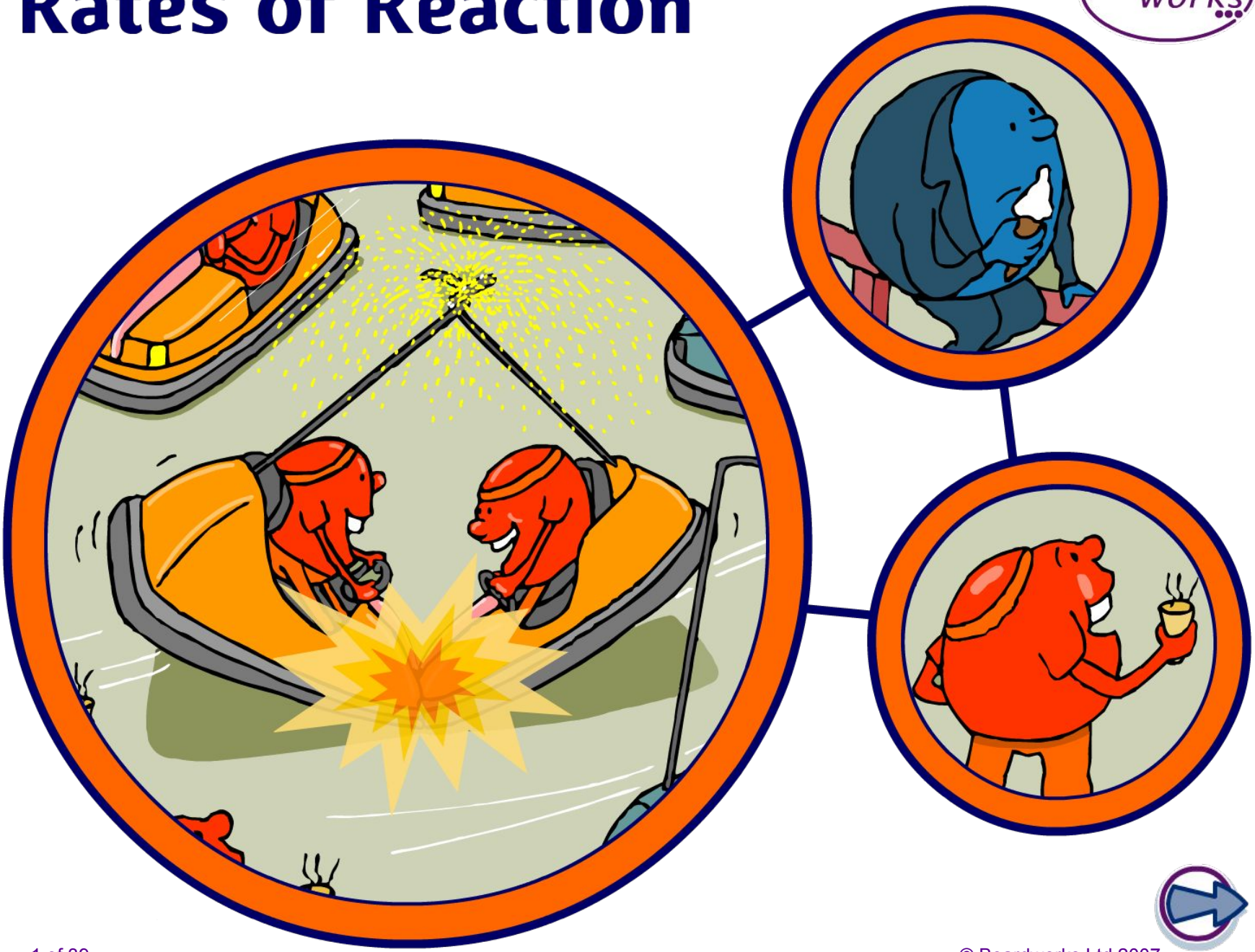
Rates of Reaction



Rates of Reaction

Contents

- Particles and collisions
- Temperature
- Concentration and pressure
- Surface area and catalysts
- Summary activities

What does rate of reaction mean?

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?

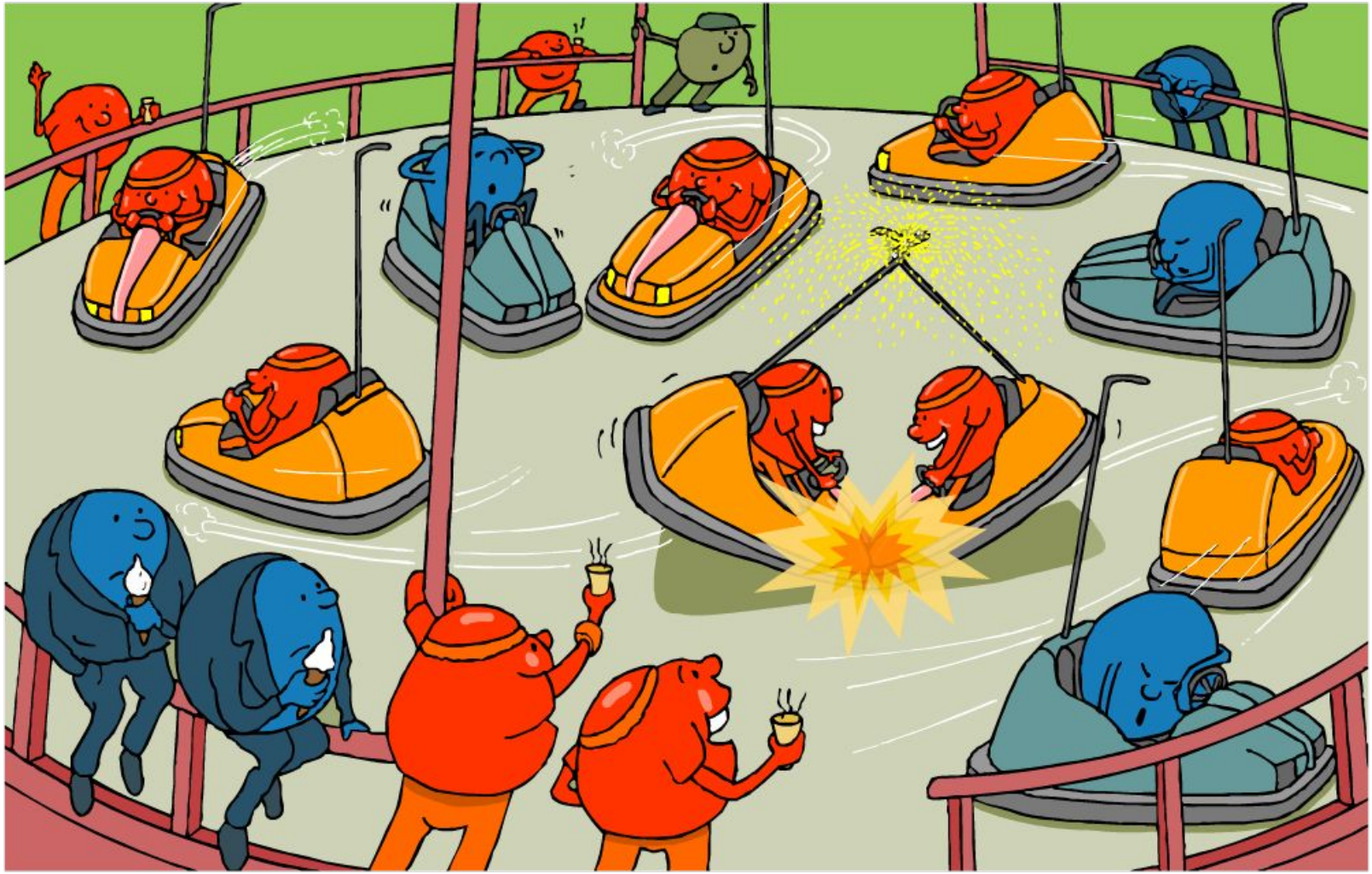
slow

fast

very fast

Rates of reaction

Why are some reactions faster than others?



Reactions, particles and collisions

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

The minimum amount of energy needed for the particles to react is called the **activation energy**, and is different for each reaction.

The rate of a reaction depends on two things:

- the **frequency** of collisions between particles
- the **energy** 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 affect the rate of reactions?

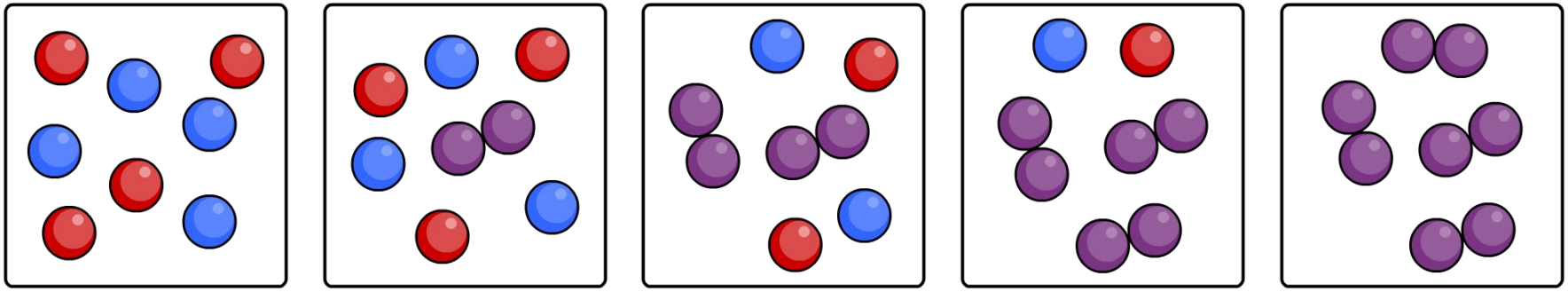
- increased **temperature**
- increased **concentration** of dissolved reactants, and increased **pressure** of gaseous reactants
- increased **surface area** of solid reactants
- use of a **catalyst**.

Slower and slower!

Reactions do not proceed at a steady rate. 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.



0% 25% 50% 75% 100%

reactants

product

percentage completion of reaction

Graphing rates of reaction

Reactant–product mix

How can rate of reaction be measured?

Measuring the rate of a reaction means measuring the change in the amount of a reactant or the amount of a product.

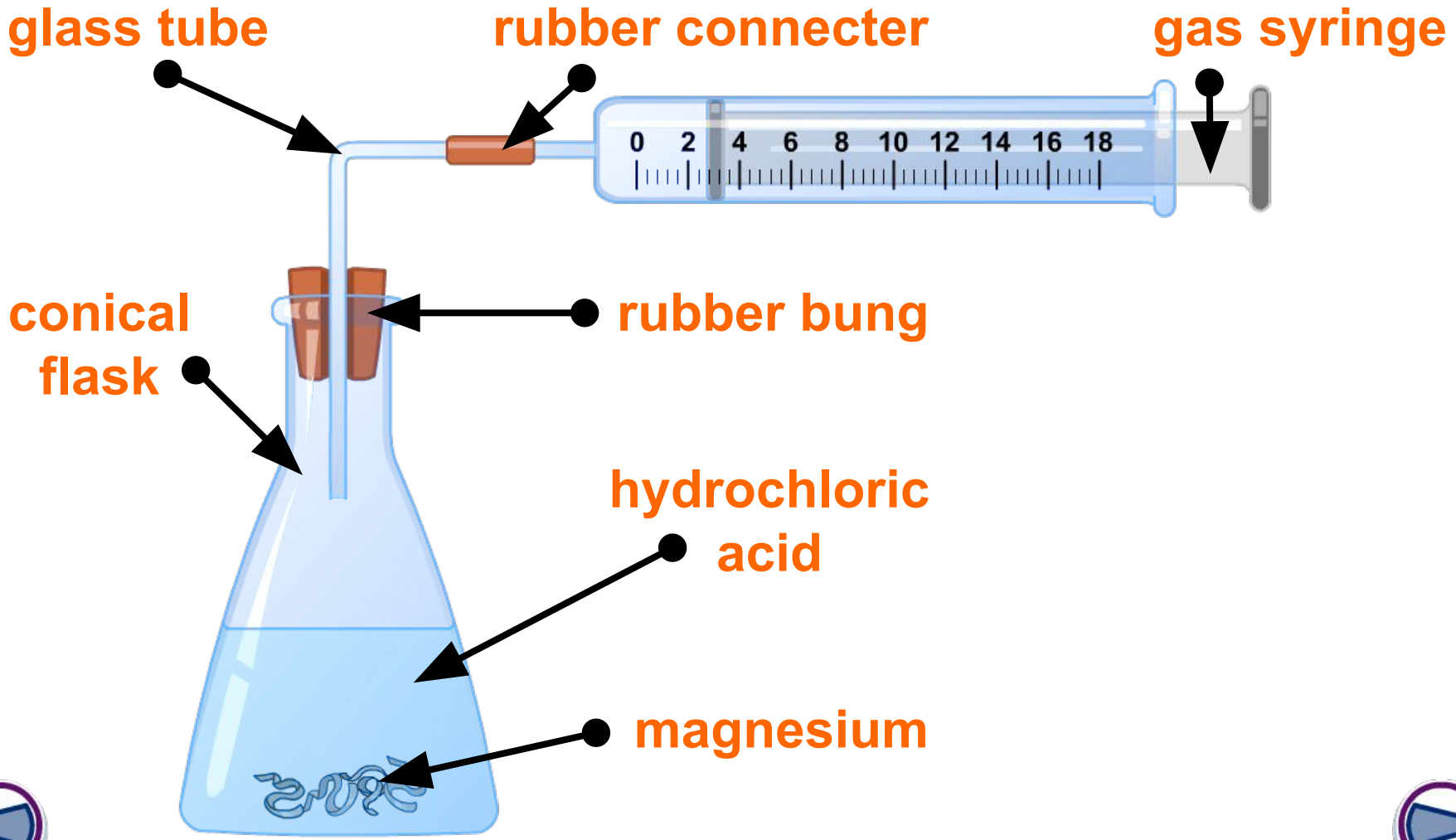
What can be measured to calculate the rate of reaction between magnesium and hydrochloric acid?

magnesium + hydrochloric acid → magnesium chloride + hydrogen

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

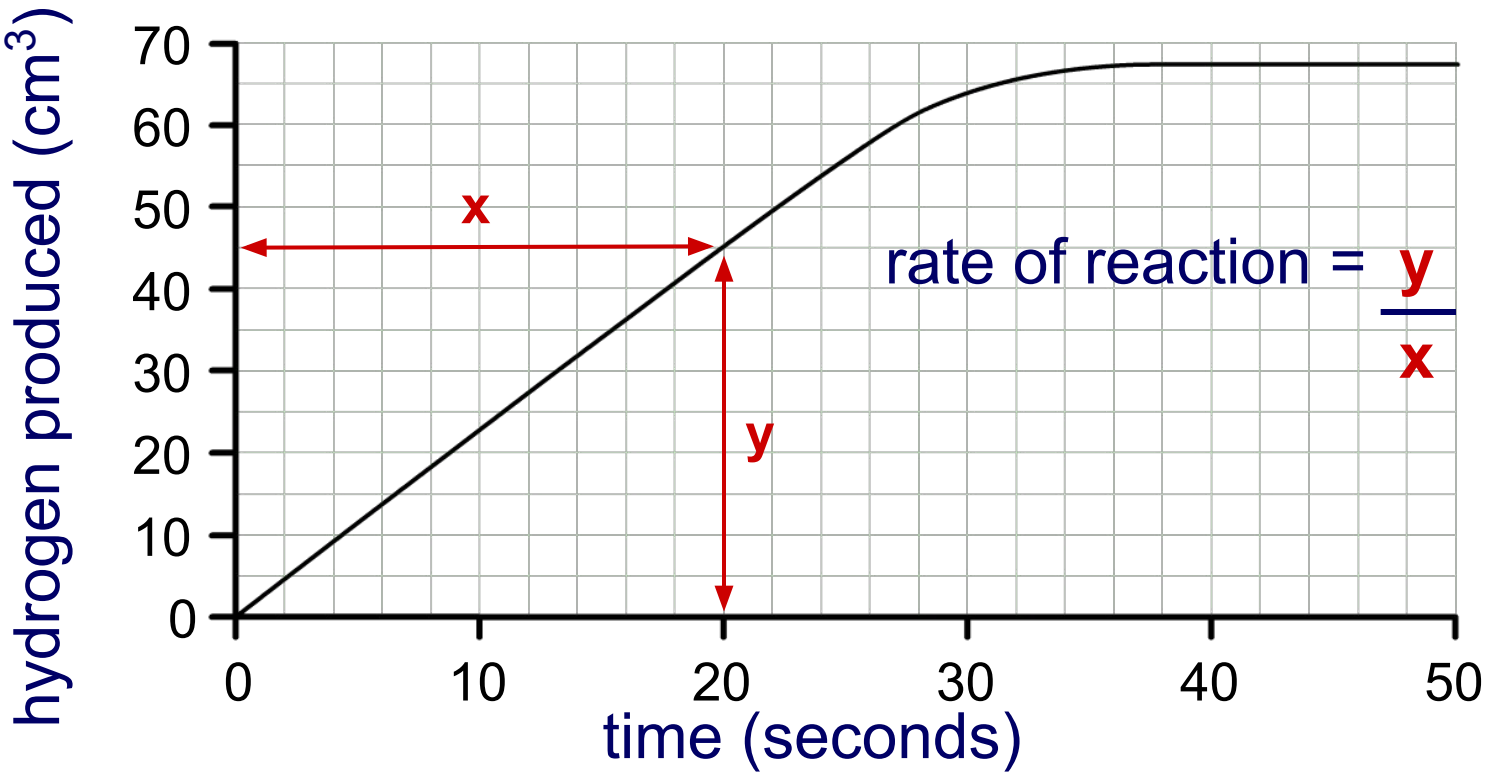
Setting up rate experiments

What equipment is needed to investigate the rate of hydrogen production?



Calculating rate of reaction from graphs

How can the rate of reaction be calculated from a graph?



The gradient of the graph is equal to the initial rate of reaction at that time

$$\text{rate of reaction} = \frac{45\,\text{cm}^3}{20\,\text{s}} \qquad \text{rate of reaction} = 2.25\,\text{cm}^3/\text{s}$$

The reactant/product mix

Collisions and reactions: summary

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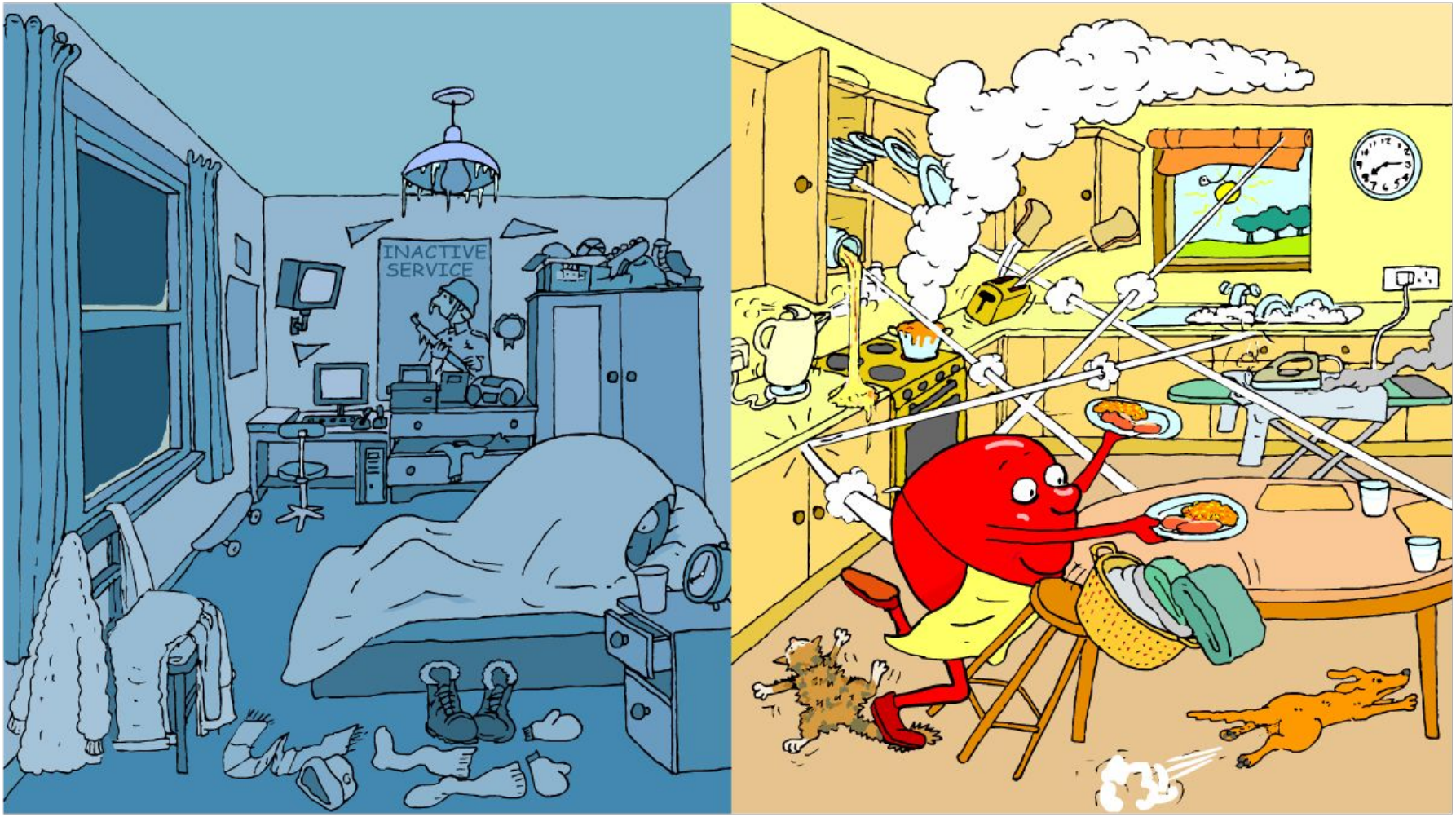
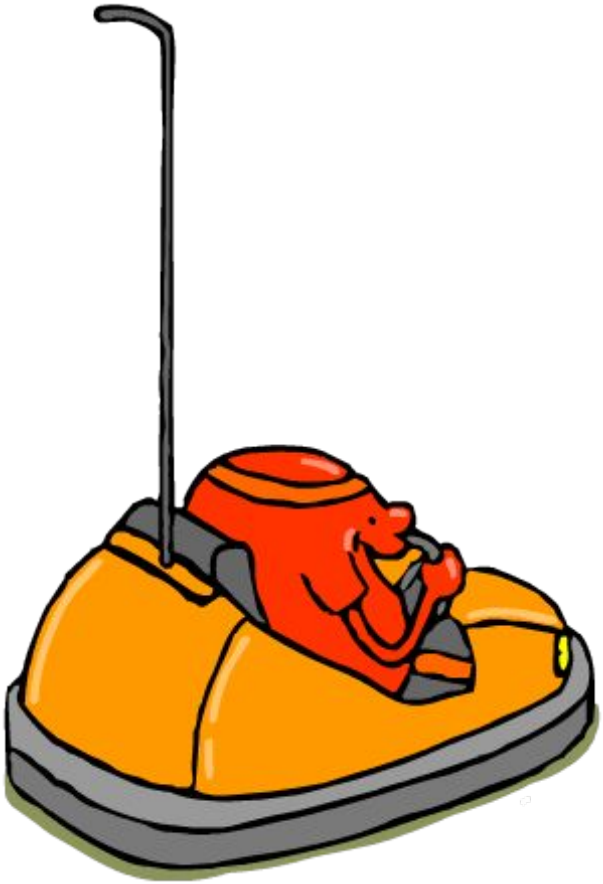
Temperature and collisions

How does temperature affect the rate of particle collision?



Effect of temperature on rate

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 particle collisions

Temperature and batteries

Why are batteries more likely to rundown more quickly in cold weather?

At low temperatures the reaction that generates the electric current proceeds more slowly than at higher temperatures.

This means batteries are less likely to deliver enough current to meet demand.

How does temperature affect rate?

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.

How can this fact be used to measure the effect of temperature on rate of reaction?

The effect of temperature on rate

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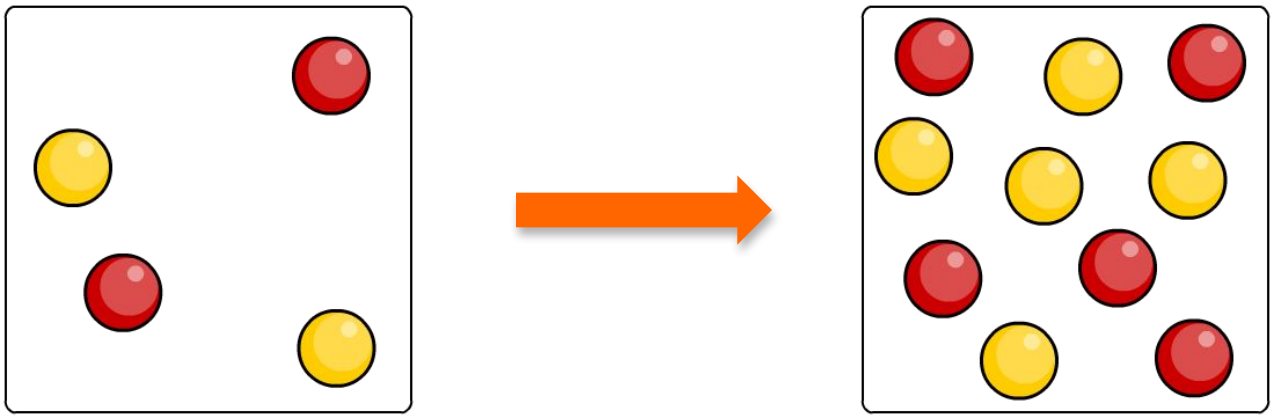
Effect of concentration on rate of reaction

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 the particles are more likely to collide and therefore more likely to react.



lower concentration

higher concentration

Concentration and particle collisions

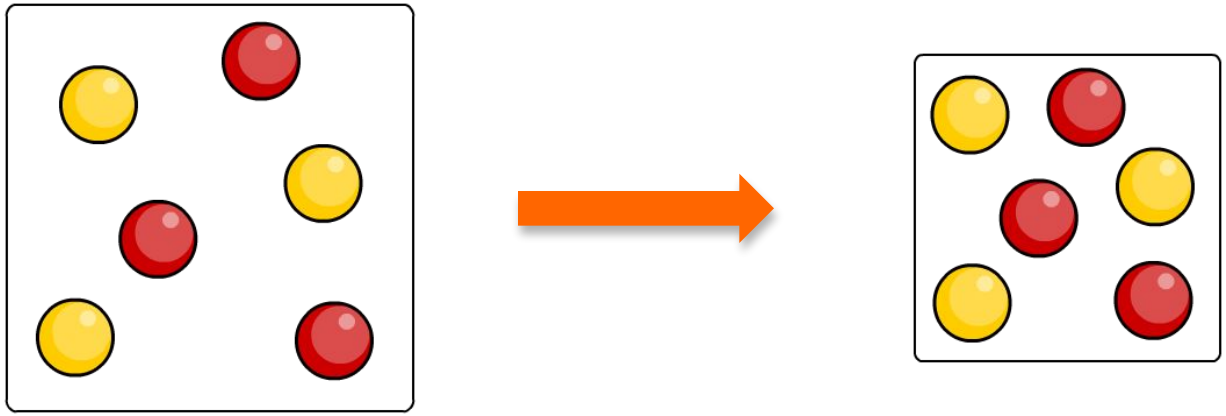
The effect of concentration on rate

Effect of pressure on rate of reaction

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.

The gas particles become closer together, increasing the frequency of collisions. This means that the particles are more likely to react.



lower pressure

higher pressure

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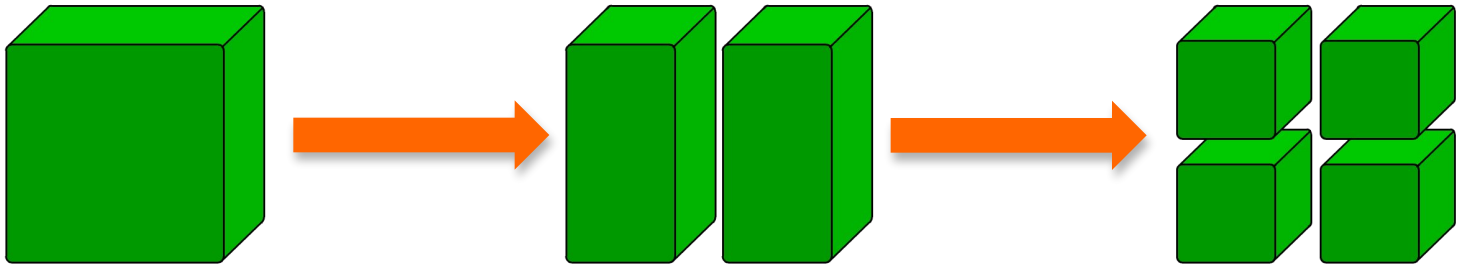
Effect of surface area on rate of reaction

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

If the solid is split into several pieces, the surface area increases. What effect will this have on rate of reaction?



low surface area

high surface area

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

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

Surface area and particle collisions

Reaction between a carbonate and acid

Marble chips are made of calcium carbonate. They react with hydrochloric acid to produce carbon dioxide.

calcium carbonate	+	hydrochloric acid	→	calcium chloride	+	water	+	carbon dioxide
$CaCO_3$ (aq)	+	2HCl (aq)	→	$CaCl_2$ (aq)	+	H_2O (aq)	+	CO_2 (g)

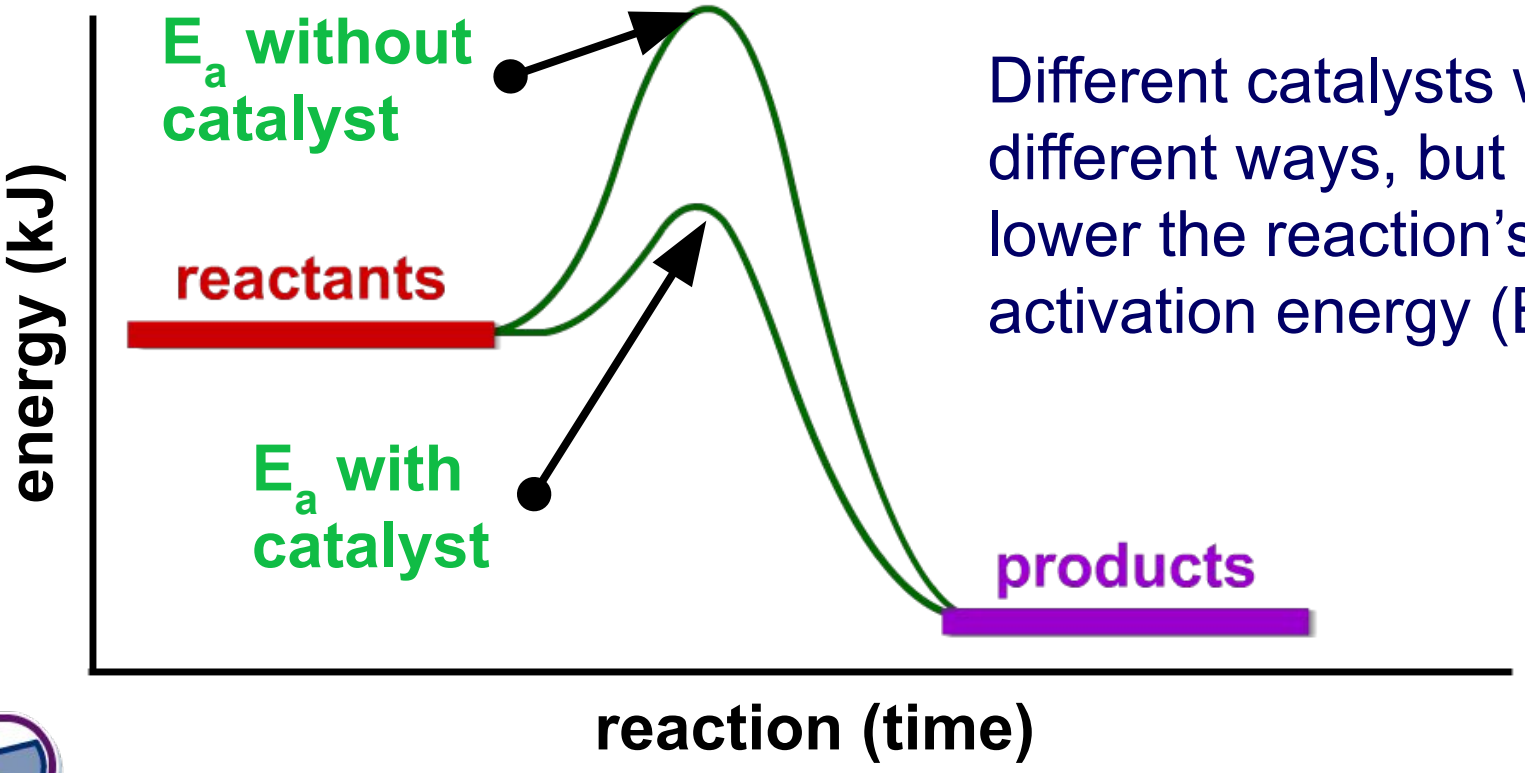
The effect of increasing surface area on the rate of reaction can be measured by comparing how quickly the mass of the reactants decreases using marble chips of different sizes.

The effect of surface area on rate

What are catalysts?

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

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



Different catalysts work in different ways, but most lower the reaction's activation energy (E_a).

Everyday catalysts

Many catalysts are transition metals or their compounds. 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 catalyzes the conversion of carbon monoxide and nitrogen oxide into the less polluting carbon dioxide and nitrogen.

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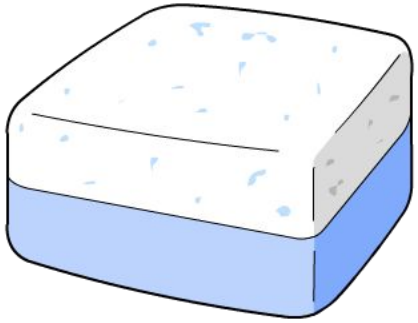
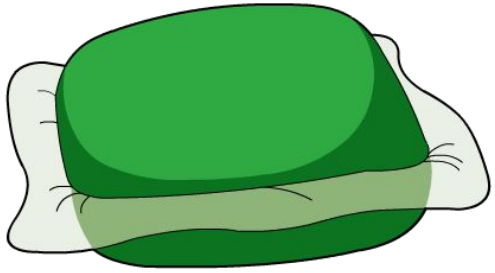
Catalysts in industry

Why are catalysts so important for industry?



- Products can be made more quickly, saving time and money.



- Catalysts reduce the need for high temperatures, saving fuel and reducing pollution.

Catalysts are also essential for living cells. Biological catalysts are special types of protein called **enzymes**.

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Glossary

- **activation energy –** The amount of energy needed to start a reaction.
- **catalyst –** A substance that increases the rate of a chemical reaction without being used up.
- **concentration –** The number of molecules of a substance in a given volume.
- **enzyme –** A biological catalyst.
- **rate of reaction –** The change in the concentration over a certain period of time.

Anagrams

Rates of reaction: summary

Multiple-choice quiz