Combustion

There are three different types of combustion.

- Slow combustion occurs where there is a large block of fuel and a limited supply of air. By controlling the amount of air, the speed of combustion can be controlled. Since the fuel is large, combustion only occurs on the surface.

- Fast combustion occurs where smaller particles are exposed to an abundant supply of air. Due to a larger surface area of the fuel, this combustion occurs relatively faster. For example, in a power station, coal is ground into tiny particles which are then exposed to oxygen.

- Explosive combustion occurs in the cylinders of petrol and diesel engines in vehicles. In petrol engines, a spark is what starts the explosion. In diesel engines liquid fuel is vaporised and then exposed to heat.

All these different types of combustion are also spontaneous reactions, meaning that once the combustion process has been started, they will continue to burn without further assistance until the fuel runs out.

The conditions under which combustion occurs affects the rate of reaction. These conditions include:

- The concentration of the reactant

- The temperature under which the reaction occurs

- The presence and influence of a catalyst

Some reactions also require conditions where there is the presence of visible or ultraviolet light.

Collisions

In order for a chemical reaction to occur, the particles of the reactants need to successfully collide. The particles need to be moving at a high enough speed to produce enough energy for the collision to result in a chemical reaction. In accordance with the collision theory, not all collisions lead to chemical reaction- only collisions that take place between particles with sufficient energy (activation energy) will result in a reaction. The particles also need to collide on the right surface of the particle (its orientation) for a chemical reaction to take place. In a chemical reaction, old bonds are broken and new bonds are made, forming the products. This rearrangement occurs when the particles collide.

Increasing the concentration of the reactants, the surface area of the reactants and the rate of stirring affects the rate of collision and thus the rate of reaction. E.g.

- Concentration of the reactant- the higher the concentration (no. of particles per unit of volume), the more chance that the particles will collide and thus increasing the reaction rate

- The surface area of the reactants- a larger surface area allows more collisions to occur, causing the rate of reaction to increase.

Rate of Stirring- by stirring a solution, the solid is kept suspended in the solution, meaning that it is more exposed to colliding particles. Also, by stirring, the solid particle is constantly exposed to fresh solution, allowing the solid particles to react with as many solution particles as possible. Therefore, stirring increases the rate of collision and hence the rate of reaction.

Temperature and Kinetic Energy

Kinetic energy is the "the energy of an object due to its motion."1 The higher the temperature of a particle, the more kinetic energy it contains, i.e. the faster it moves. For example, gases have a higher temperature than their solid form and thus move much more due to their higher level of kinetic energy. In the same way, increasing the temperature of the reactant causes the particles in the substance to vibrate faster, i.e. their kinetic energy grows. Since so, since the particles are moving at a faster speed, there will be more collisions, and more potential for successful collisions and thus the reaction rate increases (more particles contain enough energy to reach the level of activation energy required for a chemical reaction and products to be formed). Therefore increasing the temperature of a particle will increase the kinetic energy of the particle.

Explosions

For an explosion to occur, the following conditions must be present:

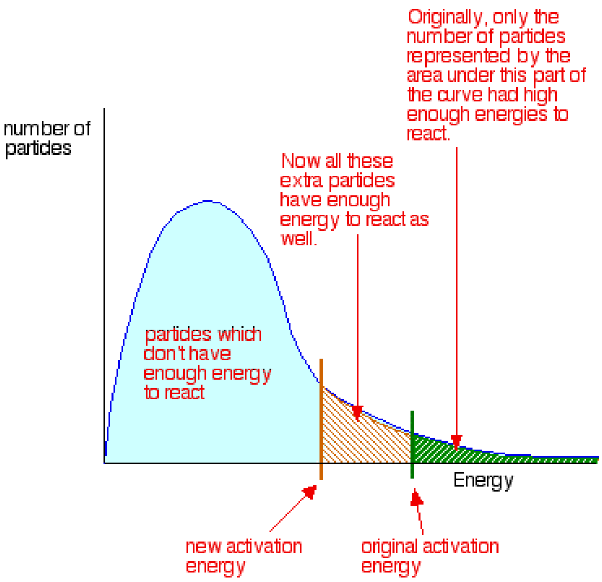
- An oxidant, e.g. oxygen in the air
- A source of combustion, e.g. flame or spark- the activation energy
- A fue, e.g. gas or vapour, powders or dust (wood, metal, carbon etc). The surface area of the flammable material is important. Fine particles are highly flammable, since they have a large surface area which is exposed to a ready supply of oxygen in the air.

In order to reduce the risk of explosion, it is important to take these safety precautions:

When dealing with fine particles that are exposed in the air (presence of oxygen) (e.g. of wheat, wood, cotton or paper) ensure that the area is well ventilated to prevent the build up of these flammable particles. Also, ensure that the area does not get too hot or that there are no naked flames etc. This in turn reduces the risk of an explosion.

Activation Energy

Activation energy, Ea, is the minimum amount of energy that the reactants require in order for products to be formed i.e. for a chemical reaction to occur. It is often measured as the amount of kilojoules (kJ) it takes for one mole of a substance to react.



The Role of Catalysts & Activation Energy

Catalysts are usually used where the activation energy for the reaction to occur is quite high.

The catalyst does not lower the level of activation energy needed. Rather, it provides a pathway of lower energy in which the reaction can occur. By

[1] http://chandra.harvard.edu/resources/glossaryKL.html

providing an alternate route with a lower level of activation energy needed, less energy is needed for the chemical reaction to take place and more particles contain sufficient energy to successfully collide. More successful collisions mean that the rate of reaction is increased.

Therefore, since less energy is needed for the chemical reaction to occur, the reaction rate is increased.

Catalysts and Chemical Reactions

A catalyst is a substance that increases the reaction rate of a chemical reaction. The catalyst is not consumed in the process, and it does not change the enthalpy charge of the reaction.

Catalysts are especially important for industrial use as they allow reactions that could take days, weeks or even years to occur within minutes or hours. They allow manufacturers to make their products quickly and thus make more money.

An example of a common industrial catalyst is the use of iron as a catalyst for the synthesis of ammonia to produce fertiliser from N2 (nitrogen) and H2 (hydrogen).

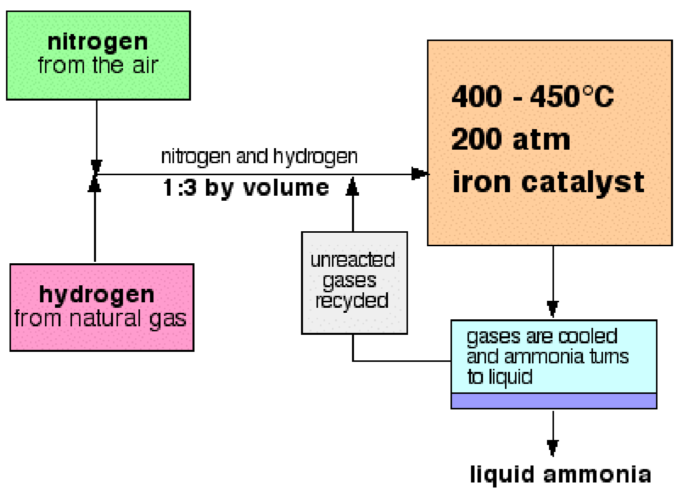
Under normal conditions, the reaction between nitrogen and hydrogen would take years. Ammonia is important as it contains nitrates which are important for replenishing the nitrogen in soil. Nitrogen is important for the growth of plants.

Ammonia synthesis today takes place in large steel reactors which can withstand the corrosive properties of hydrogen gas, as well as withstand high temperatures and high pressures.

$N_2 + 3H_2 \rightarrow 2NH_3$

At the beginning of the 20th century, there was a shortage of naturally occurring, nitrogen rich fertilisers. Many scientists began to look for ways to produce ammonia, which could then be used to produce fertiliser. The current method of ammonia synthesis was developed in the early 20th century by Fritz Haber, and adapted for industrial use by Carl Bosch. The iron catalyst used is magnetite, an iron ore (Fe_3O_4). Studies of the iron catalyst have shown that when the catalyst absorbs the nitrogen molecules, it causes a faster dissociation of nitrogen bonds. This leads to a faster rate of reaction, and ammonia is produced relatively quickly.

Sometimes, promoters, e.g. potassium hydroxide, are added to the iron catalyst to increase the surface area of the catalyst so that it can absorb more nitrogen molecules. These promoters also include compounds of aluminium (Al), potassium (K) and calcium (Ca).



There are three steps in the synthesis of ammonia. First, methane and steam react to form hydrogen and carbon monoxide. The carbon monoxide is removed from the mixture and replaced with nitrogen. This mixture of hydrogen and nitrogen then undergo ammonia synthesis.

In ammonia synthesis, high temperatures are used to reach the ‘equilibrium position’ in a short time, and high pressures are used to bring the reactant molecules closer together. The catalyst simply speeds up the process of ammonia synthesis so that the yield is viable enough for commercial application.

The Impact of Changing Temperature & Concentration on Reaction Rates

Aim: To investigate the impact of changing concentration and changing temperature on reaction rates by experimenting with hydrochloric acid and magnesium metal.

Hypothesis: The higher the concentration, the faster the reaction rate. The higher the temperature, the faster the reaction rate. I.e., the higher the concentration of the hydrochloric acid, the faster the reaction rate, and the higher the temperature of the hydrochloric acid, the faster the reaction rate.

Method:

- A long strip of magnesium ribbon (at least 24cm long) was polished with sandpaper to remove the oxide, and then was cut into 24 pieces, each one centimeter long.

- Changing Concentration

  1. Three test tubes with 5mL of hydrochloric acid each were prepared- one with concentration of 1 M, the other of 2 M and the last of 3 M. The test tubes were then placed in test tube holders.

  2. A one centimeter piece of magnesium was dropped into the first test tube with the 1 M HCl solution, and the time it took to dissolve was timed with a stopwatch.

  3. The above step was repeated with the 2 M and 3 M solutions of hydrochloric acid, and the reaction times noted.

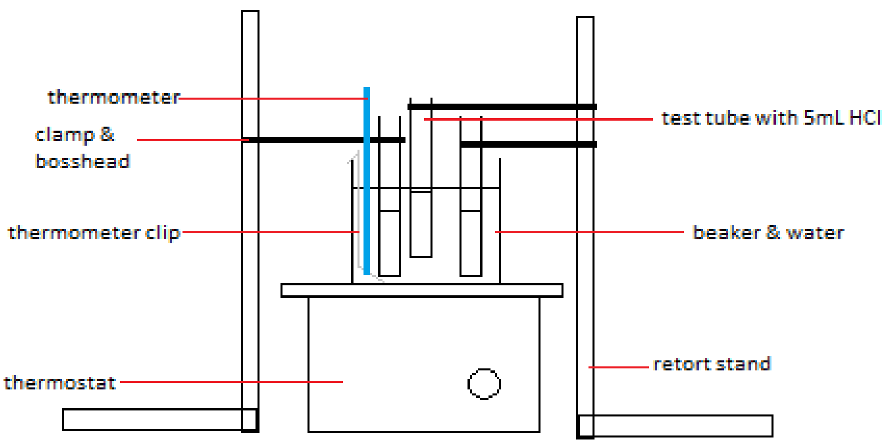
  4. The whole experiment was repeated four times for each concentration.

  5. The average time for each concentration: 1 M, 2 M & 3 M was calculated.

- Changing Temperature

  1. Three test tubes with 5mL of hydrochloric acid, each with a concentration of 2M each were prepared.

  2. The apparatus for the experiment was set up according to the below diagram



  3. The thermostat was set at temperature level 2 and the water was allowed to heat up.

4. When the thermometer reading of the water bath was 30ºC, the thermostat was turned off.

5. Straight away, a one centimeter piece of magnesium was dropped into the first test tube, and the time it took to fully dissolve was timed with a stopwatch.

6. The thermostat was then turned on again and the previous steps were repeated when the temperature of the water bath (according to the thermometer reading) reached 60º and 90º.

7. The whole experiment was repeated four times for each temperature.

8. The average reaction rate (time for Mg to fully dissolve) was calculated.

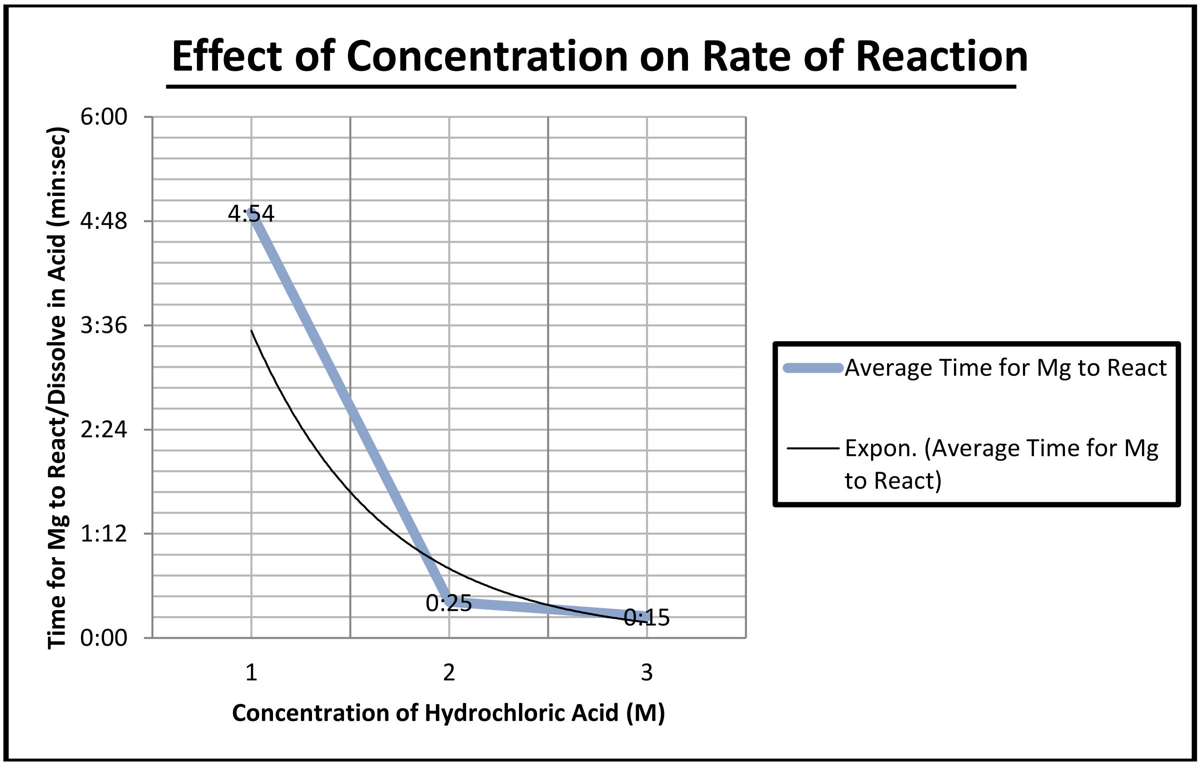
Results:

- Table of Results

Reaction Time of Magnesium and Different Concentrations of Hydrochloric Acid

Concentration (M)	Time to Dissolve (min: secs)				
	Trial 1	2	3	4	Average
1	4:33	4:53	5:13	4:57	4:54
2	0:19	0:28	0:23	0:29	0:25
3	0:11	0:16	0:16	0:17	0:15

- Graph of Results



- Observations

    - The presence of a gas (hydrogen) was indicated during the experiment between the hydrochloric acid and the magnesium by fizzing bubbles as the magnesium dissolved.

    - The test tube also warmed up slightly during the reaction

Discussion:

- The initial hypothesis was right- as the concentration of the hydrochloric acid increased from 1M to 2M to 3M, the average time to dissolve decreased (i.e. faster reaction rate) from 4:54 minutes to 0:25 minutes to 0:15 minutes. Thus, the higher the concentration of the hydrochloric acid, the faster the reaction rate.

- $2HCl(aq) + Mg(s) \rightarrow H_2(g) + MgCl_2(aq)$

- The above equation shows that the hydrochloric acid reacted with the magnesium metal to produce hydrogen gas and magnesium chloride.

- It was not possible to perform the temperature part of the experiment, as the thermostats were actually simmer stats. This meant that they actually kept increasing temperature until they reached a high temperature and automatically turned off. Thus, it was hard to keep the temperature constant during the duration of the experiment.

- Since the temperature part of the experiment could not be done due to the way the simmer stat works, next time, a laboratory water bath could be used instead

There were many possible errors:

- The measuring cylinder. There could have been human error, e.g. parallax error, which may have caused some test tubes to receive slightly more acid than others and vice versa. Maybe next time could try using a pipette to increase accuracy or try weighing the acid instead of measuring out the volume.

- Since the experiment was conducted over a period of two days, the two days had different room temperatures, which could have either sped up or slowed down the concentration part experiment. This could not be avoided. But perhaps by setting the air conditioner at a set temperature on the two days could have reduced the effect of this error?

- Also human reaction with the stopwatch. There may have been a time lapse between the moment when the magnesium touched the acid and when the stopwatch was started. The only way to correct this or reduce the effect of this error on my results was to repeat the experiment many times and then average the results.

- Each piece of magnesium was not exactly the same weight, or exactly the same length, even though I tried to get it as accurate as possible. I.e., some may have been a millimeter off etc. Thus, the ‘larger’ pieces of magnesium may have taken slightly longer to fully dissolve than normal. The only way to reduce the effect of this error would be to repeat the experiment as many times as possible to increase the accuracy.

- It was hard to tell when the reaction finished, as the stopwatch was stopped when the magnesium became invisible from the naked eye, when really, the magnesium may still have been reacting. The only way to reduce the effect of this error would be to repeat the experiment as many times as possible to increase the accuracy.

Conclusion:

In conclusion, the impact of changing concentration on reaction rates can be investigated by examining the reaction between different concentrations of hydrochloric acid and magnesium metal.

In the experiment, the higher the concentration of the hydrochloric acid, the faster the magnesium dissolved. At 1 M, the average reaction time was 4:54 minutes, at 2 M it was 0:25 minutes, and at 3 M, it was 0:15 minutes. Thus the reaction rate increased. This shows that the higher the concentration, the faster the reaction rate. Thus the experiment results support the initial hypothesis.

The temperature component of the experiment could not be completed as the right equipment was not available. Thus, the hypothesis for the effect of changing temperature on reaction rates is yet to be tested.

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