CIE Chemistry A-Level

Topic 8 - Reaction Kinetics

Flashcards

What is meant by *rate of reaction*?

What is meant by *rate of reaction*?

The change in concentration of reactants or products over time.

How does concentration affect rate of reaction?

How does concentration affect rate of reaction?

- Increasing the concentration increases the number of molecules per unit volume.
- This leads to more frequent collisions and hence a greater frequency of successful collisions.
- This increases the rate of reaction.

What is linked by the rate constant?

(A level only)

What is linked by the rate constant? **(A level only)**

Rate of reaction and the concentrations of the reactants raised to their orders in the rate equation.

How do you work out the units of a rate constant?

(A level only)

How do you work out the units of a rate constant? **(A level only)**

- Rearrange the rate equation to make *k* the subject.
- Substitute units into the equation.
- Cancel the common units to find the units for *k*.

Work out the units of the rate constant in the following equation: Rate = $k[A][B]^2$

(A level only)

Work out the units of the rate constant in the following equation: Rate = $k[A][B]^2$ **(A level only)**

$$k = \frac{Rate}{[A][B]^2}$$

$$k = \frac{\cancel{mol\ dm^{-3}}\ s^{-1}}{\cancel{mol\ dm^{-3}} \times (mol\ dm^{-3})^2} = k = \frac{s^{-1}}{mol^2\ dm^{-6}}$$

$$k = dm^6\ mol^{-2}\ s^{-1}$$

How is the order of reaction used in the rate equation? What is meant by the overall order?

(A level only)

How is the order of reaction used in the rate equation? What is meant by the overall order?

(A level only)

- The order with respect to a reactant is the power to which the concentration of that reactant is raised to in the rate equation.
- Overall order = sum of the orders of each reactant in an equation.

How does the order with respect to a reactant affect rate?

(A level only)

How does the order with respect to a reactant affect rate? **(A level only)**

- Zero order: if rate $\propto [A]^0$ then the rate of reaction is unaffected by changing [A].
- First order: if rate $\propto [A]^1$ then rate of reaction increases at the same rate as [A] increases.
- Second order: if rate $\propto [A]^2$ then rate will increase by the square of the factor [A] increases by.

What is a rate equation?

(A level only)

What is a rate equation? **(A level only)**

For a reaction between A and B:

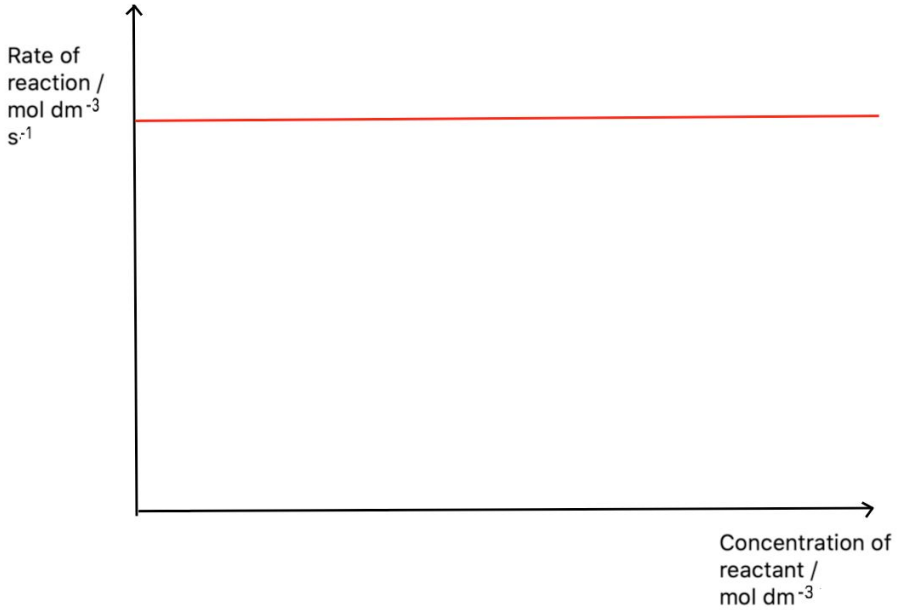
Rate = $k[A]^m[B]^n$

- *m* and *n* represent the orders with respect to each reactant.
- *K* is the rate constant.

Draw a rate-concentration graph for a zero order reactant

(A level only)

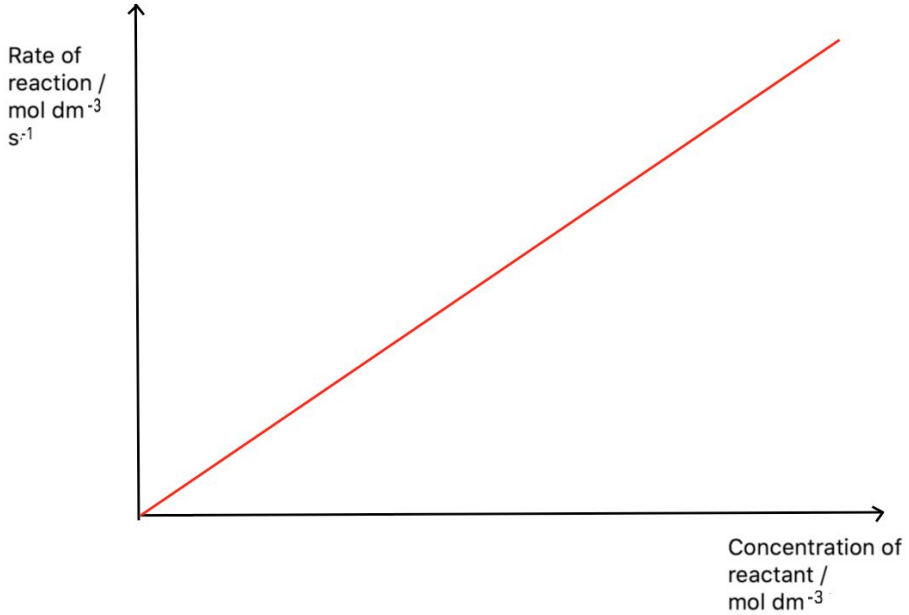
Draw a rate-concentration graph for a zero order reactant **(A level only)**



Draw a rate-concentration graph for a first order reactant

(A level only)

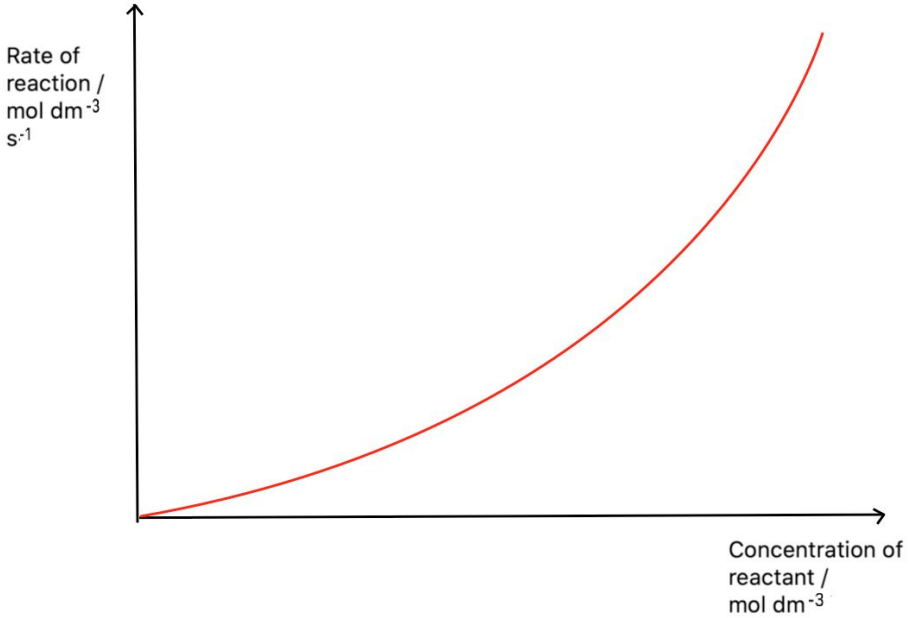
Draw a rate-concentration graph for a zero order reactant **(A level only)**



Draw a rate-concentration graph for a second order reactant

(A level only)

Draw a rate-concentration graph for a second order reactant **(A level only)**



What is meant by the half-life of a reaction?

(A level only)

What is meant by the half-life of a reaction?
(A level only)

The average time taken for the concentration of the reactant to decrease by half, $t_{1/2}$.

How do you calculate the rate constant, k from half life, $t_{1/2}$ for a first order reaction?

(A level only)

How do you calculate the rate constant, *k* from half life, $t_{1/2}$ for a first order reaction? **(A level only)**

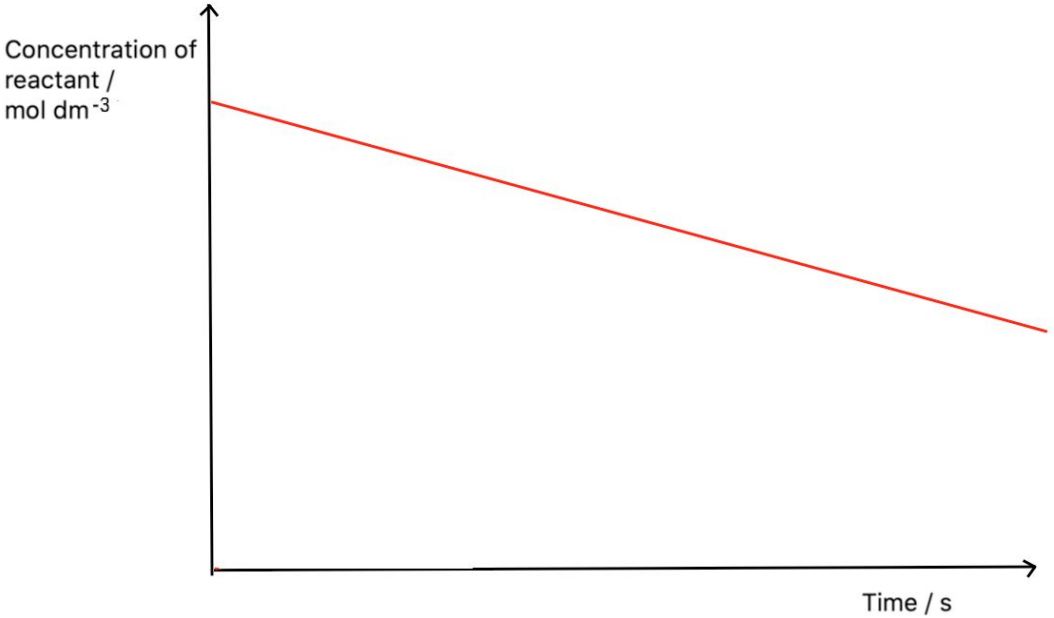
$k = \ln 2 / t_{1/2}$

- This equation applies to first-order reactants only.
- The half life of a first order reactant is independent of concentration.

Draw a concentration-time graph for a zero order reactant

(A level only)

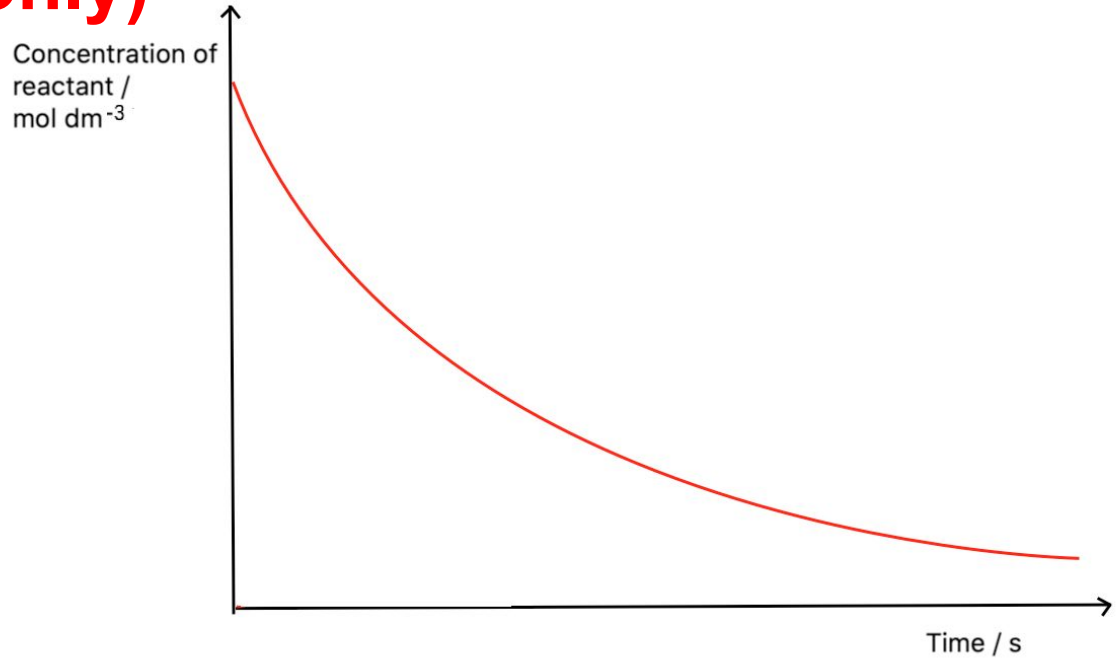
Draw a concentration-time graph for a zero order reactant **(A level only)**



Draw a concentration-time for a first order reactant

(A level only)

Draw a concentration-time for a first order reactant **(A level only)**



How do you calculate half life from a first order concentration-time graph?

(A level only)

How do you calculate half life from a first order concentration-time graph? **(A level only)**

Using the graph, find the time taken for the concentration to halve. Then find the time taken for it to halve again (to increase accuracy). Calculate the average of these values and this will be the half life.

How do you calculate the rate from a first order concentration-time graph?

(A level only)

How do you calculate the rate from a first order concentration-time graph? **(A level only)**

- Draw a tangent at the time you want the rate of reaction.
- The gradient of this tangent will equal the rate of reaction.
  Gradient = change in y ÷ change in x

How do you calculate *k* from a first order rate-concentration graph?

(A level only)

How do you calculate *k* from a first order rate-concentration graph? **(A level only)**

- Calculate the gradient of the line of best fit (change in y ÷ change in x).
- The gradient will equal the rate constant, *k*.

What is the rate-determining step?

(A level only)

What is the rate-determining step? **(A level only)**

- The slowest step of the reaction.
- Only species that take part in the rate determining step (or steps that take place before it) affect the rate.

What is the relation between the rate-determining step and the rate equation?

(A level only)

What is the relation between the rate-determining step and the rate equation? **(A level only)**

- The species present in the rate equation are those that take part in the rate determining step.
- For any reactant in the rate equation, the order attached to it tells you how many molecules of it are involved in the rate determining step.

Suggest a step-by-step reaction mechanism for the reaction below:

Overall equation: $CO_{(g)} + NO_{2(g)} \rightarrow CO_{2(g)} + NO_{(g)}$

Rate equation: rate = $k[NO_2]^2$

(A level only)

Suggest a step-by-step reaction mechanism for the reaction below:

Overall equation: $CO_{(g)} + NO_{2(g)} \rightarrow CO_{2(g)} + NO_{(g)}$

Rate equation: rate = $k[NO_2]^2$

(A level only)

Step 1: $2NO_2 \rightarrow NO + NO_3$ (slow)

Step 2: $NO_3 + CO \rightarrow NO_2 + CO_2$

How can the order of a reactant be predicted using a reaction mechanism?

(A level only)

How can the order of a reactant be predicted using a reaction mechanism? **(A level only)**

- Identify the rate-determining step.
- Observe how many molecules of each reactant react in the rate-determining step.
- E.g. if two molecule of reactant A react in the rate determining step, the reaction is second order with respect to A.

How can rate of reaction be measured?

(A level only)

How can rate of reaction be measured? **(A level only)**

- Initial rates method- i.e. the iodine clock reaction.
- A continuous monitoring method- i.e. measuring the volume of gas released in a reaction over time.

Describe the initial rates method

(A level only)

Describe the initial rates method **(A level only)**

Measure the initial rate of a reaction for several different sets of initial concentrations and see how rate varies.

Describe a continuous monitoring method when measuring rate of reaction **(A level only)**

Describe a continuous monitoring method when measuring rate of reaction **(A level only)**

Measure the change in concentration of a reactant or product over time (or measuring volume of gas released) as the reaction progresses.

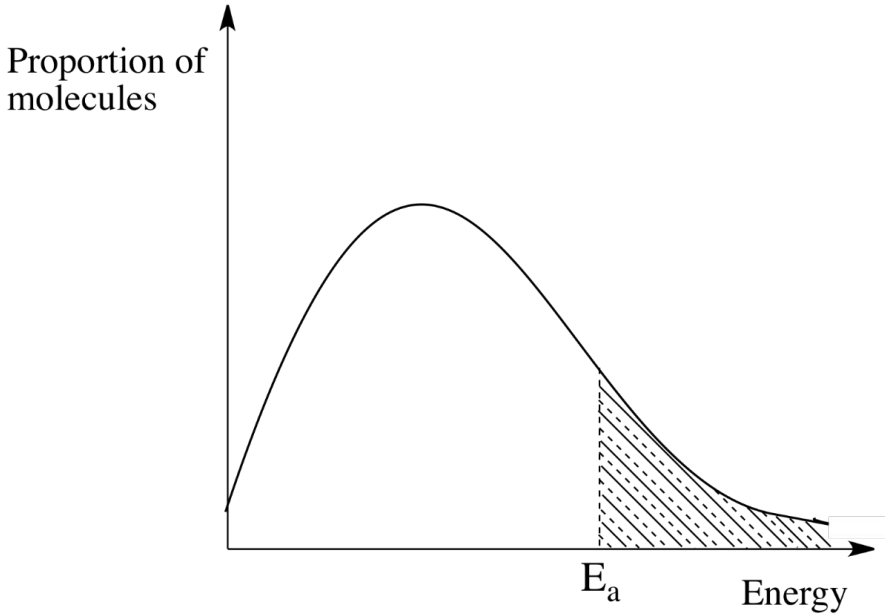
What is activation energy?

What is activation energy?

The minimum amount of energy required for a particular reaction to occur.

What is the Boltzmann distribution?

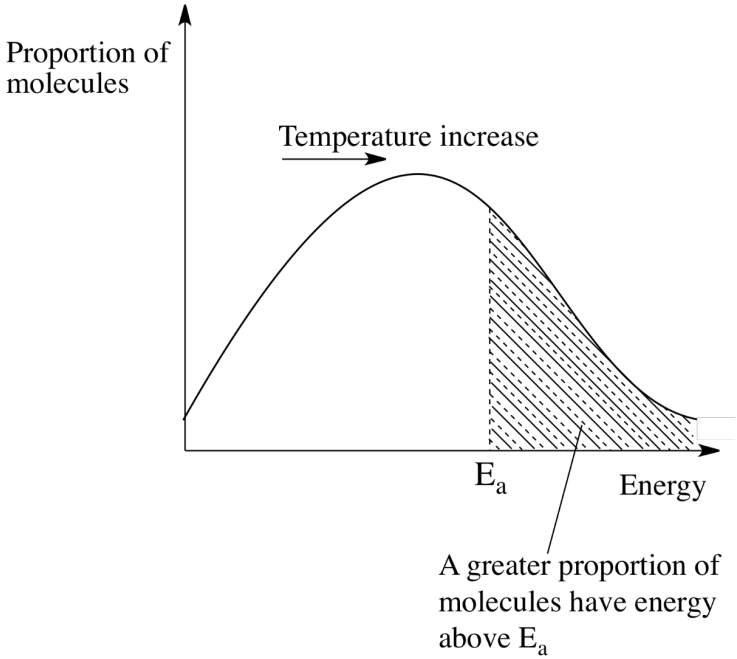
What is the Boltzmann distribution?



- The Boltzmann distribution shows the relative energies of molecules.
- Area under the graph = total number of molecules.
- As you can see, only a small proportion of molecules have energies greater than the activation energy.

Using the Boltzmann distribution to explain the effect of temperature on the rate of reaction

Using the Boltzmann distribution to explain the effect of temperature on the rate of reaction



- Increasing the temperature increases the kinetic energies of the molecules.
- This means a greater proportion of molecules have energy **greater** than the activation energy.
- Hence rate of reaction **increases** as more molecules are able to react.
- You can also see from the diagram that the **average** energy of the molecules is also greater.

How does the rate constant, *k* vary with increasing temperature?

(A level only)

How does the rate constant, *k* vary with increasing temperature? **(A level only)**

- As temperature increases there are more particles with energy above the activation energy. As a result, there are more frequent successful collisions so rate of reaction increases.
- An increase in temperature therefore causes an increase in *k.*
- For every 10℃ increase, the rate and k both approximately double.

What is catalysis?

What is catalysis?

The increase in rate of a chemical reaction due to the addition of a catalyst.

What is a homogeneous catalyst?

What is a homogeneous catalyst?

A catalyst that is in the same state as the reactants.

What is a heterogeneous catalyst?

What is a heterogeneous catalyst?

A catalyst that is in a different state to the reactants.

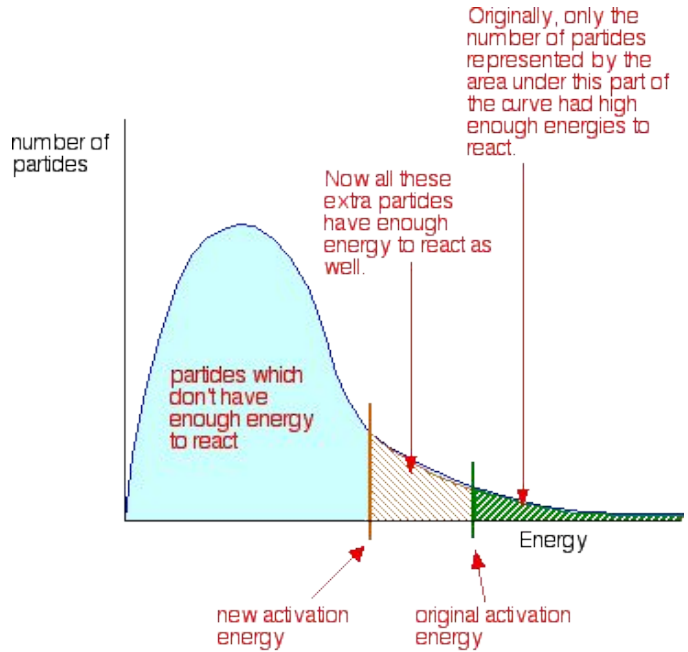
Why do catalysts increase the rate of reaction?

Why do catalysts increase the rate of reaction?

A catalyst lowers the activation energy of a reaction by causing the reaction to have a different mechanism.

Use a Boltzmann distribution to show the effect of catalysts

Use a Boltzmann distribution to show the effect of catalysts



Jim Clark, 'The effect of catalysts on reaction rates', Chemguide

What are enzymes?

What are enzymes?

- Biological catalysts that increase the rate of biochemical reactions.
- Proteins with a specific structure.
- Typically catalyse a specific reaction.

What catalyst is used in the Haber process? Describe the role of this catalyst

(A level only)

What catalyst is used in the Haber process? Describe the role of this catalyst **(A level only)**

- Heterogeneous iron catalyst.
- The iron also has KOH added to it to act as a promoter (increases efficiency).
- Nitrogen and hydrogen are adsorbed onto the catalyst surface, breaking the bonds in the nitrogen and hydrogen molecules.
- New bonds form between the iron and individual nitrogen and hydrogen atoms.
- Nitrogen then bonds to hydrogen to form ammonia which desorbs from the catalyst.

How does a catalytic converter reduce harmful emissions from a car exhaust?

(A level only)

How does a catalytic converter reduce harmful emissions from a car exhaust? **(A level only)**

$$2CO + 2NO \rightarrow 2CO_2 + H_2$$

- Heterogeneous catalyst.
- Metals like platinum, palladium and rhodium are used.

How do oxides of nitrogen catalyse the oxidation of sulfur dioxide?

(A level only)

How do oxides of nitrogen catalyse the oxidation of sulfur dioxide? **(A level only)**

- Homogeneous catalyst, nitrogen dioxide
- Nitrogen dioxide reacts with sulfur dioxide before being regenerated:

$$SO_2(g) + NO_2(g) \rightarrow SO_3(g) + NO(g)$$

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

How do iron ions act as a catalyst in the $I^-/S_2O_8^{2-}$ reaction?

(A level only)

How do iron ions act as a catalyst in the $I^-/S_2O_8^{2-}$ reaction? **(A level only)**

- Homogeneous iron catalyst (either Fe^{2+} or Fe^{3+}).
- $S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$.
- Iron ions react with the reactants to form intermediates (this is a much more successful pathway as two negatively charged reactants do not have to collide).

How do enzymes act as catalysts?

(A level only)

How do enzymes act as catalysts? **(A level only)**

- They lower the activation energy by creating a transition state between enzyme and substrate.
- It allows the bonds to be broken more easily.

What is the lock and key model?

(A level only)

What is the lock and key model? **(A level only)**

The lock and key theory states that an enzyme's active site is completely complementary to its substrate (it is a perfect fit) and will only bind to this substrate to form an enzyme-substrate complex.