Speed of Reaction

Rate of reaction

- The speed of a reaction- usually called the rate of reaction tells us how rapidly the products are formed from the reactants
- Chemical companies need to know how to make their products as quickly and cheaply as possible
- Knowing the rate of reaction helps them to do this

Following the progress of a reaction

To find the rate of reaction, we can either:

i. Measure how quickly the reactants are used up
ii. Measure how quickly the products are formed

Calculating the rate of reaction depends on measuring something that changes with time, for example, volume of gas, mass of the reaction mixture or the amount of light transmitted through a solution

- There are many methods for measuring rate of reaction
- You can use any property that changes during a reaction
- You could use a pH meter or an electrical conductivity meter if hydrogen ions are present
- You could also record changes in pressure for reactions involving gases

Calculating the rate of reaction

$$Rate\ of\ reaction = \frac{amount\ of\ product\ formed\ or\ reactant\ used\ up}{time}$$

$$Rate = \frac{change\ in\ concentration\ of\ reactant\ or\ product}{time}$$

A graph of results

- The slope of the curve tells you how fast the reaction is going
- The slope keeps changing until the curve flattens out-which tells us the rate of reaction keeps changing
- The curve is steepest at the start, so the reaction is fastest then (rate is greatest)
- The curve becomes less steep as time passes, showing that that the reaction is slowing down
- When the curve is flat, it means the reaction has stopped
- The reaction rate is zero

Limiting reactants

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

The hydrochloric acid is the limiting reagent

The magnesium is in excess

Surface area and the rate of reaction

- Increasing the surface area of a solid reactant increases the rate of reaction
- Smaller particles of solid have a larger surface area than larger one with the same total volume
- Many industrial processes cause fine powders to get into the air
- These powders are highly combustible
- They burn readily in air because of their very large surface area

Catalysts

- A catalyst speeds up the rate of reaction but it is not used up in the reaction itself
- A catalyst lowers the activation energy therefore lowering average costs
- A catalyst works by allowing the reactants to get close together on its surface so less energy is needed to get the reaction to occur
- Catalysts are generally used in the form of pellets or wire gauzes
- Catalysts are usually transition metals or oxides of transition metals
- This gives them a large surface area for the reactions to occur on
- We only need tiny amounts of catalysts but they are often expensive
- However, they can be used over and over again
- More chemicals can be produced at a lower temperature with a catalyst

Enzymes

- Enzymes are proteins made by living cells, they are biological catalysts
- Enzymes in yeast cells are used as a catalyst in making enzymes, enzymes made by bacteria are used in biological detergents
- Enzymes work in a limited range of temperature and pH
- If the temperature and pH is not optimal, the enzyme will denature

Concentration affecting rate of reaction

- Increasing the concentration of reactants increases the rate of reaction
- Increasing the concentration of reactants increases the frequency of collision of the particles and so increases the reaction rate

The collision theory

- For a reaction to take place, there must be a collision between the reactant particles
- But not every collision leads to reaction, some are unsuccessful
- A successful collision is one where the colliding particles have enough energy to react

Example: Reaction of magnesium with a solution of hydrochloric acid

- If the temperature is increases, the particles have more energy. They move faster, collide more often and more of the collisions are successful

- If the concentration of the acid is increased, it means there are more acid particles on the same volume. So there are more successful collisions
- The surface area of the metal exposed is increased, by using magnesium powder. So more magnesium atoms are exposed, giving more successful collisions

The collision theory and gas reactions

In reactions between gases, the rate increases as temperature and pressure increases

i. As the temperature rises, the gas molecules gain more energy and move faster
ii. Increasing the pressure pushes the gas molecules closer together

Temperature and the rate of reaction

- The higher the temperature, the greater rate of reaction
- When we heat up a reaction mixture, the particles gain energy. When particles gain energy they move faster and collide more often. The frequency of collisions is increased. This results in an increased rate of reaction
- In order to react, particles must collide with a minimum amount of energy (activation energy)
- As temperature increases, more and more particles have this minimum amount of energy when they collide
- As the temperature is increased there is more chance of a collision between the reactant particles being successful
- We say the number of effective collision in a given time increases as temperature increases

Light sensitive reactions

- Chemicals started by ultraviolet or visible light are called photochemical reactions

Photosynthesis

- $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- The glucose is turned into macromolecules called starch and cellulose
- Photosynthesis is catalysed by green pigments in plants called chlorophylls

Photography

- The surface of black and white photographic film contains tiny crystals of silver bromide mixed with gelatine
- When light shines on the film, the silver bromide is activated
- Some of the silver bromide decomposes (breaks down) to form silver

$$2AgBr \rightarrow 2Ag + Br_2$$

- The silver appears black in colour because the particles are very small
- In this reaction the silver ions in the silver bromide accept electrons from the bromide ions and become silver atoms (redox reaction)
- The silver ions are reduced because they accept electrons and the bromide ions are oxidised because they lose electrons

$$2Ag^+ + 2e^- \rightarrow 2Ag$$

$$2Br^- \rightarrow Br_2 + 2e^-$$

- The parts of the film exposed to stronger light appear black and the parts not exposed appear white
- The greater the intensity of the light, the faster the reaction
- A positive print is made by shining light through the negative onto a piece of photographic paper