# Energy Matters

## Reactions Rates

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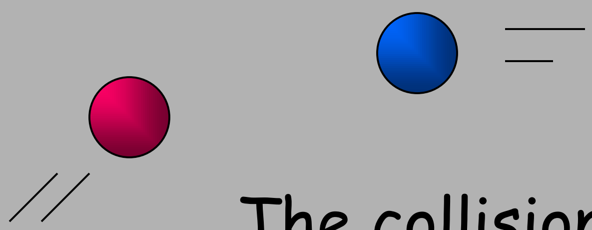
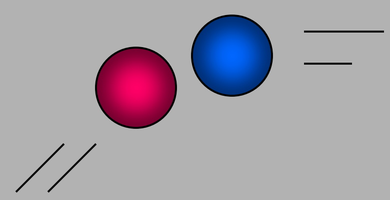
# Collision Theory

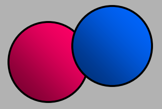


For a chemical reaction to occur, reactant molecules must collide.

The collision must provide enough energy to break the bonds in the reactant molecules



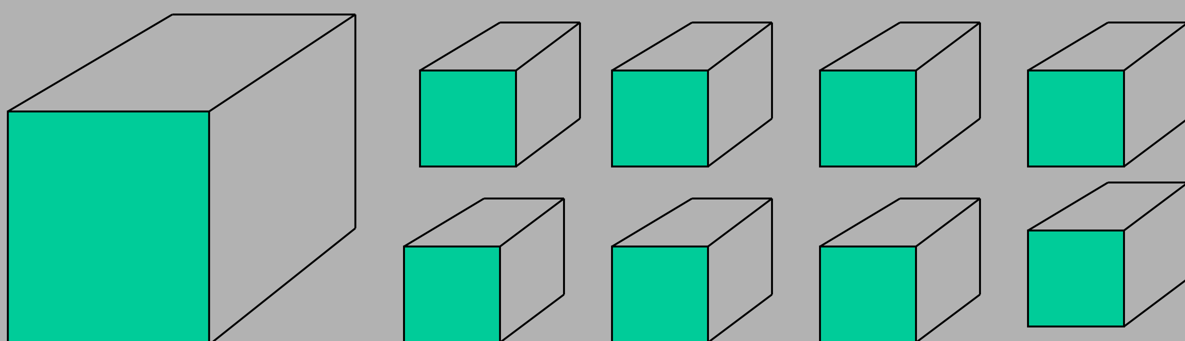
Then new chemical bonds form to make product molecules.



# Increasing the rate

Concentration, the more particles in a given space, the more chance there is of successful collisions.

Particle size, the smaller the particles, the greater the surface area, the greater the chance of successful collisions.



$4 \times 4 = 16\ cm^2$

$16 \times 6 = 96\ cm^2$

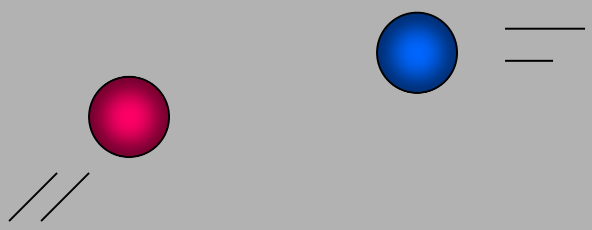
$2 \times 2 = 4\ cm^2$

$4 \times 6 = 24\ cm^2$

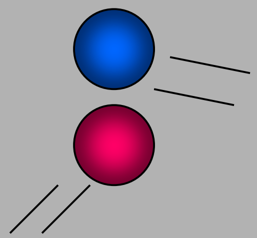
$24 \times 8 = 192\ cm^2$

# Collision Theory

For a chemical reaction to take place particles must colloid with each other



Not all collisions result in a chemical reaction

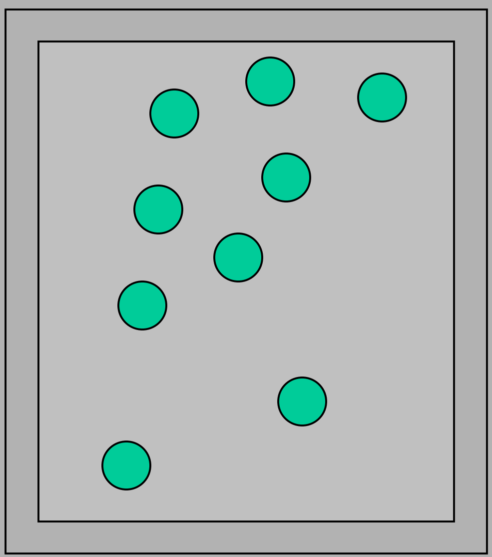


For any given temperature, the energy is spread among all the particles.

Only a certain number of particles will have sufficient energy to react.

# Temperature

What do we mean by temperature and heat (thermal energy) ?



The thermal energy of a system is a measure of both the potential and kinetic energy within the system.

The temperature is a measure of how 'hot' a system is. **Click on the diagram!!**

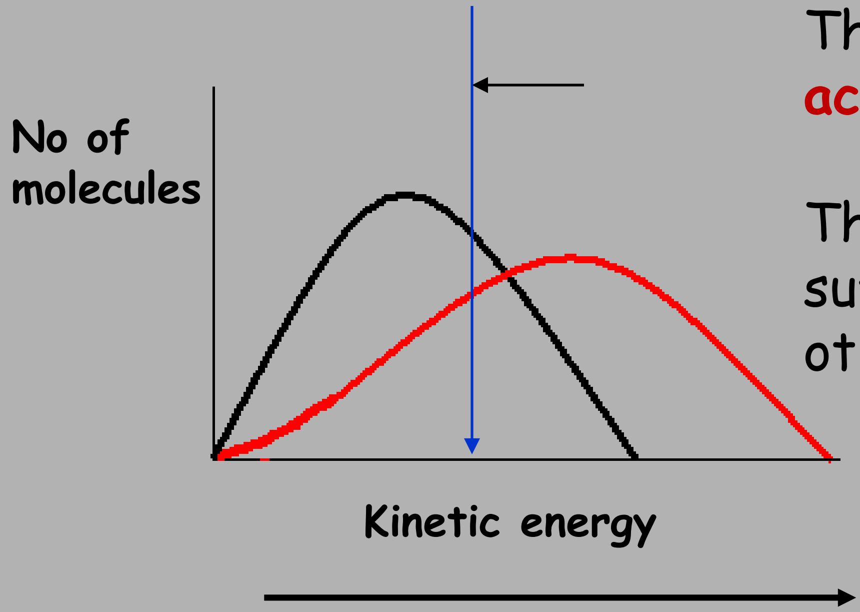
The temperature is a measure of the average kinetic energy in a system..

A 10 $^{o}$C rise in temperature produces a roughly x2 rate increase, yet the number of collisions per second increases by only two percent.

# Temperature

As the temperature increases the particles gain kinetic energy, so **more** particles have enough **energy** to complete a successful **collision**.

Not only must particles collide in order to react,
they must have enough energy to reorganise their bonds.




This energy is described as the **activation energy** $E_a$

The point at which particles have sufficient energy to react with each other

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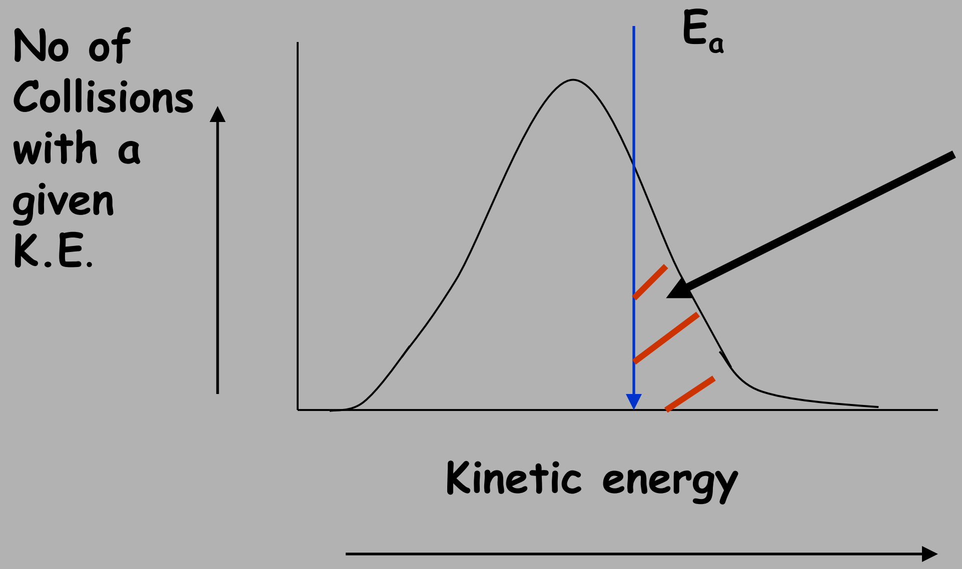
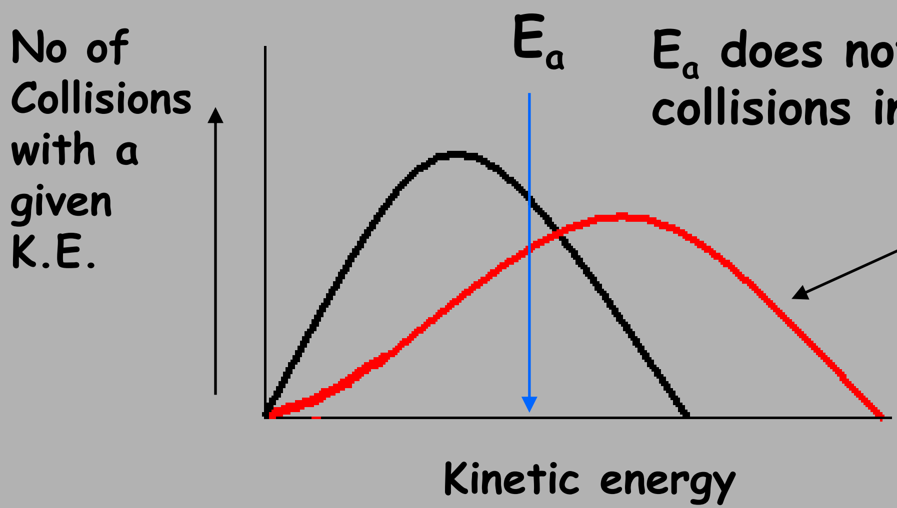
# Energy Distribution




Number of collisions which result in new products being formed.

Total number of collisions with sufficient K.E. energy is the **area under** the graph to the right of the $\mathbf{E_a}$ .

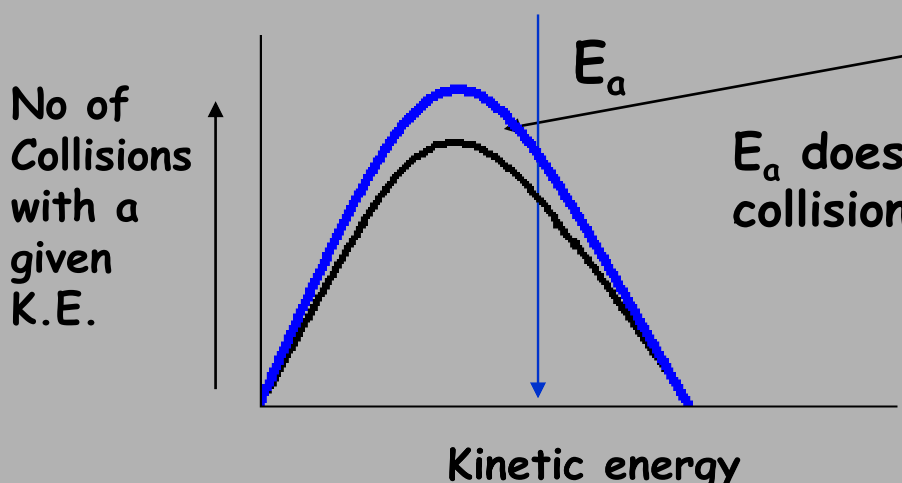
# Energy distribution




$E_a$ does not change but the number of successful collisions increases significantly, so rate increases.

Increased temperature

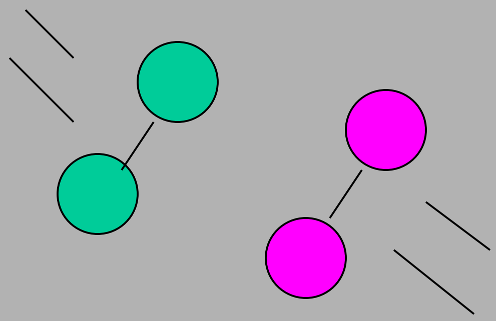
Increased concentration



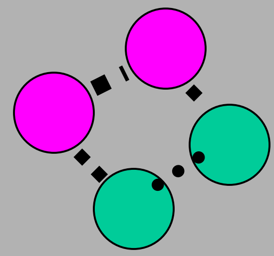

$E_a$ does not change but the number of successful collisions increases.

# Activation Energy

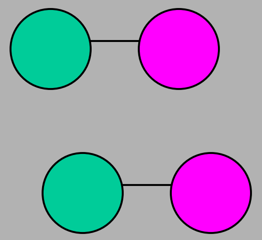
Reactants ⟶ Products



1. Before collision
Reactants



2. In full collision
Activated complex
Partially broken reactant bonds and partially formed product bonds



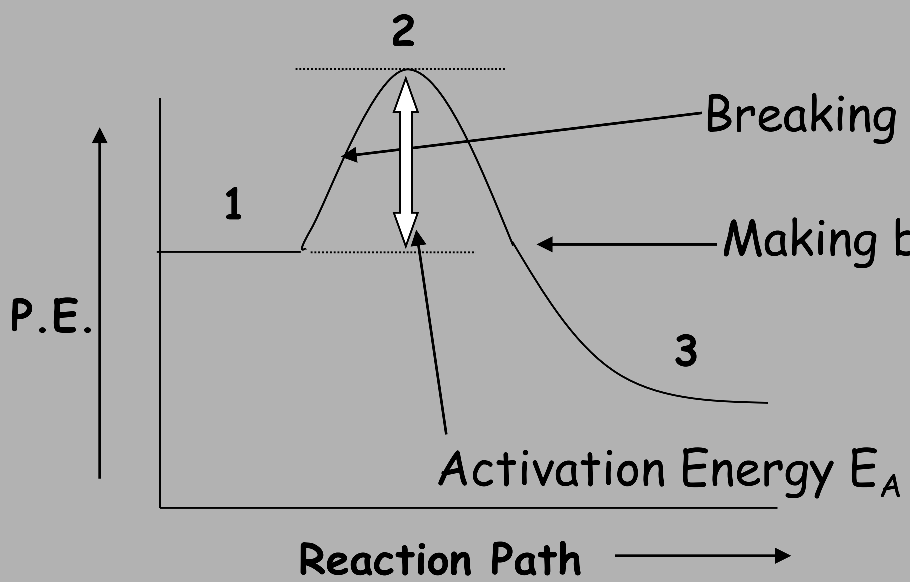
3. After collision
Products

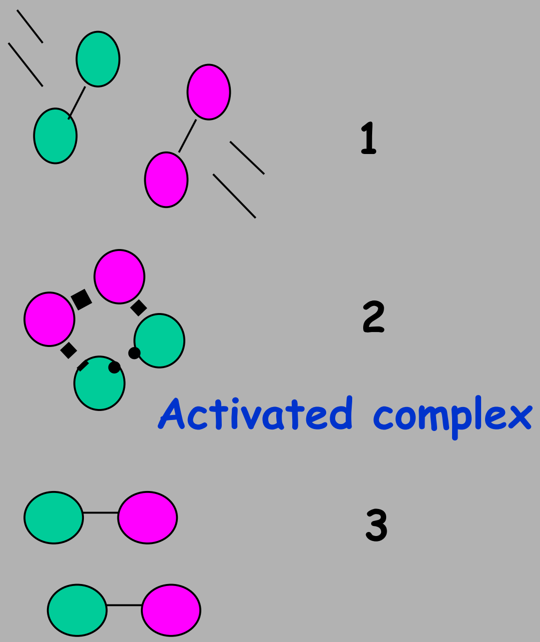
## Energy changes

If the reactants have enough combined K.E.to overcome $E_a$ , their K.E. is converted into the P.E. needed to form the activation complex.

During the whole process the total energy of the particles remains constant.

# Potential Energy Graph

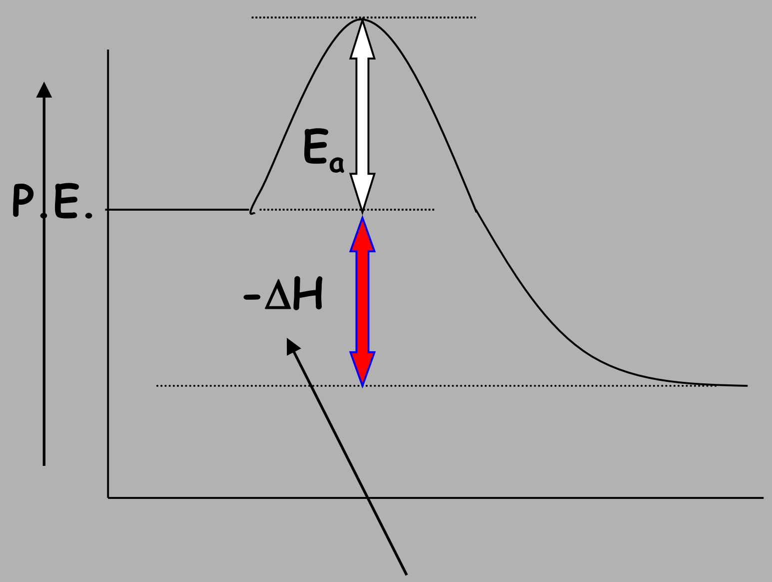


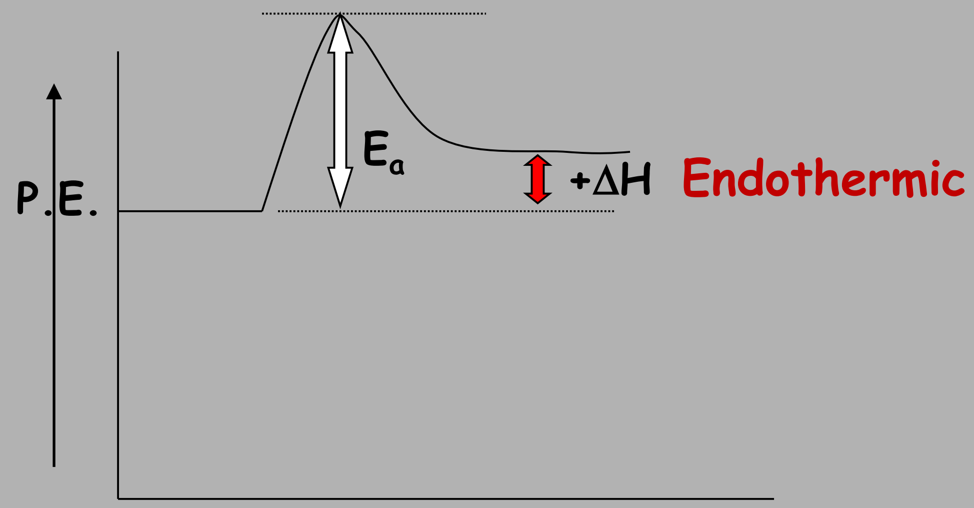




**Activation Energy** is the **additional P.E.** which has to be attained by colliding molecules to form an activated complex.

**Activated complex** is the **unstable arrangement** of atoms formed at the maximum of the potential energy barrier.

# Exothermic and Endothermic Reactions

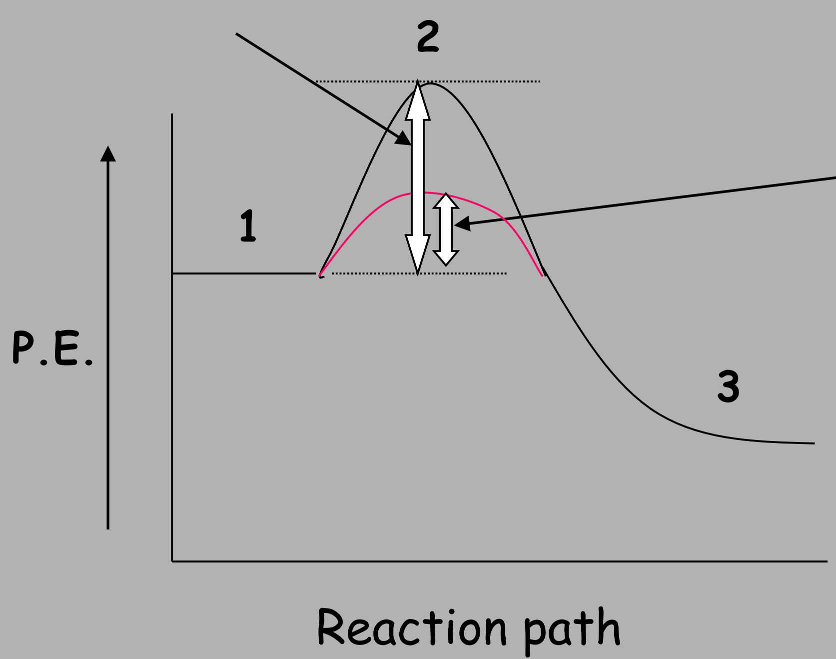



**Exothermic** reactions give out thermal energy, while **endothermic** reactions take in thermal energy from their surroundings.

# Potential energy graphs and catalysts

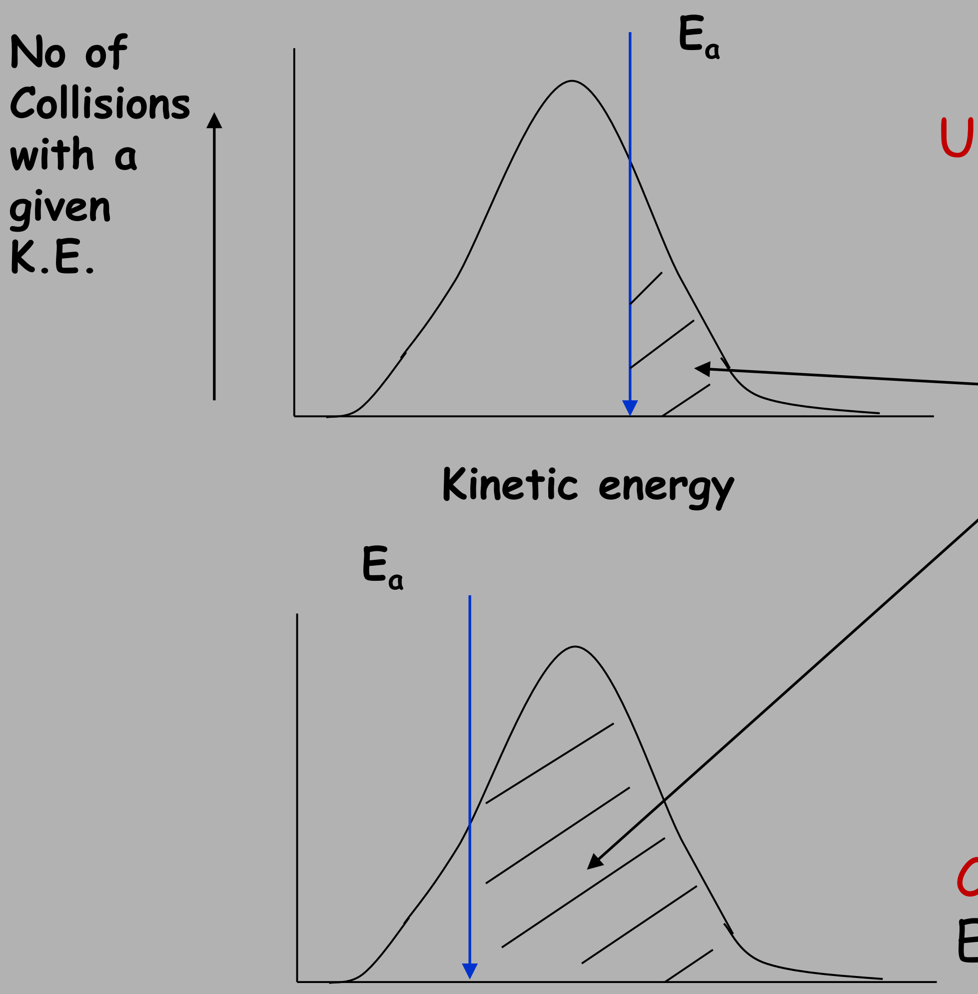
Activation energy $E_A$ without a catalyst




Activation energy $E_A$ with a catalyst

Catalysts lower the activation energy needed for a successful collision.

# Energy distribution and catalysts




Un-catalysed reaction

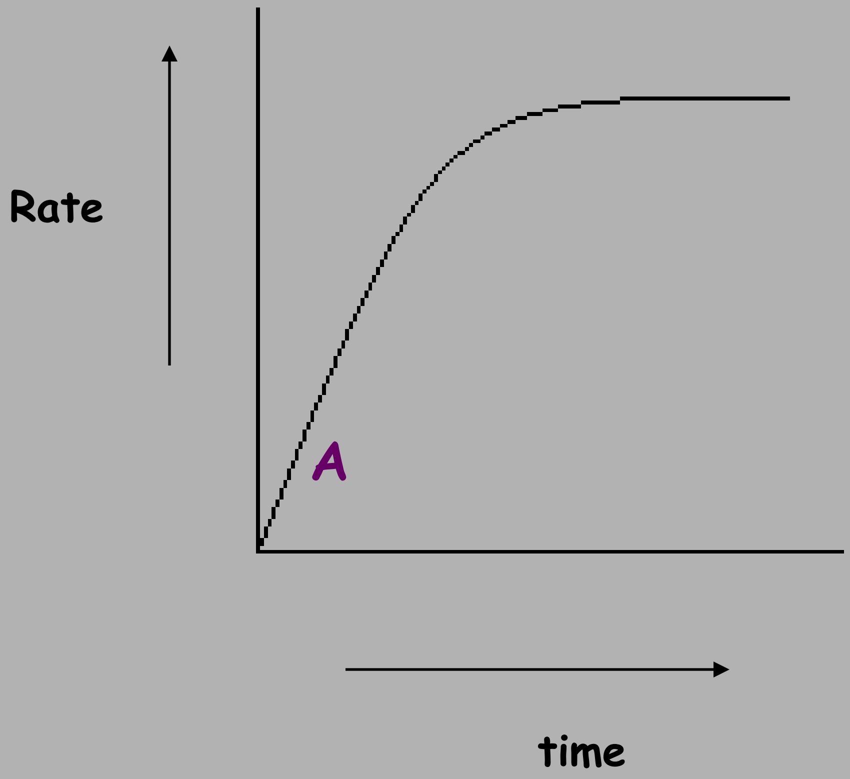
**Total number of collisions (area under the graph) with sufficient K.E. energy to create new products.**

Catalysed reaction

$E_a$ is reduced

# Progress of a Reaction

Reactions can be followed by measuring changes in concentration, mass and volume of reactants and products.




A. Where is the reaction the quickest?

B. Why does the graph level off?

**No more products formed.**

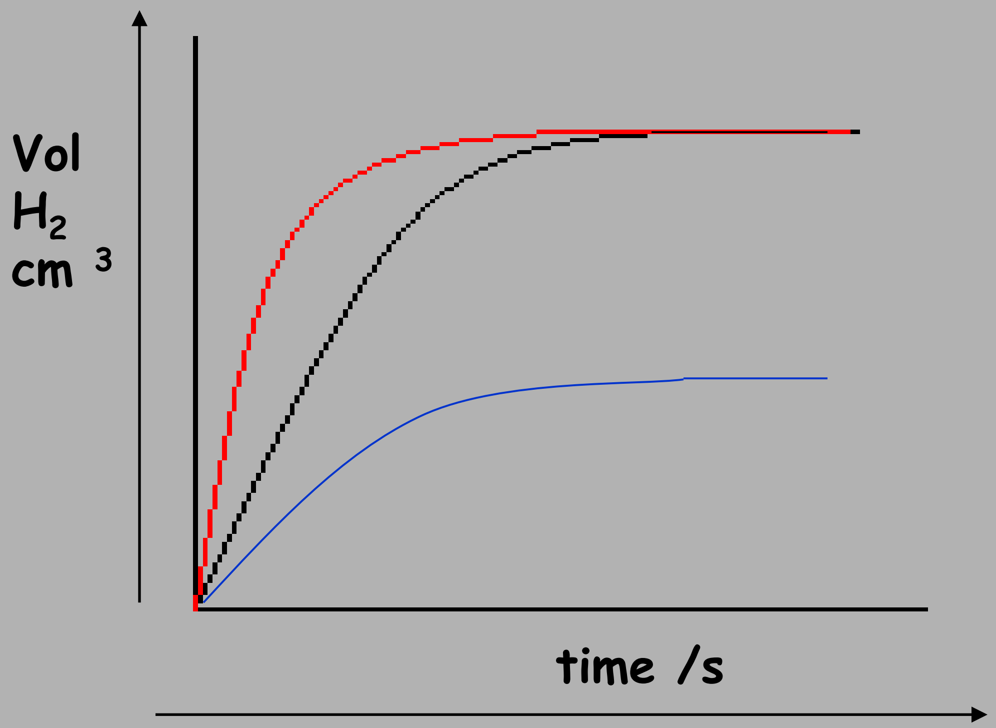
C. Why does the graph curve?

**The concentration of the reactants decrease with time.**

# Graphs and Rates of Reaction

e.g. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

Mass of Zn Constant



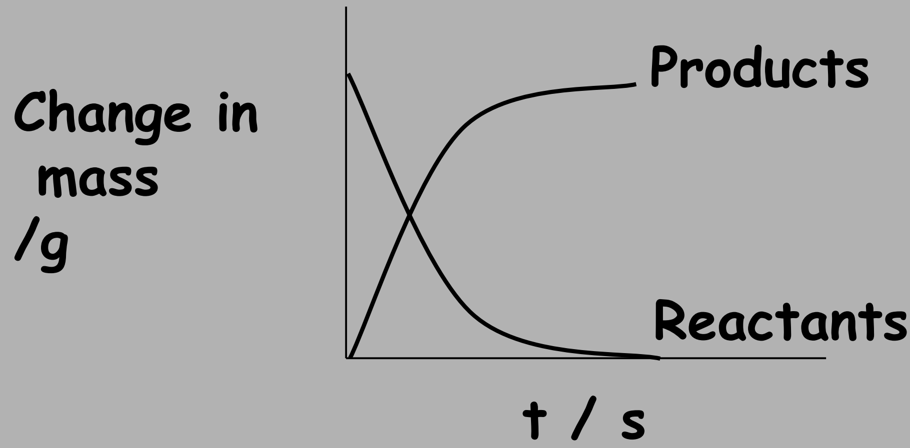

2mol $l^{-1}$ HCl 20°C

2mol $l^{-1}$ HCl 40°C
Faster, but same amount of gas produced

1 mol $l^{-1}$ HCl 20°C
Half the gas produced

Δ This symbol represents change

# Measuring reaction rates




Av rate of reaction = $\dfrac{\Delta \text{ in concentration of product or reactant}}{\Delta \text{ in time for the change to occur}}$ Units g $s^{-1}$

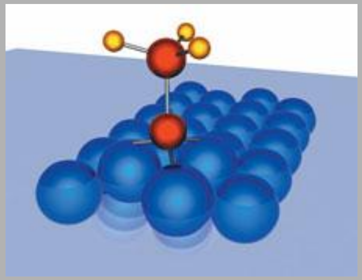
**Average rate** of a reaction would therefore be the total change in concentration divided by the total time taken

**Rate of a reaction** = $\dfrac{1}{\mathbf{t}}$ Units $s^{-1}$

# Catalysts at Work

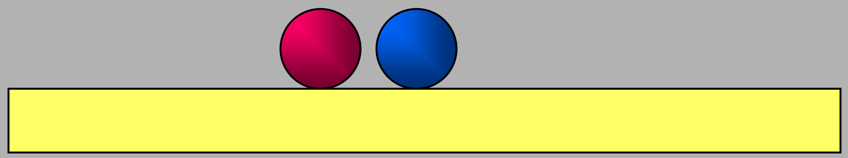
A catalyst increases the rate of reaction without taking part in the reaction.

The Catalytic Mechanism involves the reactant particles being adsorbed onto the surface of the catalyst.



# Catalysts at Work

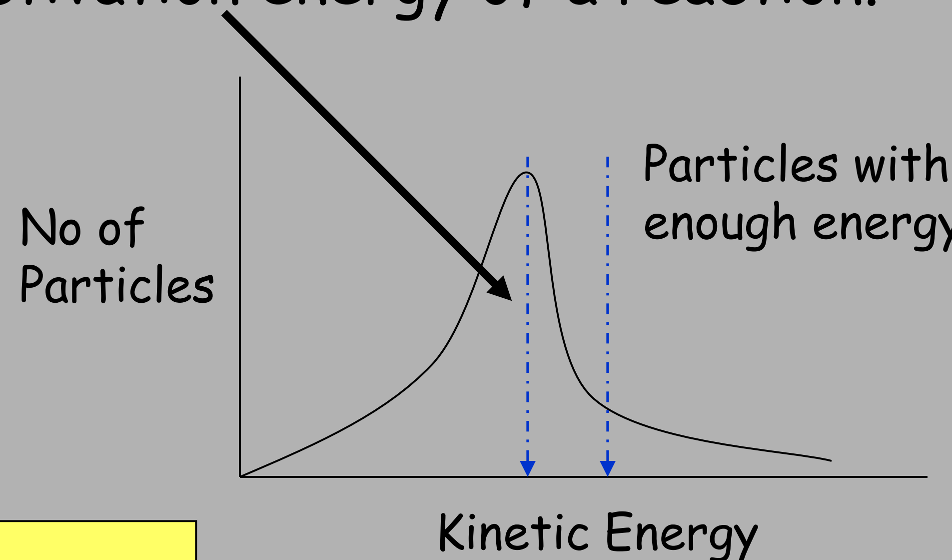
The reactant particles form weak bonds with the surface of the catalyst.

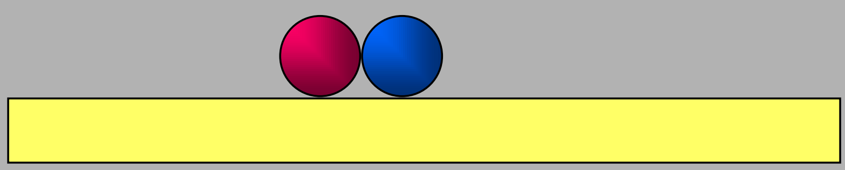


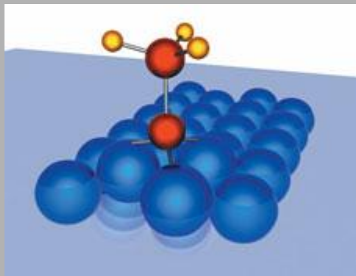
# Catalysts at Work

The reactant particles form weak bonds with the surface of the catalyst.

Catalysts lower the activation energy of a reaction.



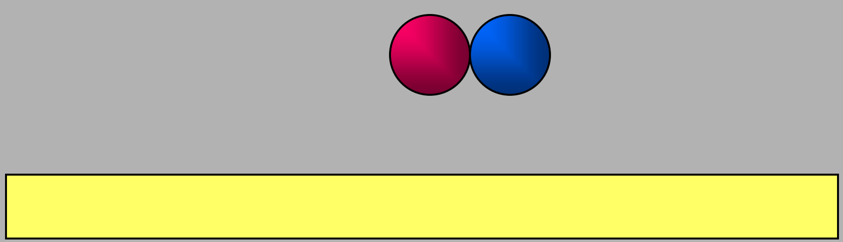





# Catalysts at Work

When the product molecule has been formed, the weak bonds holding the particles to the catalyst break, releasing the new molecule.

When the effective surface of the catalyst has been reduced, i.e. poisoned, the catalyst will stop working because there will be a smaller active surface. However, catalysts can be regenerated. e.g. burning off carbon



# Catalytic Converters

These are fitted to cars to reduce car exhaust pollution. So-called '3-way' converters simultaneously convert….

$$CO \xrightarrow{\text{oxidation}} CO_2$$

$$C_xH_y \xrightarrow{\text{oxidation}} CO_2 + H_2O$$

$$NO_x \xrightarrow{\text{reduction}} N_2$$

Catalytic converts

$NO$, $NO_2$ and $CO$ into
$N_2$ and $CO_2$

Three precious metals are used, rhodium, platinum and palladium on a surface of aluminium oxide. This is then supported by a honeycomb structure made of steel or ceramics.
Cars use 'lead-free' petrol to prevent poisoning of the catalyst

# Catalysts at Work

## Heterogeneous

When the catalyst and reactants are in different states you have 'Heterogeneous Catalysis'. They work by the adsorption of reactant molecules.

E.g. Ostwald Process (Pt) for making nitric acid and the Haber Process (Fe) for making ammonia and the Contact Process (Pt) for making Sulphuric Acid.

## Homogeneous

When the catalyst and reactants are in the same state you have 'Homogeneous Catalysis'. E.g. making ethanoic acid from methanol and CO using a soluble iridium complex.

**Enzymes** are biological catalysts, and are protein molecules that work by homogeneous catalysis. E.g. invertase and lactase. Enzymes are used in many industrial processes

# Rate measurement and concentration.
# Iodine/thiosulphate reaction

$$2I^-_{(aq)} + H_2O_{2\,(aq)} + 2H^+_{(aq)} \rightarrow 2H_2O_{(l)} + I_{2\,(aq)}$$

$$I_{2\,(aq)} + 2S_2O_3^{2-}{}_{(aa)} \rightarrow 2I^-_{(aq)} + S_4O_6^{2-}{}_{(ag)}$$

The thiosulphate $2S_2O_3^{2-}$ is used to mop up $I_{2,}$

The longer the **iodine** takes to form, the slower the reaction rate. So if you double the rate the iodine will form in $^1/_2$ the time.

$$\text{Relative Rate} = \frac{1}{\mathbf{t}} \qquad \text{Units } s^{-1}$$

**t** being a measure of how long it takes for the blue/black colour to form. (when excess $I_2$ forms)

PPA

# Rate measurement and temperature.
# Oxalic acid/permanganate reaction

$$5(COOH)_{2\,(aq)} + 6H^{+}_{(aa)} + 2MnO_4^{2-}{}_{(aq)} \rightarrow 2Mn^{2+}{}_{(aq)} + 10\ CO_2\,(aq)\ 8H_2O_{(l)}$$

**What colour change takes place?**

As with the reaction between Hydrogen Peroxide and Iodide ions, you need to be able to state the following.

**State the**;
- **Aim of the experiment.**
- **Method, which variables to control and change.**
- **What to measure and how.**
- **How to record your results.**
- **What graph to draw.**
- **Make a conclusion.**
- **Evaluate.**

**PPA**