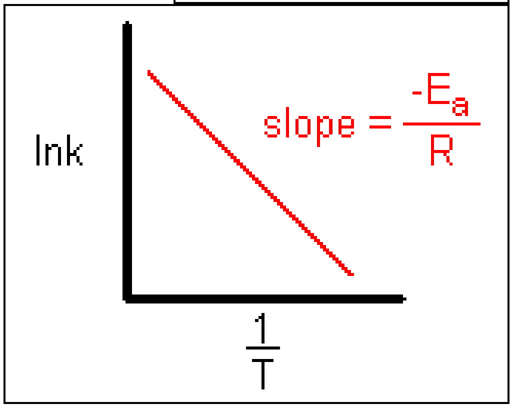
$$k = Ae^{-\frac{E_a}{RT}} \quad \text{or} \quad \ln k = -\frac{E_a}{RT} + \ln A$$

Where:
k = Chemical Reaction Rate
A = Pre-exponential Factor
E_a = Activation Energy
R = Gas Constant
T = Temperature in Kelvin

Image courtesy of SlidePlayer

It is a very useful equation and the **logged form** can be used in the form **'y = mx + c'** to show the relationship graphically. On a graph of lnk against 1/T, the gradient is **negative and constant** and the y-intercept is lnA:

Image courtesy of www.chem.fsu.edu



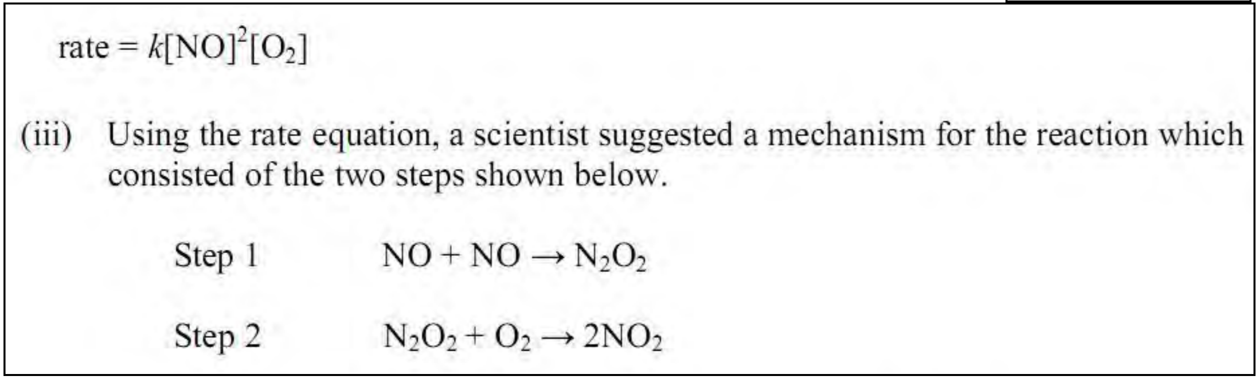
Rate Determining Step

Not all stages of a reaction occur at the same rate, but the overall rate is **determined by the slowest step** of the reaction. Therefore the rate equation contains all the species involved in the stages **up to and including the rate determining step**.

This means that the rate determining step can be identified from a reaction sequence by looking which steps include the species in the rate equation.

Example:

Image courtesy of The Student Room



rate = $k[NO]^2[O_2]$

(iii) Using the rate equation, a scientist suggested a mechanism for the reaction which consisted of the two steps shown below.

Step 1 $NO + NO \rightarrow N_2O_2$

Step 2 $N_2O_2 + O_2 \rightarrow 2NO_2$

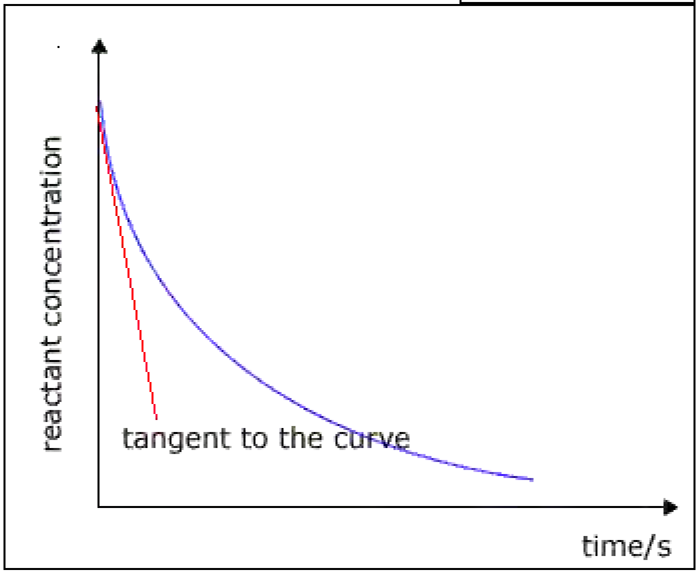
In this question, step 2 would be the rate determining step as all the reactants of this step are in the rate equation given at the start.

3.1.9.2 - Determining Rate Equations

Rate equations can be determined **experimentally** by monitoring concentration of a reaction mixture over time. The **concentration-time graph** produced can be used to find the rate by drawing a tangent to the curve at **t=0**.

Example:

Image courtesy of IBChem



The tangent is drawn at this point as it is the only time in the reaction where the **exact concentration is known**.

This method is then repeated at **varying concentrations** to get a set of data for concentration and rate of reaction. A graph of **rate against concentration** can then be plotted to determine the order of reaction of the reaction.