REACTION RATES

Every chemical reaction involves collisions between the reacting particles. Old bonds break and new bonds are formed e.g.

NO_2 + CO -> NO + CO_2

The more often these particles collide, the faster the reaction.

When reactions occur the quantities of reactants and products change : if we time how long a specified change in quantity takes, we can estimate the rate of reaction.

Example In the above reaction between NO_2 and CO, the quantity of CO changes from 5 moles to 3 moles in 50 minutes. What is the rate of the reaction?

Answer:

$$\text{Rate of disappearance of CO} = \frac{\text{change in quantity}}{\text{time}}$$

$$= \frac{5 - 3}{50}$$

$$= \frac{2}{50}$$

$$= 0.04 \text{ moles per minute}$$

We can use changes in concentration, mass, and volume of reactants or products to measure the rate of reaction.

SPEEDING UP REACTIONS

We will use the reaction between Magnesium and Hydrochloric acid to try to find out how to speed up reactions.

Mg + HCl -> $MgCl_2$ + H_2

If we drop a piece of Magnesium into the acid it fizzes and bubbles giving off Hydrogen gas. The piece of Magnesium gets smaller and smaller as it is used up. We will time how long a fixed length of Magnesium ribbon takes to completely react.

The shorter this time (t), the faster the reaction.

This means that rate depends on 1/t. We call 1/t the 'relative rate'.

If t = 5 s then relative rate = 1/5 = 0.2 s^{-1} [FAST]

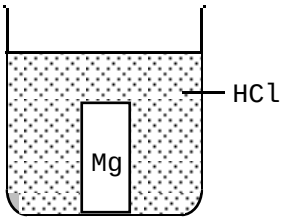
If t = 50 s then relative rate = 1/50 = 0.02 s^{-1} [SLOW]

There are FOUR ways of speeding up reactions.

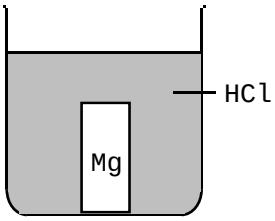
INCREASE THE CONCENTRATION OF REACTANTS

The more 'bunched together' the reactants the more often they will collide.

The reaction of Magnesium with Hydrochloric acid is faster if the concentration of the HCl is increased:



Dilute acid
Fewer collisions
Slower reaction

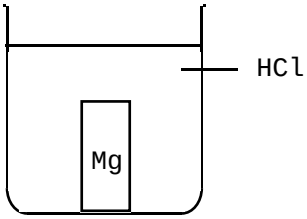


Concentrated acid
More collisions
Faster reaction

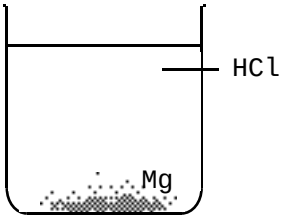
In everyday life, we know that charcoal in a barbecue burns much faster when you fan it. This is because a higher concentration of Oxygen in the air is then reacting with the charcoal.

INCREASE THE SURFACE AREA OF REACTANTS

The Magnesium in the above reaction can only react with the HCl molecules on its surface. If we make the Magnesium into a powder, the HCl can get round each little grain in the powder, increasing the number of collisions and therefore speeding up the reaction.



Magnesium block
Fewer collisions
Slower reaction



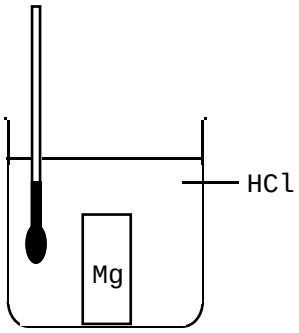
Powdered Magnesium
More collisions
Faster reaction

In everyday life, we know that potatoes will cook quicker if they are cut into small pieces.

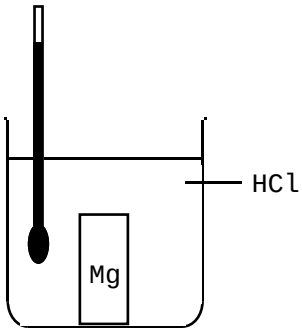
INCREASE THE TEMPERATURE OF THE REACTION MIXTURE

The higher the temperature the faster and more violent the collisions. Bonds are more likely to break and reactions are therefore faster.

Magnesium reacts faster with Hydrochloric acid when the temperature of the reaction mixture is increased:



Low temperature
Low energy collisions
Slower reaction



High temperature
High energy collisions
Faster reaction

In everyday life, we know that foods are kept in fridges to slow down the decomposition process.

USE A CATALYST

Catalysts are substances which speed up reactions by taking part in the reactions. They are regenerated and can be recovered unchanged at the end of the reaction.

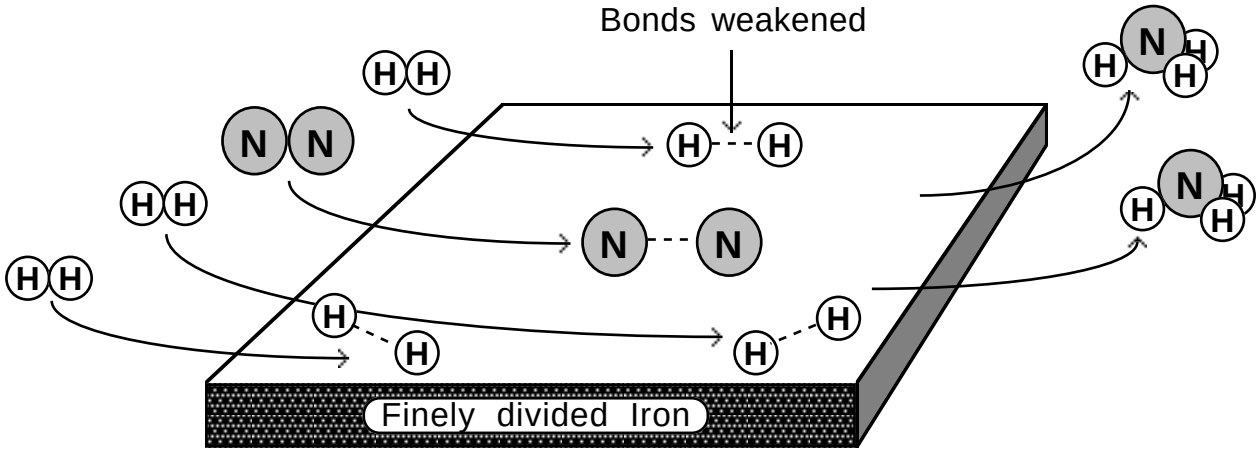
There are two types of catalyst: heterogeneous and homogeneous.

Heterogeneous catalysts

These are surface catalysts. They are in a different state from the reactants. Reactants become adsorbed on the catalyst surface which must, therefore, have a large surface area. This crowds the molecules together. New bonds form with the catalyst weakening the original bonds. Reaction occurs on the catalyst and the products are desorbed leaving the site vacant for further reaction.

Example: Solid Iron is used to speed up the reaction between the gases in the Haber Process:

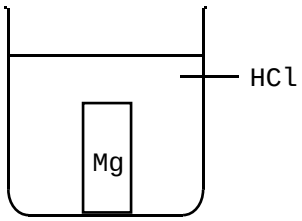
$$3\ H_2 + N_2 \rightarrow 2\ NH_3$$



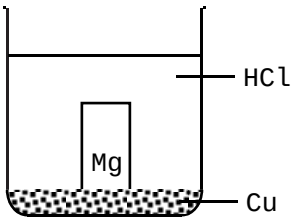
When a heterogeneous catalyst is used the reactants must be carefully purified since certain impurities become, themselves, adsorbed on the catalyst surface. This blocks or poisons the active sites on the catalyst and prevents access of reactant molecules. The catalyst ceases to function properly. Iron in the Haber process is easily poisoned by Sulphur, Arsenic, Water, Carbon monoxide and Carbon dioxide. Poisoned catalysts must be either regenerated or renewed.

Example 1

SOLID Copper speeds up the reaction between Magnesium and Hydrochloric acid **SOLUTION**:



Catalyst not present
Slower reaction



Catalyst present
Faster reaction

Example 2

SOLID Platinum/Rhodium alloy is used in the catalytic converter to speed up the reaction between the exhaust **GASES** in a car e.g.

$$CO + NO \rightarrow CO_2 + N_2$$

Lead-free petrol must be used as Lead would poison the catalyst.

Example 3

SOLID Vanadium(V) oxide is used to speed up the reaction between the **GASES** in the Contact Process:

$$SO_2 + O_2 \rightarrow SO_3$$

Homogeneous catalysts are in the same state as the reactants

Example

Enzymes catalyse the chemical reactions which take place in the living cells of plants and animals. Both enzyme and reactants are in solution. They find uses in the home and in industry:

- Biological washing powders contain enzymes which speed up the reaction of protein stains (blood, egg etc) with Water.
- In the brewing industry, plant enzymes are used to convert Starch into alcohol.