WEEK TWO (22ND-26TH MARCH 2020)

CHEMISTRY

CHAPTER SEVEN: CHEMICAL REACTIONS PART 1 & 2

Physical and Chemical Change

Physical change

- Physical changes (such as melting, evaporating, dissolving) do not produce any new chemical substances, but there is a change in appearance of the substance.
- These changes are often easy to reverse and mixtures produced are usually relatively easy to separate, since they consist of elements/compounds that are not fully combined, eg. Fractional distillation of crude oil.

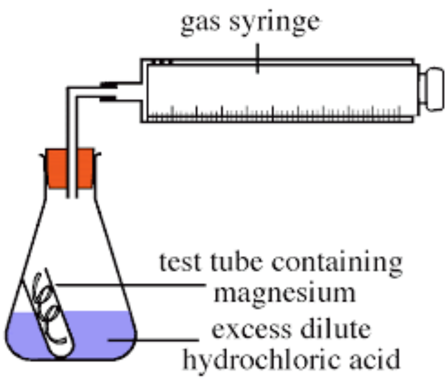
Chemical change

- In chemical reactions, new chemical products are formed that have very different properties to the reactants.
- Most chemical reactions are impossible to reverse.
- Energy changes also accompany chemical changes and energy can be given our (exothermic) or taken in (endothermic) when atomic bonds are broken or created.
- The majority of chemical reactions are exothermic with only a small number being endothermic.
- Eg. Neutralization reactions to produce salts, rusting.

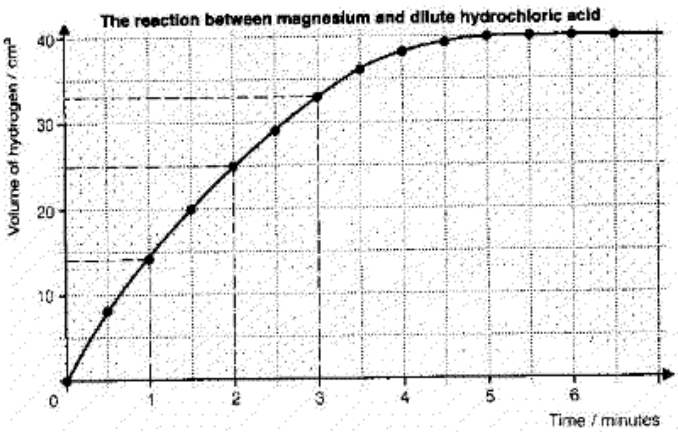
Rate (Speed) of Reactions

Rate is a measure of change per unit time.
A **reaction rate** or **rate of a reaction** is the speed at which reactants are converted into products.

Rate of reaction between magnesium and hydrochloric acid



- Set up the apparatus as described above.
- Once the test tube is removed and the magnesium ribbon touches the hydrochloric acid solution, start the **stopwatch**.
- At equal intervals of time, record the volume in the gas syringe (eg. 30 seconds).
- Repeat the experiment and obtain average to improve reliability of the experiment.

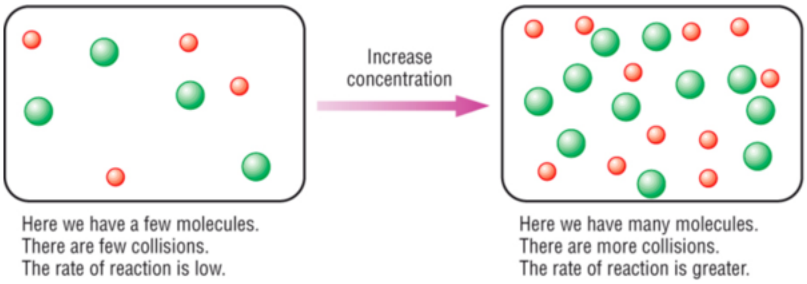


- At 30 seconds, reaction is fastest (highest gradient)
- At 3 minutes, reaction slows down (decreased gradient)
- At 5 minutes, the reaction has stopped (gradient is zero)

Rates of Reaction Factors

- Concentration
- Surface area/ Particle size
- Catalysts
- Temperature
- Pressure (for gases only)

Effect of Concentration

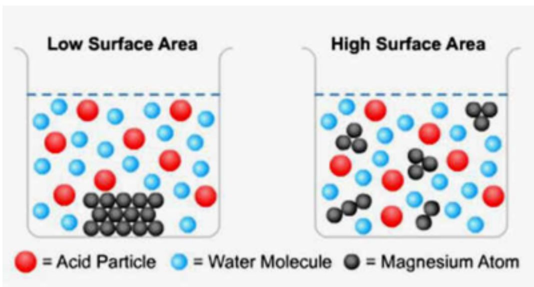


Reason:

- Increase in the concentration of a solution, the rate of reaction will increase.

- This is because there will be more reactant particles in a given volume, allowing more **frequent** and **successful** collisions per second, increasing the rate of reaction.

Effect of Surface Area



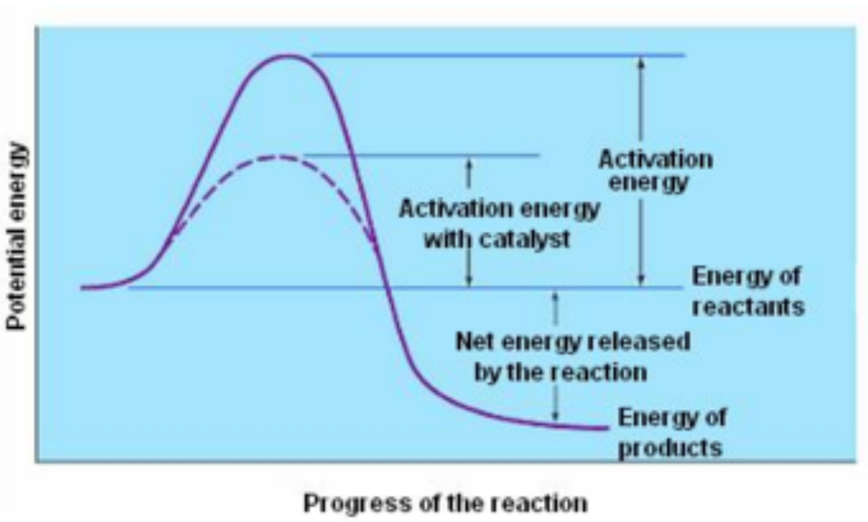
smaller surface area: volume ratio → bigger surface area: volume ratio

Reason:

- Increase in the surface area of the solid, the rate of reaction will increase.

- This is because more surface area particles will be exposed to the other reactant so there will be more frequent and successful collisions per second, increasing the rate of reaction.
- This is why powdered magnesium reacts faster than a lump of magnesium. Increasing the surface area increases the rate of reaction but does not alter the total amount of product formed.

Effect of Using a Catalyst

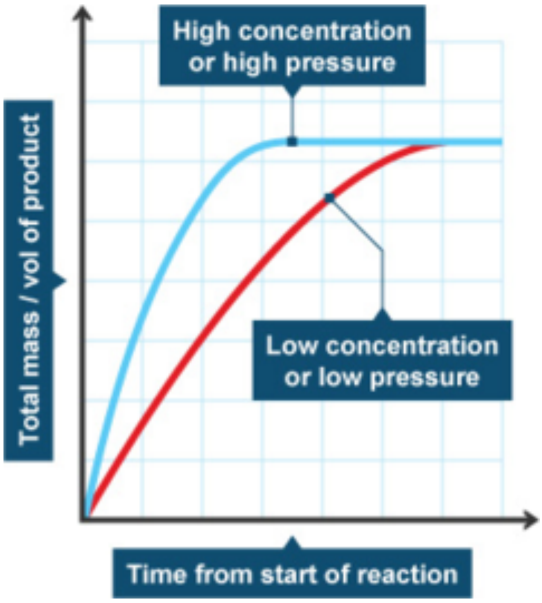


Reason:

- A catalyst is a substance that speeds up a reaction, but is not used up in the process (is not a reactant).
- Catalysts reduce the activation energy of a reaction. Activation energy is the energy needed to initiate a chemical reaction.
- A certain level of energy is often needed in order to break existing bond, before new bonds can be formed and energy is released.
- This can be seen on the graph as a 'hump' -energy must first be put into the reaction (the graph rises), before energy is released from the reaction (the graph fall).
- A catalyst means that less energy is needed to get the reaction started.
- Catalysts reduce the activation energy as they create alternative pathways requiring lower activation energy, allowing more successful and frequent collisions.

- Some catalysts (such as enzymes) increase the rate of reaction by temporarily binding with the reactants and providing them with the correct orientation for a successful collision to occur.
- A catalyst does not increase the frequency of collisions but increases the likelihood that each collision will be successful.

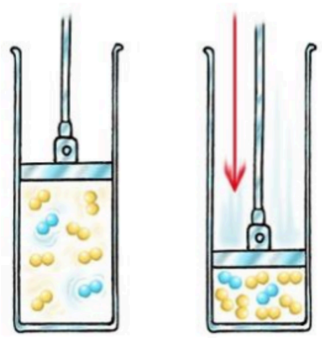
Effect of Temperature



Reason:

- Increasing the temperature increases the kinetic energy of the reactant particles.
- The particles move more quickly increasing the frequency of collisions. The particles also collide with more energy which increases the likelihood of each collision being successful.
- Increasing the temperature does not alter the total amount of product that is formed. This is because the amount of reactant particles doesn't change.
- If the temperature is low it simply takes longer for the same amount of product to be formed. This is why the line representing the reaction at a lower temperature is flatter but still eventually reaches the same height.

Effect of Pressure (gases only)



- Increasing the pressure in gaseous systems increases the rate of reaction.
- The distance between particles is reduced under pressure.
- There are more particles per unit volume, so the collision rate increases, resulting in an increased rate of reaction.

https://www.youtube.com/watch?v=6HCGWhWMEMI

Explosive Combustion

- Explosive combustion occurs when there are many **fine particles** in the air.
- Many industrial processes such as metal working, coal mining or flour milling produce very fine and tiny particles.
- These particles have a very large **surface area** and are **combustible** in air.
- Even a small spark may cause them to ignite and since the surface area is so large, the rate of reaction can be incredibly **fast,** hence they are explosive.
- Methane gas mixed with air in coal mines can also form an explosive mixture.
- In flour mills, a high concentration of flour powder (high surface area) can react with air, causing a spark.
- In both cases, a spark to provide activation energy can cause a very rapid explosive reaction.

Experiments to Determine Rate

Use the equations below to find the rate of reaction to compare the effect of changes in surface area/particle size, concentration, temperature, use of a catalyst etc...

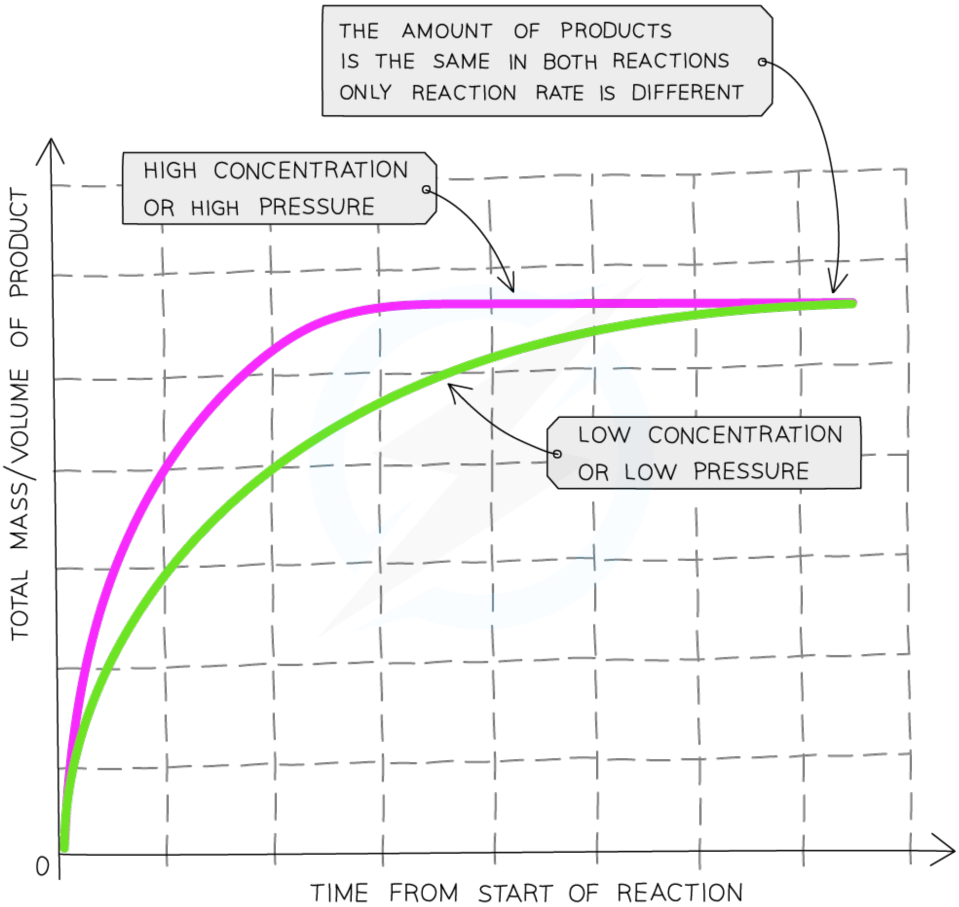
Rates of reactions can be measured using the amount of reactant used, or amount of product formed over time:

$$\text{Rate of reaction} = \frac{\text{Amount of reactant used}}{\text{Time}}$$

$$\text{Rate of reaction} = \frac{\text{Amount of product formed}}{\text{Time}}$$

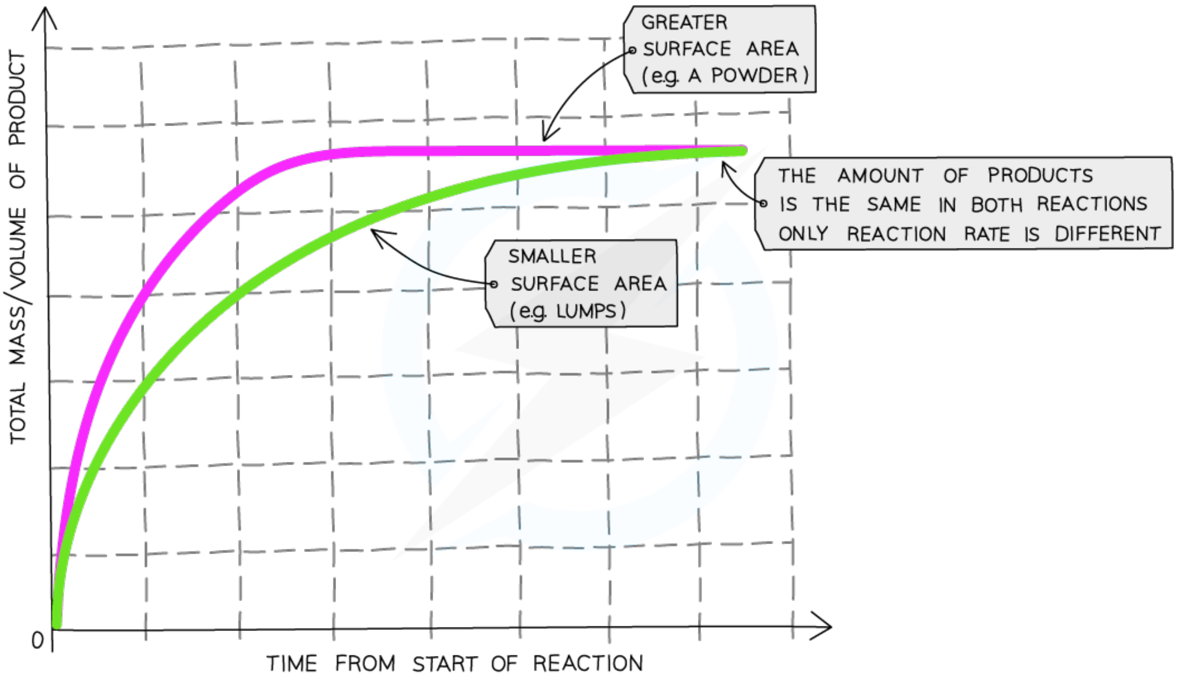
- Quantity of reactant or product can be measured by the mass in grams or by a volume in cm^3
- If a gas is produced in a reaction, you can either collect the gas produced in a gas syringe and measure the volume over time, or let the gas escape and measure loss of mass over time
- Units of rate of reaction may be given as g/s or cm^3/s
- Use quantity of reactants in terms of moles and therefore, units for rate of reaction is in mol/s
- You would want to do multiple experiments changing the variable e.g. if it was temperature do the experiment at 20^0C, 25^0C, 30^0C etc... measuring the rate at regular intervals each time to then compare (possibly graphically)

Effect of concentration on rate of reaction



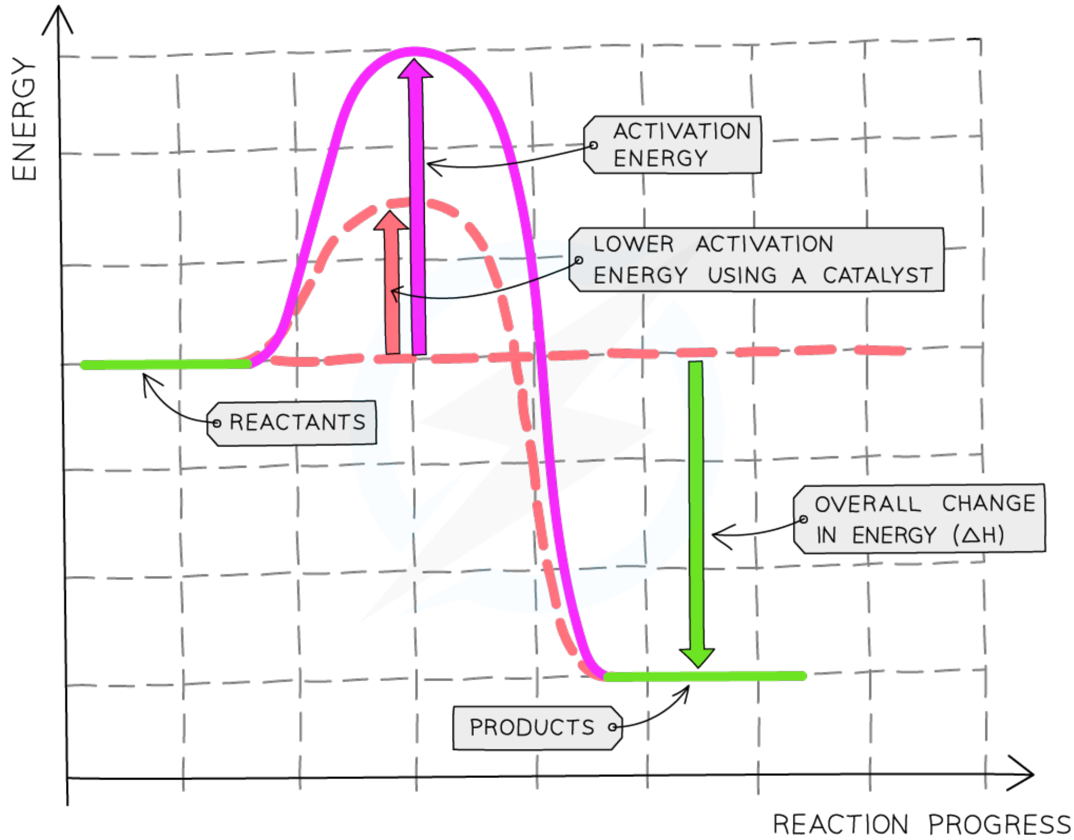
- The graph with higher concentration has a steeper gradient than the one with lower concentration.
- If you take the total mass/volume of product at a given time, the higher concentration would produce more total mass/volume of product than the graph of lower concentration.
- This can be observed through the obtaining the gradient of the graph.
- Additionally, the graph of higher concentration becomes steeper sooner.
- This indicates that an increase in concentration causes an increase in the rate of reaction.
- This is because in higher concentration, more reactant particles are in a given volume, allowing more **frequent** and **successful** collisions per second, increasing the rate of reaction.

Effect of surface area on rate of reaction

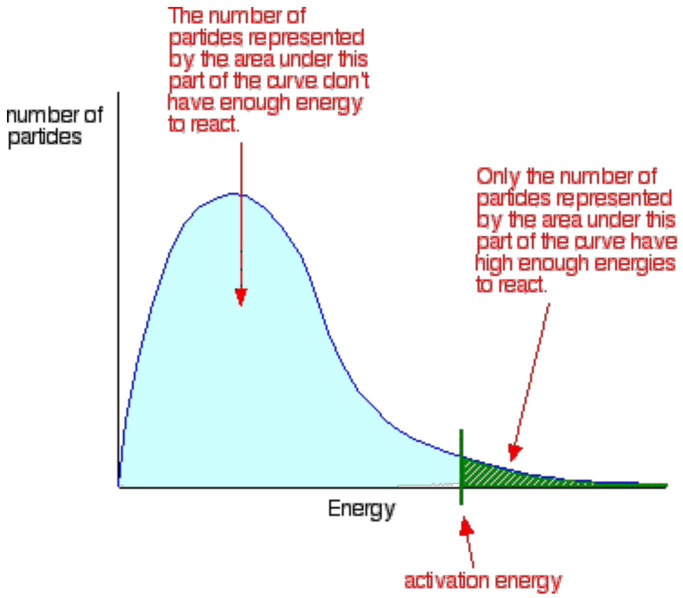


- The graph with higher surface area has a steeper gradient than the one with lower surface area.
- If you take the total mass/volume of product at a given time, the higher surface area would produce more total mass/volume of product than the graph of lower surface area.
- This can be observed through the obtaining the gradient of the graph.
- Additionally, the graph of higher surface area becomes steeper sooner.
- This indicates that an increase in surface area causes an increase in the rate of reaction.
- In higher surface area, more surface area particles will be exposed to the other reactant so there will be more frequent and successful collisions per second, thus increasing the rate of reaction.

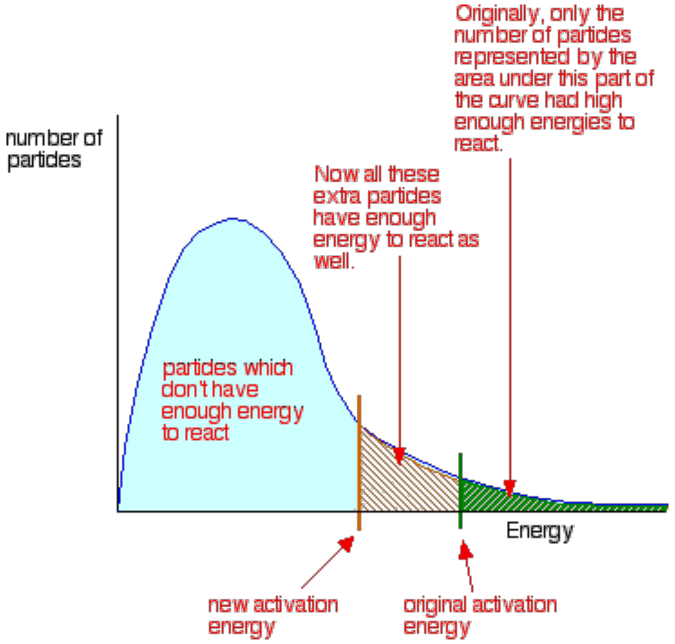
Effect of using a catalyst on the rate of a reaction



- The graph with the catalyst has a lower peak than the one without the catalyst.
- Using a catalyst lowers the activation energy needed for a reaction to take place, and creates and alternate pathway requiring lower activation energy, allowing more successful and frequent collisions.
- This causes the reaction using the catalyst to occur faster and yield the product sooner.
- This indicates that using a catalyst causes an increase in the rate of reaction.

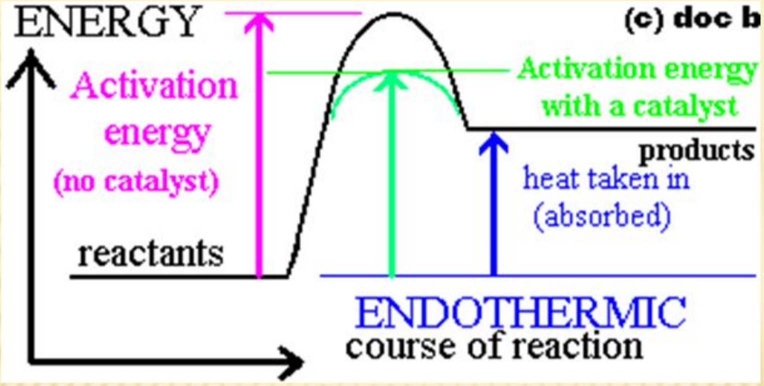


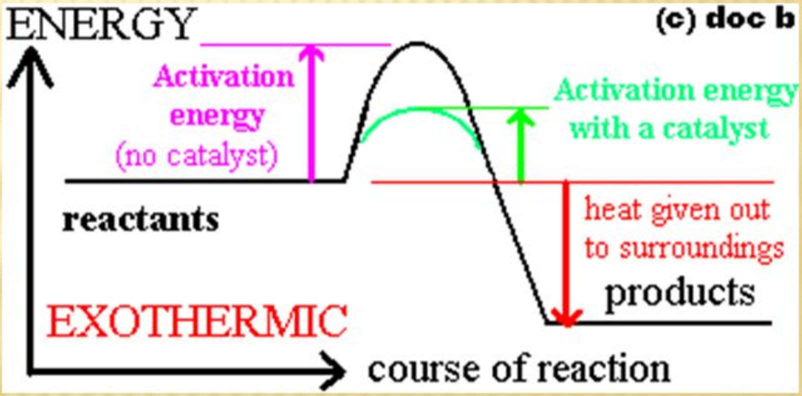
Only the particles in the shaded green area will have enough activation energy to collide and react. The ones that don't will simply collide but bounce back, and no reaction will take place. The shaded green section indicates a very few amount of particles with enough energy, causing a slow reaction.



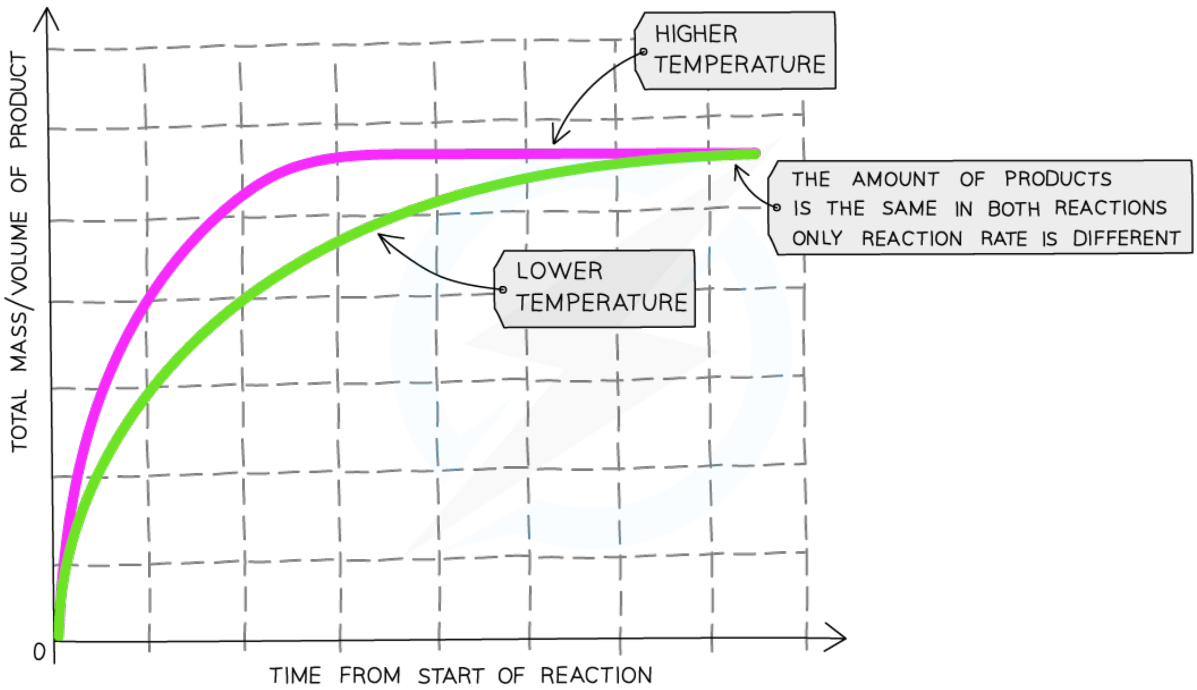
As before, particles which don't have enough energy at a particular time will at some time gain energy from random collisions, just as other particles will lose energy. You mustn't get the idea that those particles in the blue area of the graph can never react - given time they will.

Adding a catalyst has exactly this effect of shifting the activation energy. A catalyst provides an alternative route for the reaction. That alternative route has a lower activation energy.

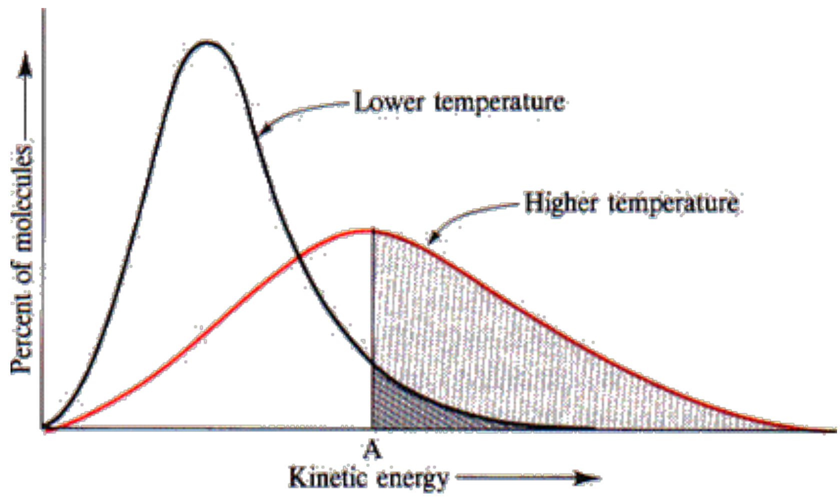

ENERGY
(c) doc b
Activation energy (no catalyst)
Activation energy with a catalyst
products
heat taken in (absorbed)
reactants
ENDOTHERMIC
course of reaction


ENERGY
(c) doc b
Activation energy (no catalyst)
Activation energy with a catalyst
reactants
heat given out to surroundings
products
EXOTHERMIC
course of reaction

Effect of temperature on rate of reaction



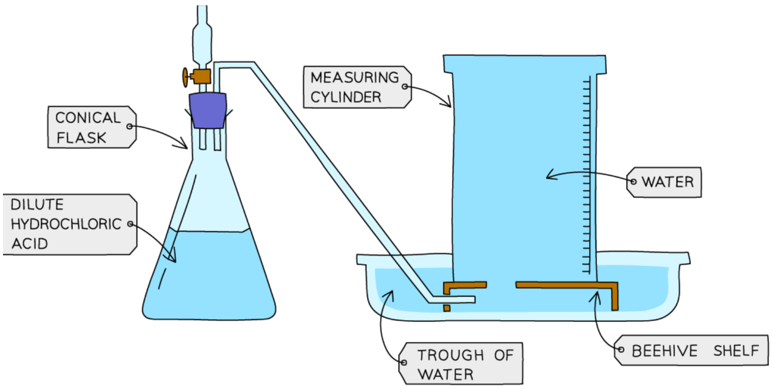
- The graph with higher temperature has a steeper gradient than the one with lower temperature.
- If you take the total mass/volume of product at a given time, the higher temperature would produce more total mass/volume of product than the graph of lower temperature.
- This can be observed through the obtaining the gradient of the graph.
- Additionally, the graph of higher temperature becomes steeper sooner.
- This indicates that an increase in temperature causes an increase in the rate of reaction.
- This is because in higher temperature, more reactant particles have more kinetic energy, allowing more **frequent** and **successful** collisions per second, increasing the rate of reaction.



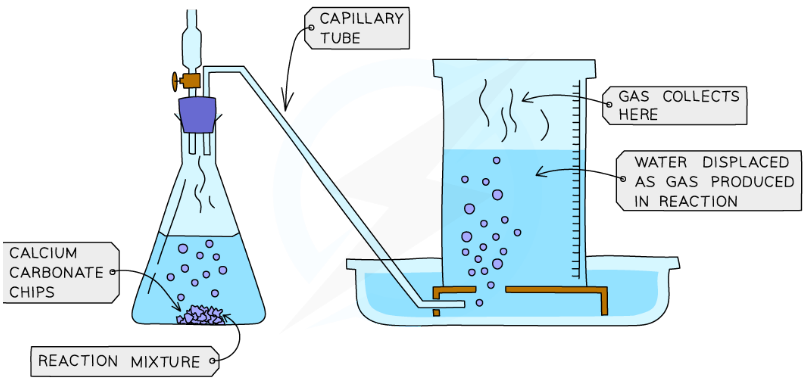
Investigating the Rate of Reaction

Effect of Surface Area of a Solid on Rate of Reaction

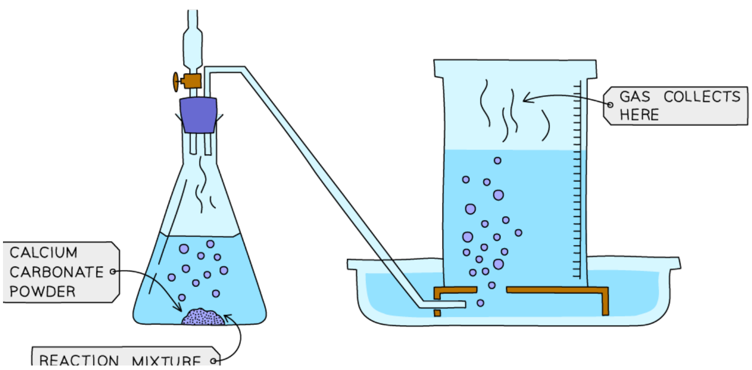
1 SET UP EQUIPMENT AS SHOWN



2 ADD CALCIUM CARBONATE CHIPS TO ACID, AFTER A FIXED TIME RECORD THE VOLUME OF WATER DISPLACED



2 REPEAT, USING DIFFERENT FORMS OF CALCIUM CARBONATE



Method:

- Add dilute hydrochloric acid into a conical flask.
- Use a capillary tube to connect this flask to a measuring cylinder upside down in a bucket of water (downwards displacement).
- Add calcium carbonate chips into the conical flask and close the bung.
- Measure the volume of gas produced in a fixed time using the measuring cylinder.
- Repeat with different sizes of calcium carbonate chips (solid, crushed and powdered).

Result:

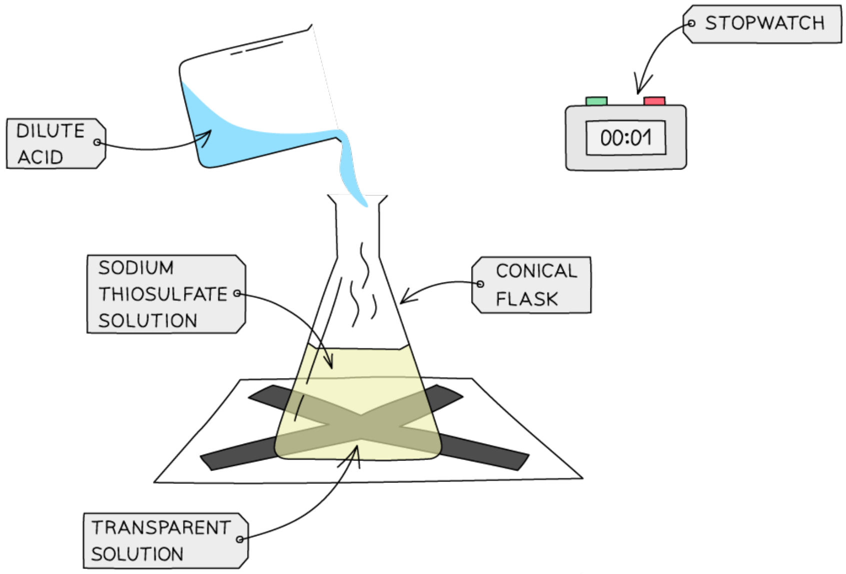
- Smaller sizes of chips causes an increase in the surface area of the solid, so the rate of reaction will increase.
- This is because more surface area of the particles will be exposed to the other reactant so there will be more frequent and successful collisions, increasing the rate of reaction.

Note:

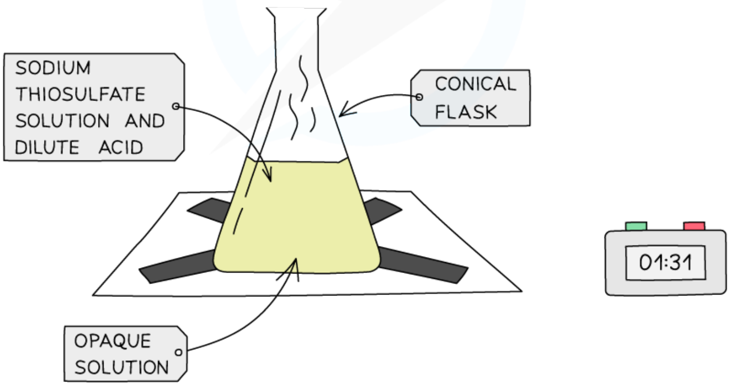
- The calcium carbonate chips can be replaced with magnesium ribbon.
- Large surface area can mean danger: Flour dust, wood dust, custard powder, instant coffee, sugar, and dried milk have large surface areas, and are combustible. A spark from a machine, or a lit match, can cause an explosion, this also applies to gases from mines.

Effect of Concentration of a Solution on Rate of Reaction

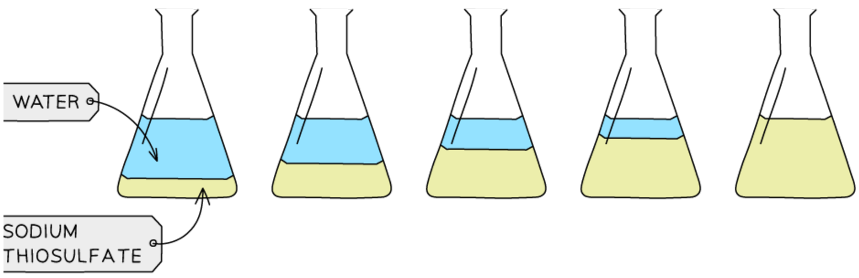
1 ADD ACID TO SODIUM THIOSULFATE SOLUTION, START TIMER.



2 STOP TIMER WHEN 'X' IS NO LONGER VISIBLE. RECORD TIME.



3 REPEAT STEPS 1–2 WITH DIFFERENT CONCENTRATIONS OF SODIUM THIOSULFATE (MADE BY MIXING DIFFERENT VOLUMES OF WATER AND SODIUM THIOSULFATE)



Method:

- Measure 50 cm^3 of Sodium Thiosulfate solution into a flask.
- Measure 5 cm^3 of dilute Hydrochloric acid into a measuring cylinder.
- Draw a cross on a piece of paper and put it underneath the flask.
- Add the acid into the flask and immediately start the stopwatch.
- Look down at the cross from above and stop the stopwatch when the cross can no longer be seen.
- Repeat using different concentrations of Sodium Thiosulfate solution (mix different volumes of sodium thiosulfate solution with water to dilute it).

Result:

- With an increase in the concentration of a solution, the rate of reaction will increase.
- This is because there will be more reactant particles in a given volume, allowing more frequent and successful collisions, increasing the rate of reaction.

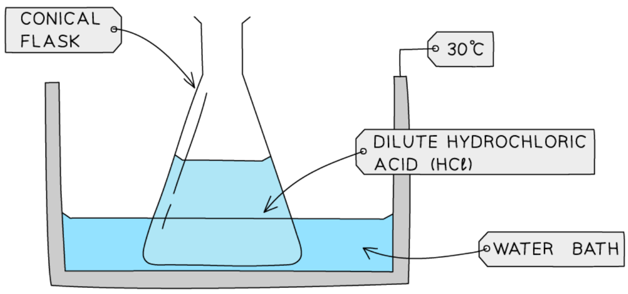
$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + 2NaCl(aq)$$

Note:

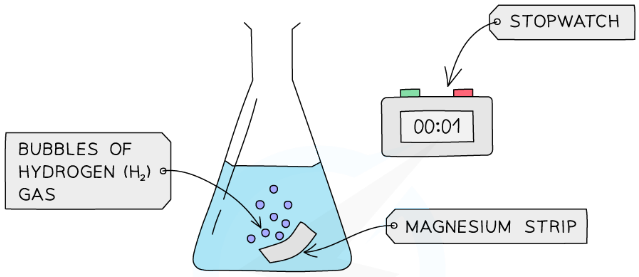
- Hydrochloric acid and sodium thiosulfate react together to produce sulfur, which is insoluble in water, hence it precipitates, covering the cross.
- This experiment can also be done by varying the temperature to check reaction rate.

Effect of Temperature of a Solution on Rate of Reaction

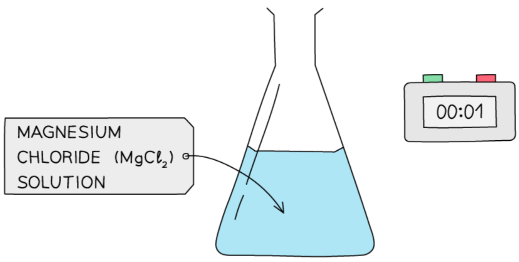
1 HEAT DILUTE HYDROCHLORIC ACID TO A DESIRED TEMPERATURE



2 ADD A STRIP OF MAGNESIUM TO THE DILUTE HCℓ AND START A STOPWATCH



3 WHEN THE MAGNESIUM STRIP HAS DISSOLVED, STOP THE STOPWATCH AND RECORD THE TIME.



3 REPEAT EXPERIMENT AT DIFFERENT TEMPERATURES

TEMP (℃)	TIME TO DISSOLVES (S)
10	
20	
30	
40	

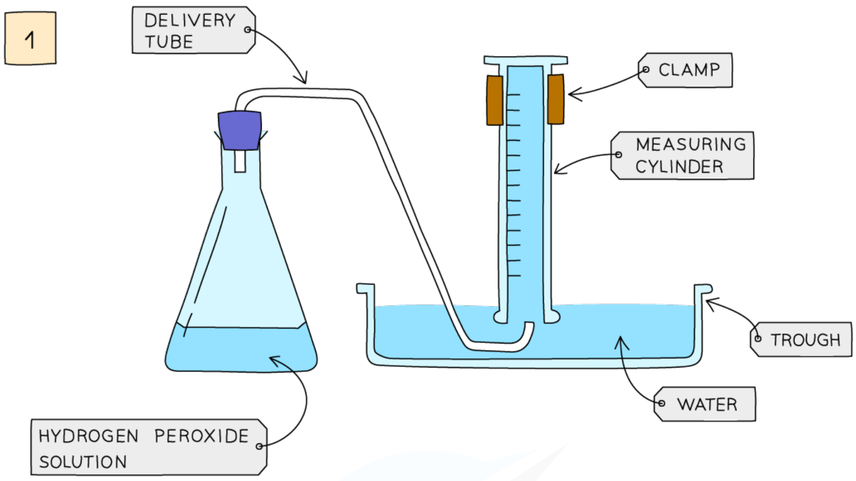
Method:

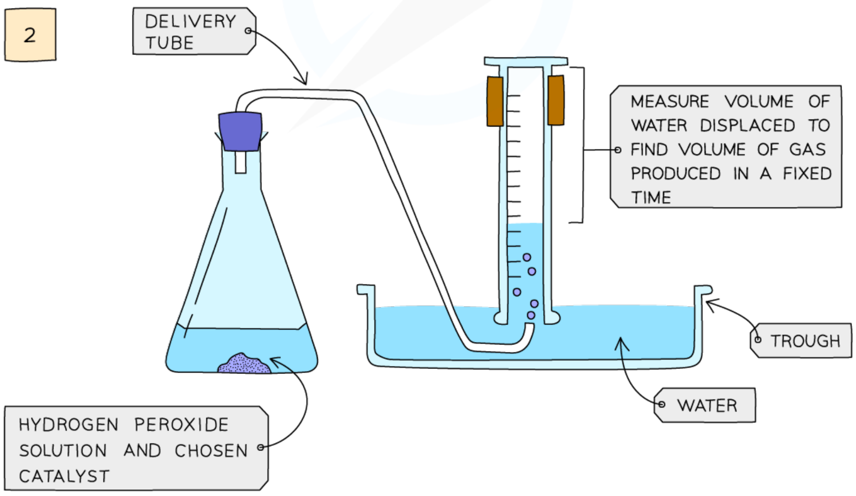
- Dilute Hydrochloric acid is heated to a set temperature using a water bath.
- Add the dilute Hydrochloric acid into a conical flask.
- Add a strip of Magnesium and start the stopwatch.
- Stop the time when the Magnesium fully dissolves.
- Repeat at different temperatures and compare results.

Result:

- With an increase in the temperature, the rate of reaction will increase.
- This is because the particles will have more kinetic energy than the required activation energy, therefore more frequent and successful collisions will occur, increasing the rate of reaction.

Effect of a Catalyst on Rate of Reaction





Method:

- Add Hydrogen Peroxide into a conical flask.
- Use a capillary tube to connect this flask to a measuring cylinder upside down in a bucket of water (downwards displacement).
- Add the catalyst Manganese(IV) Oxide into the conical flask and close the bung.
- Measure the volume of gas produced in a fixed time using the measuring cylinder.
- Repeat experiment without the catalyst of Manganese(IV) Oxide and compare results.
- Note that potassium iodide can also be used as a catalyst for this reaction.

Result:

- Using a catalyst will increase the rate of reaction.
- The catalyst will provide an **alternative pathway requiring lower activation energy** so more colliding particles will have the necessary activation energy to react.
- This will allow more frequent and successful collisions, increasing the rate of reaction.

Photochemistry

- These reactions occur in the presence of light.
- The greater the intensity of ultraviolet light then the greater the rate of reaction.
- E.g: photosynthesis, film photography, the substitution of hydrogen atoms in methane by chlorine:

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

Silver salts in photography

- Black and white photography film surfaces contain crystals of silver bromide.
- When the shutter of a camera opens, it is exposed to light and the AgBr decomposes to silver:

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

- AgBr is colourless at low concentrations but the Ag appears grey-black.
- Parts of the film appear black, grey or white depending on the exposure:
    - Stronger light = black or dark grey (Ag forms fastest at the brightest parts)
    - Weaker light = light grey
    - Not exposed = white

Photosynthesis

- This is the process in which plants produce food for reproduction and growth.
- The equation is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

- The process requires sunlight and chlorophyll and produces glucose and energy.
- Chlorophyll is the green pigment in plants which absorbs sunlight and acts as the catalyst for photosynthesis.