C6 – Rate and extent of chemical change

Rate of reaction.

Measuring the rate of anything always involves a **measurement of time**

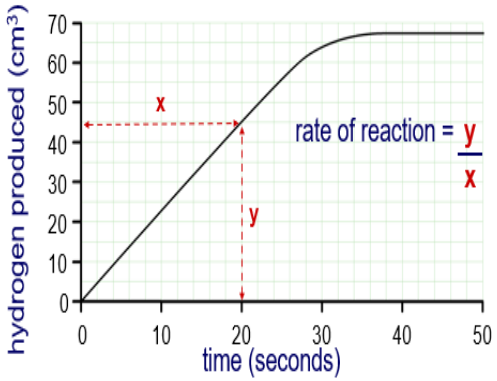
The rate of a chemical reaction can be found using:

$$\text{rate} = \frac{\text{quantity of reactant used}}{\text{time}}$$

$$\text{rate} = \frac{\text{quantity of product formed}}{\text{time}}$$

Quantities for reactants or products are measured in **mass in g** or by **volume in cm³**

Rate calculations can be done from tables of data or graphs:



Volume of hydrogen produced = 45cm
Time taken = 20 seconds
Rate = $\frac{45}{20}$ cm³

rate = 2.25 cm³/s

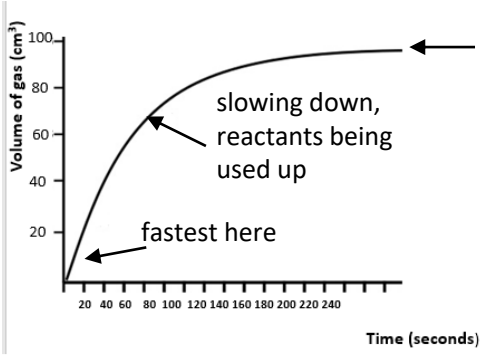
The progression of a chemical reaction

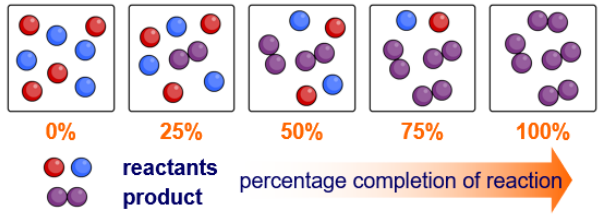
For a reaction to take place, reactant particles have to collide.

The rate of a reaction depends on the **frequency of collisions** and **the energy with which the particles collide.**

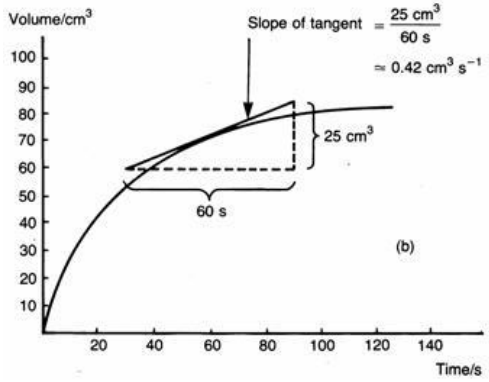
The minimum amount of energy needed to start a reaction is called the **activation energy**.

A reaction is always **fastest at the beginning** and slows down over time as the reactants get used up and the frequency of collisions decreases.





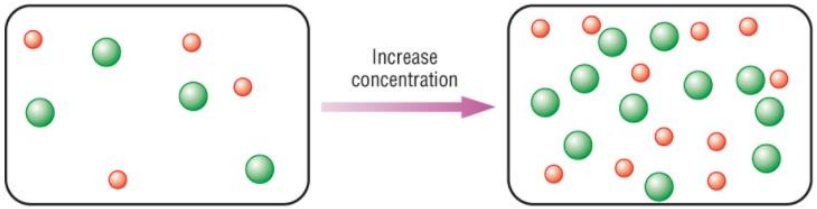
Using a tangent to calculate rate (HT)



- Draw a line along the point you're interested in. The line should touch the curve at the point given.
- Make a triangle. Try to make the angles either side of the line equal.
- Measure the change in volume and change in time
- Calculate the gradient
- Use units from the axes to determine the units for rate

C6 – Rate and extent of chemical change

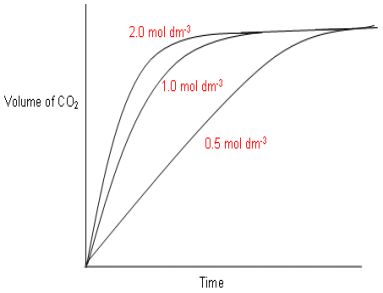
The effect of concentration



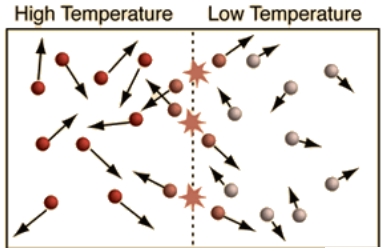
Concentration means number of particles per cm^3

Increasing the concentration of any of the reactants increases the rate of the reaction

This is because there are more particles per cm^3 so there are **more frequent collisions**, increasing the rate.

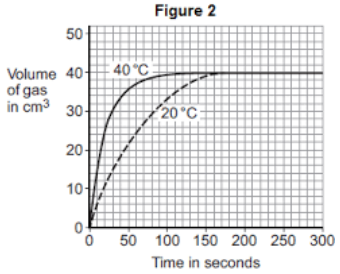


The effect of temperature



Increasing the temperature of the reactants increases the rate of the reaction.

This is because the particle have more kinetic energy and therefore move faster, so there are **more frequent collisions**, increasing the rate.

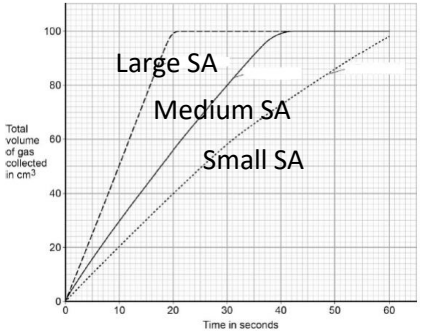


The effect of surface area

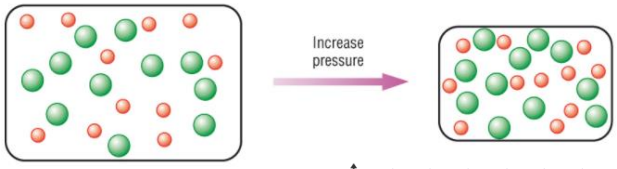
The smaller the pieces of a solid, the higher the surface area

Increasing the surface area of solid reactants increases the rate of reaction.

This is because there is a greater area available for collisions to occur so there are **more frequent collisions**, increasing the rate.

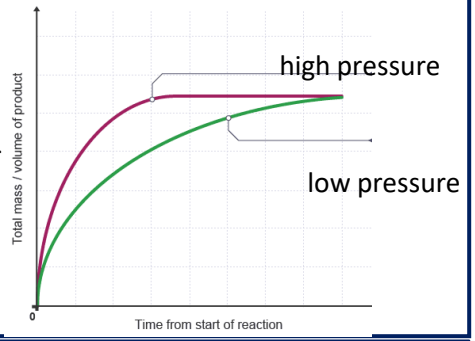


The effect of pressure



Increasing the pressure of gaseous reactions increases the rate of the reaction.

This is because the same number of particles are now in a smaller volume, so there are **more frequent collisions**, increasing the rate.



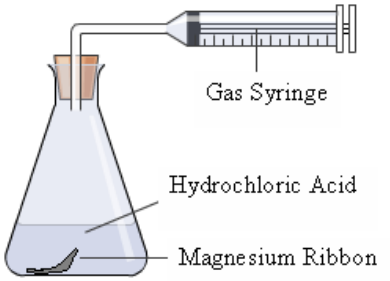
In all cases, the overall amount of product is the SAME, the end point of the reaction is just reached faster

C6 – Required practical – the effect of concentration on rate of reaction

Experiment 1

Using volume of gas collected over time as a measure of the rate

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

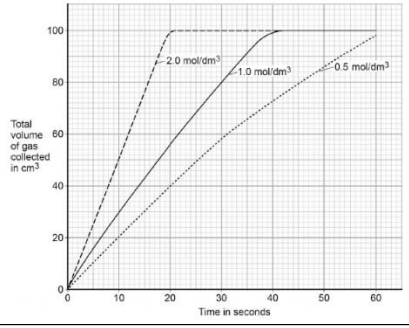


Independent variable: concentration of HCl
Dependent variable : Volume of gas produced / min
Control variables : volume of HCl, mass of Mg, temperature of acid

Method

1. Measure 20cm^3 0.5M HCl into a conical flask.
2. Insert 2 x 2cm pieces of Mg and attach a gas syringe
3. Start a stopwatch and measure the volume of gas collected every 20 seconds until the reaction is over.
4. Repeat using different concentrations of HCl.

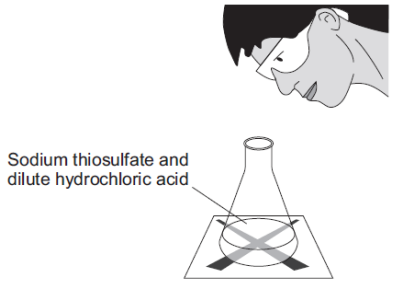
An increase in the concentration leads to an increase in the rate of the reaction, but the same volume of product overall



Experiment 2

Investigating the effect of changing the concentration of HCl on the rate of reaction

$$HCl_{(aq)} + Na_2S_2O_{3\ (aq)} \rightarrow NaCl_{(aq)} + SO_{2(g)} + S_{(s)} + H_2O_{(l)}$$



The sulphur being made is insoluble and is what makes the liquid go cloudy

Independent variable: concentration of HCl
Dependent variable : Time taken for the cross to disappear
Control variables : volume of HCl, volume of sodium thiosulphate, temperature of both solutions, concentration of sodium thiosulphate

Method

1. Use a measuring cylinder to put 10 cm^3 sodium thiosulfate solution into the conical flask.
2. Put the conical flask on the black cross.
3. Put 10 cm^3 of 0.5M hydrochloric acid into the 10 cm^3 measuring cylinder.
4. Put this acid into the flask. At the same time swirl the flask gently and start the stopwatch.
5. Look down through the top of the flask. Stop the stopwatch when you can no longer see the cross. Record the time.
6. Repeat steps 1-5 using different concentrations of HCl – 1M, 1.5M, 2M and 2.5M

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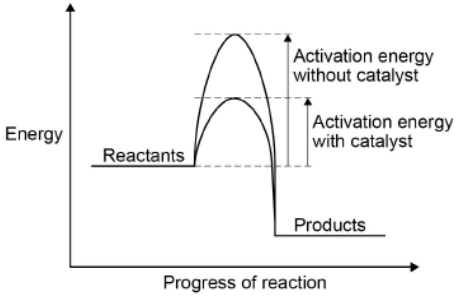
Catalysts

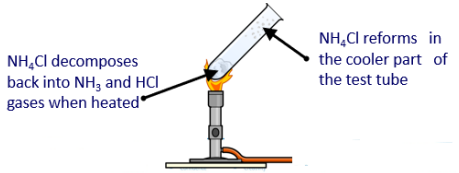
- Catalysts are substances that speed up chemical reactions without themselves being used up.
- They provide a different pathway for the reaction with a lower activation energy.
- Different reactions require different catalysts.



Reversible reactions

These are reactions in which the products can react to produce the original reactants
They are represented by the symbol ⇌
The direction of the reaction can be changed by changing the conditions
For example:

ammonium chloride $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ ammonia + hydrogen chloride



If a reaction is exothermic in one direction, it is endothermic in the opposite direction.
The same amount of energy is transferred in each case.

hydrated copper sulfate (blue) $\underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water

When a reversible reaction takes place in sealed apparatus, then a point occurs when the forward and backward reactions occur at the same rate. This is **equilibrium**

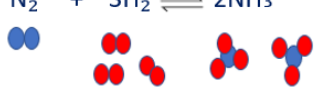
The effect of changing conditions on equilibrium (HT)

If a system is at equilibrium and a change is made to the conditions, then the system responds to counteract the change.
E.g. – if the temperature is increased, then the system will respond by increasing the rate of the endothermic reaction, to bring the temperature back down

If the concentration of the reactants is increased, then equilibrium will shift right and more products will be made.

In gaseous reactions, a change in pressure will result in equilibrium shifting to the side that restores the pressure.
E.g. :

$N_2 + 3H_2 \rightleftharpoons 2NH_3$



In this reaction, there are 4 moles of gas on the reactants side and only 2 on the product side
If the pressure is increased, equilibrium will shift right as there are fewer moles on the products side, and this will decrease the pressure.