Chemistry

Rates of Reaction

Rates of Reaction

Rates of reactions

- The speed of different chemical reactions varies hugely. Some reactions are very fast and others are very slow.

The speed of a reaction is called the **rate** of the reaction.

What is the rate of these reactions?

Reaction	Rate
rusting	slow
explosion	very fast
chemical weathering of rocks	very slow
sodium and water	fast
rotting fruit	slow

Reactions, particles and collisions

- Reactions take place when particles of reactants collide with a certain amount of energy.

  This energy is called **activation energy**, and is different for each reaction.

  The rate of a reaction depends on three things:

  - the **frequency** of collisions between particles;
  - the **energy** with which particles collide.
  - the **geometry** with which particles collide.

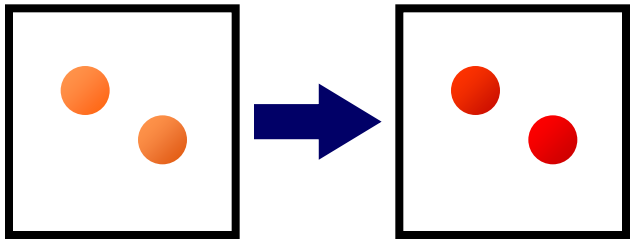
  If particles collide with less energy than the activation energy, they will not react. The particles will just bounce off each other.

Changing the rate of reactions

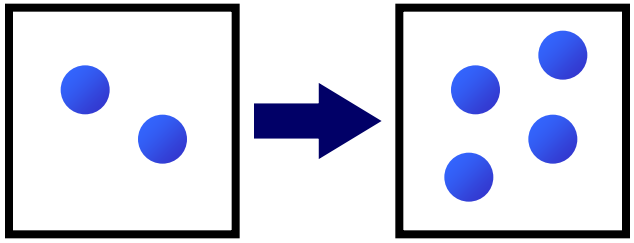
- Anything that increases the number of successful collisions between reactant particles will speed up a reaction.

What factors speed up reactions?

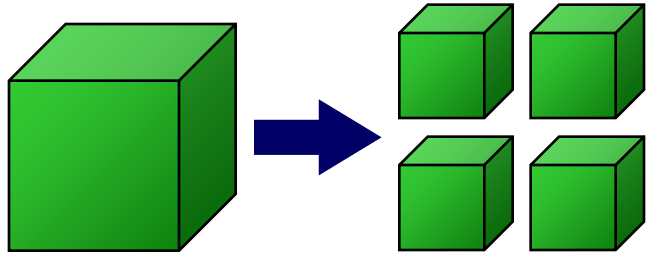
- Increased **temperature**;



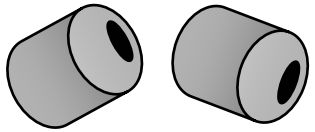
- increased **concentration** of dissolved reactants, and increased **pressure** of gaseous reactants;



- increased **surface area** of solid reactants;



- use of a **catalyst**.



Measuring rates of reaction

- Measuring the rate of a reaction means measuring the **rate of change** over a period of time.

  This means measuring the change in the amount of a reactant or the amount of a product.

  What can you measure to calculate the rate of reaction between magnesium and hydrochloric acid?

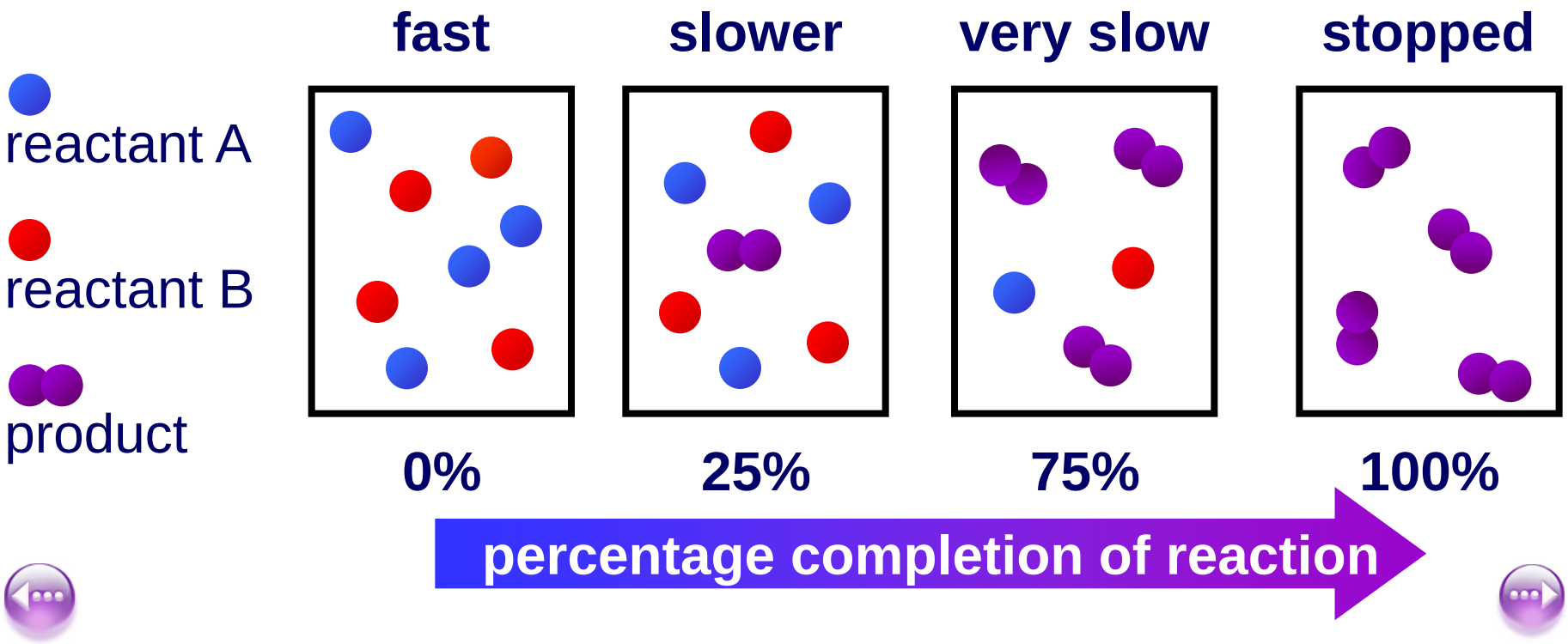
magnesium + hydrochloric acid □ magnesium chloride + hydrogen

- The amount of **magnesium used up** (g/min).
- The amount of **hydrochloric acid used up** (cm^3/min).
- The amount of **magnesium chloride produced** (g/min).
- The amount of **hydrogen produced** (cm^3/min).

Slower and slower!

- Reactions do not proceed at a steady state. They start off at a certain speed, then get slower and slower until they stop.

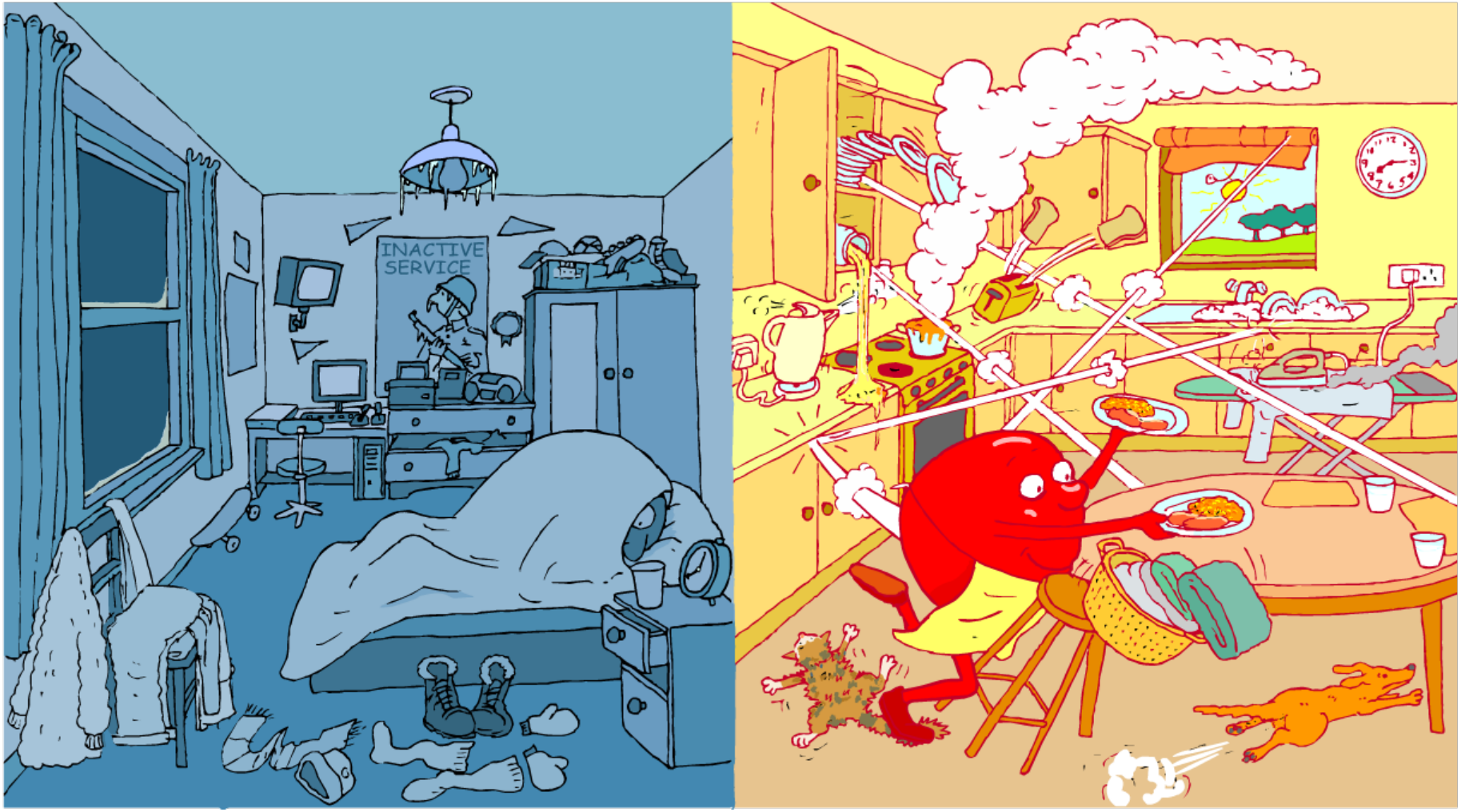
  As the reaction progresses, the concentration of reactants decreases. This reduces the frequency of collisions between particles and so the reaction slows down.



Rates of Reaction

The effect of temperature on collisions

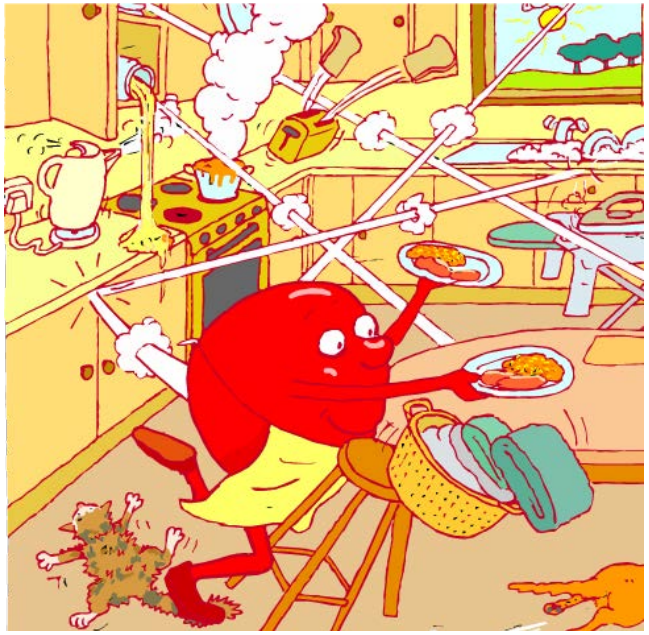
- How does temperature affect the rate of particle collision?



Temperature

- The higher the temperature, the faster the rate of a reaction. In many reactions, a rise in temperature of 10°C causes the rate of reaction to approximately double.

Why does increased temperature increase the rate of reaction?



- At a higher temperature, particles have more energy. This means they move faster and are more likely to collide with other particles.
- When the particles collide, they do so with more energy, and so the number of successful collisions increases.

Temperature and food

- Food goes off because chemical reactions take place.

Why does food remain usable for much longer if it is kept in a freezer?

The low temperature in the freezer means that particles will move much slower and with less energy than if they were at room temperature. This means that there are fewer successful collisions and so a slower rate of reaction.

Temperature and cooking

- Before microwave ovens were common, many people used pressure cookers to cook food more quickly.

In a pressure cooker, water doesn't boil until it reaches about 115°C. How does this help cooking?

The higher temperature means that particles move more quickly and with more energy. This means that there are more successful collisions between particles, and the food cooks more quickly.

Temperature and rate of reaction

- The reaction between **sodium thiosulfate** and **hydrochloric acid** produces **sulfur**.

sodium thiosulfate + **hydrochloric acid** → **sodium chloride** + **sulfur dioxide** + **sulfur** + **water**

$Na_2S_2O_3$ (aq) + 2HCl (aq) → 2NaCl (aq) + SO_2 (g) + S (s) + H_2O (l)

Sulfur is solid and so it turns the solution cloudy.

The effect of increasing temperature on the rate of reaction can be measured by comparing how long it takes the solution to turn cloudy at different temperatures.

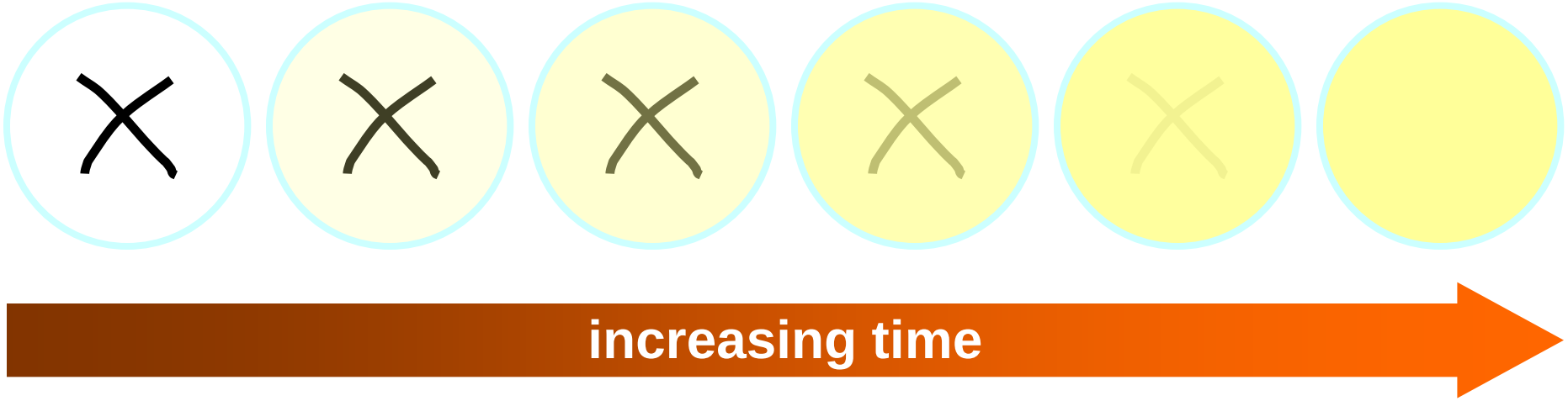
Sodium thiosulfate and hydrochloric acid

- To run the experiment investigating the effect of temperature on the rate of reaction:

1. Mark a cross on a piece of paper.
2. Add a known amount of sodium thiosulfate to a beaker, and place it on the piece of paper.
3. Add a known amount of hydrochloric acid to the beaker and immediately start a stop-clock. The solution will begin to turn cloudy.
4. As soon as the cross can no longer be seen, stop the clock and note the time.
5. Repeat the experiment at different temperatures using the same volume of reactants. Compare how long it takes the cross to disappear.

Sodium thiosulfate and hydrochloric acid

- When looking down into the beaker, the cross will become fainter over time:



The time taken for the cross to disappear can be used as the time of the reaction.

Rates of Reaction

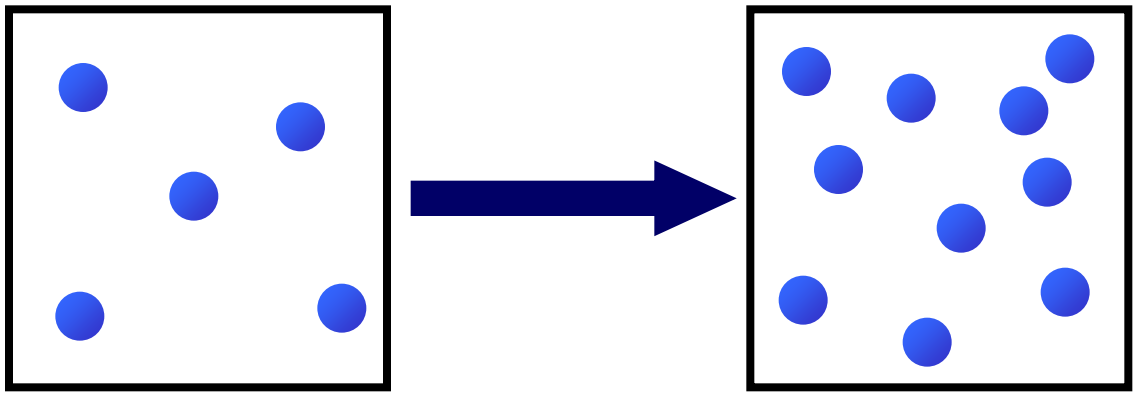
Concentration

- The higher the concentration of a dissolved reactant, the faster the rate of a reaction.

Why does increased concentration increase the rate of reaction?

At a higher concentration, there are more particles in the same amount of space. This means that particles are more likely to collide with other particles.

low concentration **high concentration**

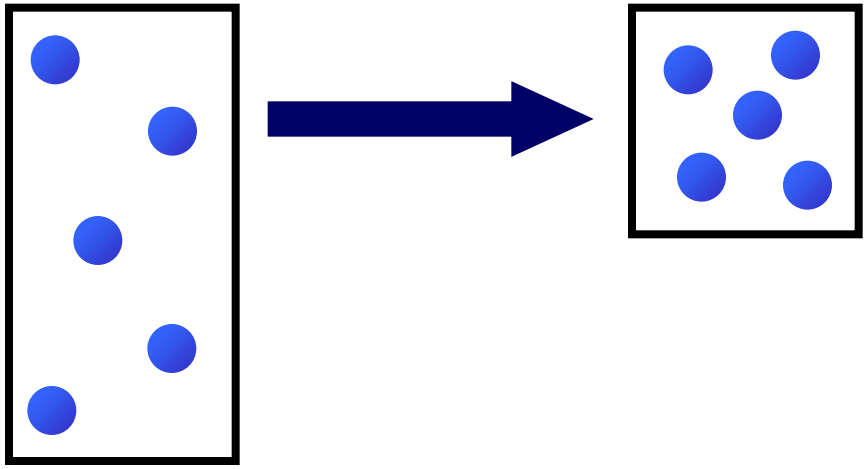


Pressure

- Why does increasing the pressure of gaseous reactants increase the rate of reaction?

  As the pressure increases, the space in which the gas particles are moving becomes smaller.

low pressure **high pressure**



The same number of particles but in a smaller space.

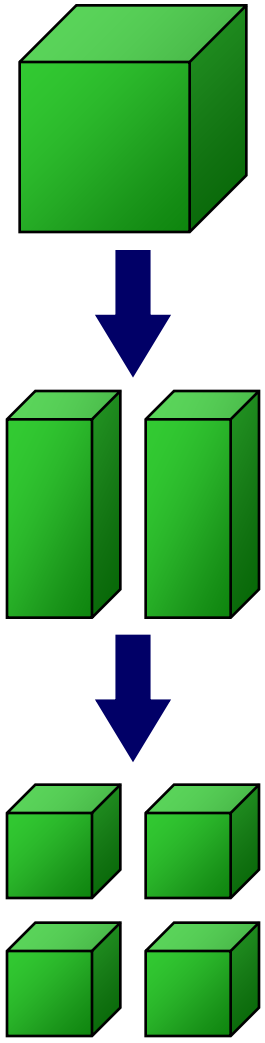
The gas particles become closer together, increasing the frequency of collisions, and so increasing the rate of reaction.

Rates of Reaction

Surface area

- Any reaction involving a solid can only take place at the surface of the solid.

slow rate



If the solid is split into several pieces, the surface area increases.

This means that there is an increased area for the non-solid reactant particles to collide with.

The smaller the pieces, the larger the surface area. This means more collisions and a faster rate of reaction.

fast rate

Rates of Reaction

What are catalysts?

- What are catalysts?

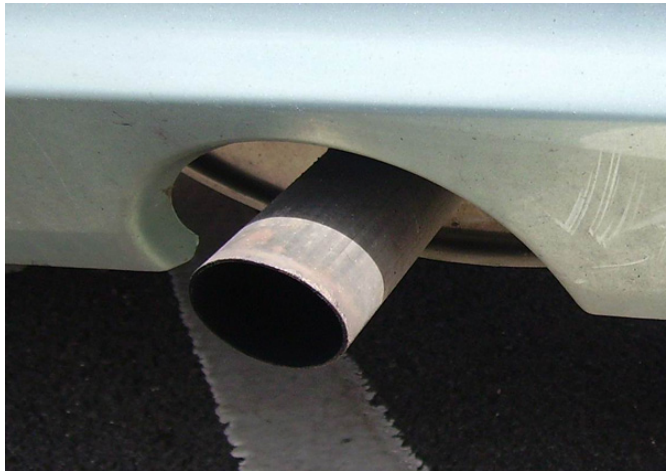
Catalysts are substances that change the rate of a reaction without being used up in the reaction.

Catalysts are very important in industry because products can be made more quickly, saving time and money. They can also avoid having to use high temperatures, so they can save fuel and reduce pollution.

Catalysts are also very important in living cells. Biological catalysts are special types of protein called **enzymes**.

Examples of catalysts

- Many catalysts are transition metals or their compounds. Different reactions use different catalysts. For example:
  - **Nickel** is a catalyst in the production of margarine (hydrogenation of vegetable oils).
  - **Iron** is a catalyst in the production of ammonia from nitrogen and hydrogen (the Haber process).
  - **Platinum** is a catalyst in the catalytic converters of car exhausts. It catalyses the conversion of carbon monoxide and nitrogen oxide into the less polluting carbon dioxide and nitrogen.



How do catalysts work?

- How do catalysts work?

For a chemical reaction to take place:

- energy is needed to break existing bonds, so new bonds can be formed;
- the reacting parts of particles need to be brought together.

Different catalysts work in different ways, but most solid catalysts work by lowering the amount of energy needed for the reaction to take place.

Catalysts work by lowering the activation energy of a reaction.

Decomposition of hydrogen peroxide

- Hydrogen peroxide decomposes into water and oxygen.

hydrogen peroxide	□	**water**	**+**	**oxygen**
$2H_2O_2$ (aq)	□	**$2H_2O$** (l)	**+**	**O_2** (g)

Without a catalyst, this reaction is very slow, and can take months. With a catalyst such as manganese (IV) oxide, the reaction takes minutes.

Catalysts never produce more product – they just produce the same amount but quicker.

Rates of Reaction

Glossary

- **activation energy –** The amount of energy needed for a reaction to begin.
- **adsorption –** The formation of a layer of molecules on the surface of a solid.
- **catalyst –** A substance that changes the rate of a reaction without being used up.
- **concentration –** The amount of particles in a given volume.
- **enzyme –** A biological catalyst.
- **rate of reaction –** The speed with which a particular chemical reaction progresses.