Fabric Cleaning Using Soaps and Detergents

Thursday, 5 September 2019 7:51 PM

Aim:

To test the effectiveness of soap and detergents for a certain stain in different concentrations of hard water, which is done by making solutions of hardwater mixed with soap and detergent and then trying to clean the stain in these solutions. The effectiveness would be how well the stain is cleaned/ decoloured.

Hypothesis:

As the concentration of $CaCl_2$ solution is increased the effectiveness of the soap solution will decrease while the detergent will remain constant. Throughout the experiment the effectiveness of the detergent will be greater than the soap, with the effectiveness being how well the stain decoloured in the brushed area.

Variables:

Independent:

- the concentration of $CaCl_2$ (aq) (hardwater)
- The type of cleaner

Dependent:

- The effectiveness of the cleaner (the degradation of the stain)

Controlled:

- Temperature of atmosphere
- Temperature of solutions
- Type of stain and other comp
- Volume of cleaning solution
- Fabric
- Surface area of cleaning
- Number of strokes
- Tool for cleaning
- Volume of calcium chloride solution

Method:

Making calcium chloride solution:

1g of calcium chloride was weighed and placed in a 500mL beaker, this step was then repeated 5 times, with another 2 500mL beakers left empty. 50mL of distilled water was placed in the empty beakers (which formed 2 0.00 mol/L calcium chloride solutions), 100mL was poured in two of the calcium chloride beaker (which formed 2 0.09011 mol/L calcium chloride solutions), 200mL was poured in another two of the calcium chloride beakers (which formed 2 0.04505 mol/L solutions) and 300mL was placed in the last 2 beakers (which formed 2 0.030035 mol/L solutions). Each beaker was checked to ensure all calcium chloride was dissolved and if not then the solution was agitated by applying force to the beaker in a circular direction. 50 mL of each solution was then withdrawn and placed in 8 separate 250mL beakers.

Adding the soap and detergents:

A large piece of soap was broken up into small pieces, roughly smaller than 0.5cm. Then 4 samples of 0.5g of these soap pieces was weighed and placed into the calcium chloride solutions, with each being placed in a different concentrated solution. 4 samples of 0.5g of detergent was weighed, with each being placed in the remaining 4 solutions. If there was any detergent left in the initial beaker a small amount of the assigned calcium chloride solution was poured into the beaker to dissolve it. Each beaker was placed in a warm water solution and then was checked to ensure that the soap or detergent was fully dissolved and if not, the beaker was shook. If the soap didn't dissolve then a stirring rod was used, however it would introduce error. Each beaker was then labelled with the concentration of calcium chloride initially in it and whether it had detergent or soap.

<u>Staining the fabric:</u>

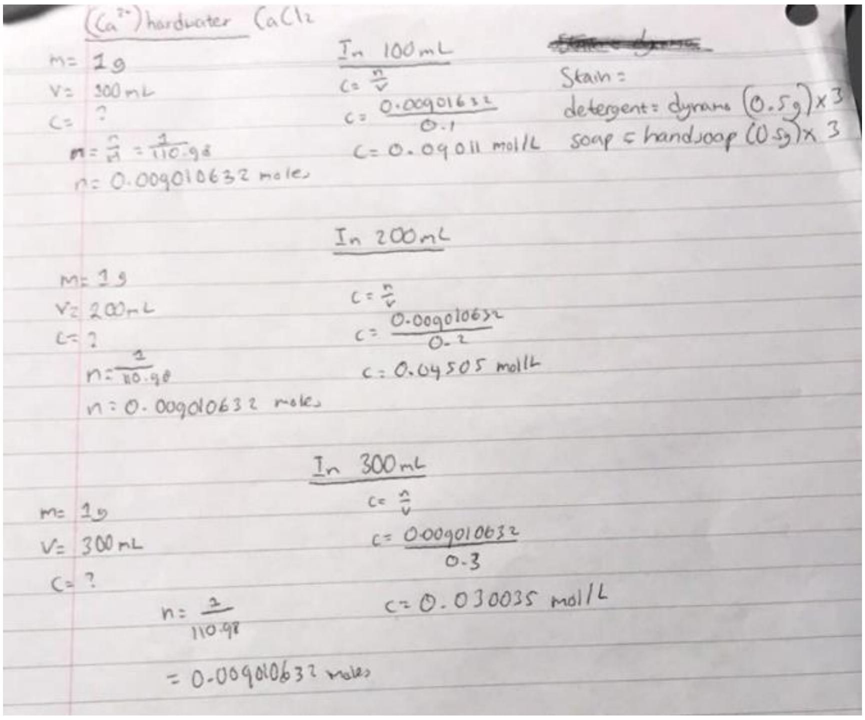
12 pieces of cotton fabric of the same size were all placed in a beaker. Wine was then poured into the beaker until it submerged the cotton. A weight, in this case a beaker filled with water was placed on top the fabric pieces to ensure that they were fully submerged. They were left for 25 minutes, ensuring there was adequate staining. The stained cotton pieces were then quickly removed and placed on a plastic coated piece of cardboard. This piece of cardboard was then placed in a dark spot so that the stained pieces of fabric could dry overnight.

<u>Cleaning process;</u>

A piece of fabric was placed and fully submerged in each beaker, leaving 4 for a reference. The beakers with fabric in them were left for 20 minutes . Then the stained fabrics were removed and placed on a plastic surface with half of the solution it was in being poured on it. 50 stokes using a toothbrush was applied to each fabric. The stokes were from the top middle of the fabric to the bottom middle, with the brush being perpendicular to its motion. After the 50 stokes were applied, the rest of the solution that the fabric was in was poured on it evenly. Another 50 strokes were applied. This concluded the cleaning process. Each fabric was then removed and placed on a clean plastic surface, which was then placed in a dark area for the fabric to dry overnight. The following day photos were taken of the each fabric, including the reference ones and results were written down.

Results and analysis:

Calculation of Concentration:



(Ca^{2+}) hardwater $CaCl_2$

m= 1g
V= 300 mL
C= ?
$n = \frac{m}{M} = \frac{1}{110.98}$
n= 0.009010632 moles

In 100mL
$c = \frac{n}{v}$
$c = \frac{0.009010632}{0.1}$
c= 0.09011 mol/L

Stain:
detergent: dynamo (0.5g)x3
soap: handsoap (0.5g)x 3

In 200mL
M= 1g
V= 200mL
C= ?
$n = \frac{1}{110.98}$
n= 0.009010632 moles
$c = \frac{n}{v}$
$c = \frac{0.009010632}{0.2}$
c= 0.04505 mol/L

In 300mL
m= 1g
V= 300 mL
C= ?
$n = \frac{1}{110.98}$
= 0.009010632 moles
$c = \frac{n}{v}$
$c = \frac{0.009010632}{0.3}$
c= 0.030035 mol/L

Observations:

Solution					
Concentration (mol/L)	Cleaner	Image:	Observation:	Effectiveness of cleaner:	Other comments:

0.00	Soap		A purple fabric was soaked in a pale cream solution and scrubbed with a brush. The fabric lost its purple pigment and turned grey while the solution turned purple. Happened relatively quick.	Full discolouration- very effective	
0.00	Detergent		A purple fabric was soaked in a pale blue solution and scrubbed with a brush. There was substantial discolouration of the purple pigment in the scrubbed area.	Noticeable discolouration on brushed area- quite effective	
0.09011	Soap		A purple fabric was soaked in a pale cream solution and scrubbed with a brush. A white solid was formed and there was a small discolouration of the purple.	Very small discolouration on brushed area- Quite ineffective	
0.09011	Detergent		A purple fabric was soaked in a pale blue solution and scrubbed with a brush. There was substantial discolouration of the purple pigment in the scrubbed area.	Noticeable discolouration on brushed area- quite effective	

0.04505	Soap		A purple fabric was soaked in a pale cream solution and scrubbed with a brush. A large amount of white solid was formed. There seemed to be no discolouration of the purple pigment.	No noticeable discolouration on brushed area - ineffective	
0.04505	Detergent		A purple fabric was soaked in a pale blue solution and scrubbed with a brush. There was substantial discolouration of the purple pigment in the scrubbed area.	Noticeable discolouration on brushed area- quite effective	
0.030035	Soap		A purple fabric was soaked in a pale cream solution and scrubbed with a brush. A relatively large amount of white solid formed and there seems to be no discolouration of the purple pigment.	No noticeable discolouration on brushed area. However fabric seem to have lost its intensity	The whole fabric seems to have lost its intensity.
0.030035	Detergent		A purple fabric was soaked in a pale blue solution and scrubbed with a brush. There was substantial discolouration of the purple pigment in the scrubbed area.	Noticeable discolouration on brushed area- quite effective. Fabric seem to have lost its intensity too.	The whole fabric seemed to have lost its intensity

Discussion:

The results showed that detergent is a relatively good cleaner of wine stains and it does not get affected by the concentration of the calcium chloride (hardwater). Soap is an excellent cleaner of wine stains (as you have seen with the soap with 0.00 mol/L calcium chloride solution), however as the concentration of the calcium chloride increases it becomes ineffective (as seen with the 0.030035 mol/L soap solution). This means that soap is a preferable when in extremely small concentration of calcium chloride due to it being more effective, however when in higher concentrations of calcium chloride, detergents are more preferable due to it being equally effective with any concentration of calcium chloride (as seen with all 4 solutions of detergent).

There are many implications that can be made with our results. It gives us a better understanding of a preferable cleaning products depending on the context of the situation. For example, Western Australia's water supply contains high levels of metal ions such as Ca^{2+} and Mg^{2+} [1]. This can cause us to evaluate our results, e.g. detergents are more effective in hard water, and recommend a cleaning solution, detergents. Additionally it can help us determine what cleaner to use that would be most beneficial for the longevity of faucets. Due to once again the precipitate that is formed by the mixing of soap and metal ions found in water can form lime scale, which will block and degrade faucets [2]. Lasts it can help us maximise the effectiveness of the cleaners we use in humanitarian relief. Many countries will have not the best water supply and therefore there might be a large concentration of metal ions. There would be no point of using soap if it doesn't clean because It would not fix the issue. People would just get infections and so on.

There definitely is a better way to test the hypothesis, as seen with the highest concentration solution fabric, the fabric discoloured, this goes against the trend and means that there must be an uncontrolled variable. To do better we could use a solution or a salt that might not affect the fabric or compromise our experiment. Our results correlate to out to relevant chemical concepts. This is due to when a typical soap is added to hard water a solid is formed. Even if the soap is soluble with the metal ion attached is not [3]. An example would be like stearate:

$$2CH_3(CH_2)_{16}COONa(aq) + Ca^{2+}(aq) \rightarrow (CH_3(CH_2)_{16}COO)_2Ca(s) + 2Na^+(aq)$$

[4]

Detergents do form insoluble salts with calcium ions or magnesium ions [5]. The chemical structures of wonder soap and detergent are not published so we can only make assumptions. The purple pigment of wine is called pyranoanthocyanins, which is a relatively small, very polar chemical that is capable of forming hydrogen bonds [5] . The soap, being capable of hydrogen bonds, forms stronger intermolecular forces with the pigment and therefore can extract it from the fabric effectively, while the detergent is not as polar, therefore its intermolecular bonding with the wine pigment is not as strong and so it doesn't remove the stain as well. Due to the wine pigment not being non-polar, the soap and detergent don't go through the cleaning action that normally occurs with a non-polar substance.

There were a few trends within our results. The effectiveness of the detergent seems to stay constant as the concentration of calcium chlorine increased, as seen with our results. This means that it does not get affected by the concentration of the hard water. Additionally, soap seemed to get more ineffective as the concentration of calcium chlorine increased, this might be explained by the trend of how the amount of the precipitate in the soup solution increased as the concentration of calcium chlorine also increased. There were 2 outliers in our results, the first one as previously mentioned was that for both (the soap and detergent) solution of 0.030035 mol/L calcium chloride solution there seemed to be quite a lot of discolouration, which contrasts with how with detergents the discolouration seems to be constant and how with soaps the discolouration should of decreased. Another outlier seems to be the amount of solid formed on the soap 0.04505mol/L piece of fabric. There is a trend of the amount of solid increasing however the amount on this sample seems to be dramatically more.

There were many difficulties that occurred with our investigation, the primary was to dissolve the soap in the solutions, this was due to it being not as soluble as we thought and so we had to use a stirring rod. It would have been better making dissolved solutions of soap and detergents by heating them and then recording the concentration. With this method it would allow the solution to be heated; due to if we recorded the concentration after the liquid that would evaporate would change the concentration. Another difficulty was applying the same magnitude of force in every stroke, it is hard to quantify how much force is being applied. We tried improving this by having the same person doing the stokes and applying as much force as we could, which hopefully would mean the same force. An even better way of doing this would be doing it mechanically, whether this is by using a washing machine which is indirect of using an automated or mechanical system that applies the same force. Another difficulty with the brushing was making sure that the tooth brush was actually brushing the path needed, e.g. the middle of the fabric. Marking it with a pen or marker would bring in another variable into our investigation which is not needed. So instead we tried, roughly brushing the same, middle area. Using an automated or mechanical system would again be beneficial due to it continually cleaning the same area and would also ensure that the brush was in the same orientation throughout the whole experiment.

There weren't many mistakes that were made. The main one was that tap water was used instead of distilled water in some of the solutions. This introduced variables that we have not accounted for. Additionally, this would have most likely increased the concentration of metal ions and affected the effectiveness of the soap. Furthermore, tap water has fluorine, which can be used as a cleaner and so it could cause unexpected discolouration for some of the fabrics. This might help explain our outliers but it would be unreasonable to assume that it is the reason. It is hard to make sure that our measurements were accurate especially when the dependent variable was qualitative. However there were a few things we did. We used a scale with a large number of decimal places to ensure it there was a smaller effect of weighing error. We ensured that we took the photos in very similar lighting and so that they were close to what the samples looked like in real life. We used clean equipment that would not introduce or increase the amounts of certain substances. We were not very accurate to be honest. We dried the samples in the same dark spot, this is due to UV light normally discolouring most substances.

Systematic error:
There was solution left in the beaker when transferring solution from one to another
There was solution left on the stirring rod when using it
The solution evaporating when storing it
The calcium chlorine is hydroscopic [6] meaning that the weight of it is exaggerated
Someone having a bias colour perception when qualitatively analysing the stains

Random error:
The scale seemed to continuously move between values
Some of the beakers seemed to be contaminated
The lighting of the environment, which could affect the perceived colour loss
The last digit rounding that the scale does.
Variation in the eye-level when reading the measuring cylinder

There are a few ways of reducing the errors. One would be using clean equipment, this would cause not as much solution being left on the beaker and the stirring rod and would also mean that the beakers are not contaminated. Additionally, if we used the reactants straight away it would decrease the amount of evaporation and would decrease the exaggeration of the calcium chloride weight. Also, as mentioned before we could also use machinery to conduct the experiment but also to analyse the result. Adobe has a program that is able to analyse the colour and so we could have numerical data rather the uncertainty of the qualitative data we have. However due to constraints, we should do multiple trials, 3 at least, with one person analysing each sample. This would reduce any random error and also reduce the bias that one person might have on certain colours. Using more precise equipment would decrease any weighing or volume errors that might arise. Lastly, to we could decrease any variation when reading the measuring cylinder or meniscus by being eyelevel with the measuring cylinder when measuring it. Some groups placed "a score" on the effectiveness of the cleaners, e.g. from 1 to 3, however the cleaning is more on a spectrum and therefore our group decided not to.

Conclusion:

The soap initially decoloured the stain better when the concentration of the calcium chloride was low but as the concentration of calcium chloride increased the detergent's effectiveness was better than the soaps. The concentration of the calcium chloride solution seemed to have no effect on the discolouration due to the detergent (the concentration has no effect on the detergent). This means when in places with a high concentration a detergent would be more beneficial to use rather than a soap. We used cotton fabric due to it being the most realistic in the current world as most clothing is constructed with it. Our results are quite valid due to use measuring what we intended to measure. We measured how the effect of the hard water and how well soaps and detergents work. We had all other variables controlled. However our results were not very reliable, we only conducted one trial so it is wrong to state that we got the same results. Additionally, there quite a few random errors that could have definitely been decreased but the time and economic constraints did have to be considered.

Response to aim:
Detergents are quite effective for a wine stain in any concentration of calcium chloride (hard water). On the other hand soaps are not very effective due to them forming solids when mixed/ reacted with hard water. The stain discoloured very well for detergents in hard water while soap was ineffective.

Response to hypothesis:
Yes, as the concentration of $CaCl_2$ is increases the effectiveness of the soap will decrease while the detergent will remain constant. However, initially the soap will be more effective in discolouring the brushed area (as seen at the 0.00mol/L solution fabrics) of the stain and then as the concentration of the calcium chloride increases (at 09011 mol/L) the detergent seems more effective.

Acknowledgements:

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The John Curtin College of the Arts Lab Technicians for providing equipment and substances; fulfilling our ludicrous requests.
Emma Patterson, my tutor for proof reading certain area and for being a great tutor.

References:

[1] Western Australia having high concentration of hard water
From Pearson Chemistry Yr 12 Pg: 442
[2] Soaps and metal ions producing lime scale which degrade faucets
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[3]Salt being soluble by its self
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[4] The reaction stearate soap and calcium ions
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[5] pyranoanthocyanins being the main purple pigment in wine
https://www.hindawi.com/journals/jchem/2013/713028/
[6] Background information on calcium chloride and it being hydroscopic

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A Chemical Reaction Revolution:

- Nitrogen
    - Most inert
    - Most abundant
- Harber-Bosch Process
    - Plucking fertilizer from thin air
    - By making ammonia (NH_3) out of nitrogen gas (N_2)
    - It relied and relies on high temperature, high pressure and hydrogen atoms to be ripped from fossil fuels
    - Ammonium fertilizes crops, which in turn nourish you
    - The process burns natural gas and releases loads of carbon
        - It is unsustainable

Bacteria and Sunlight:

- Nitrogen fixed bacteria in soil have been taking nitrogen gas from the air and converting it into ammonia
- It happens in room temperature
- The bacteria have enzymes that grab N_2 molecules and H^+ ions, orientating them just right
    - Therefore they form ammonia
- This reaction requires a jolt of energy
    - Comes from snapping a piece of a molecule called ATP

King:

- Has found that light sensitive nanorods that plug into the enzyme will give it a zap
- Basically you need to mis the cadmium-based materials, some enzymes and leave it in the sun.
- The issue is that enzymes are cost prohibitive
    - Complex molecules that have to be purified from living bacteria
    - It would take a long time and a lot of water
- 63% of the enzymes natural rate

Kanatzidis:

- Looking for a way to replace the enzyme with a man-made material called Chacogel
- The cluster is black so it absorbs light energy
- When the material is scattered into water, shine sunlight and bubble nitrogen gas through it they get ammonia
- This process is thousands of times slower than the natural process

The Ammonia Economy:

- Making fertilizer via Haber-Bosch process is like making electricity at a big central coal power plant
    - Electricity needs to be transported hundreds of miles to its point of use
    - But when used solar panels it can be made where it's used
    - While electricity storage is tricky
        - Ammonia is easy in comparison
- You can also produce electricity with the burning of ammonia too
    - You could imagine a fuel economy based on nitrogen
    - Plenty of energy is stored in ammonia
    - There is no carbon emissions

Ammonia:

- One of the most used chemicals in the world
- It is important as a source of nitrogen, also making it versatile
- The production of ammonia has had a huge increase
- Most produces industry
- Ammonia is a good cleaner:
    - $NH_{3\,(aq)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

Ammonia Production:

- Harber process is for production of ammonia
- Nitrogen is obtained from the atmosphere
- The air is liquefied and then nitrogen is extracted from fractional distillation
- Source of hydrogen depends on:
    - Availability of cost of raw material and energy
    - Natural gas, such as methane is normally used
    - The hydrogen is obtained in a process known as steam reforming

Step 1 : $CH_{4\,(g)} + H_2O_{(g)} \leftrightarrow CO_{(g)} + 3H_{2(g)}$
Step 2 : $CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2\,(g)} + H_{2\,(g)}$

Harber Process:

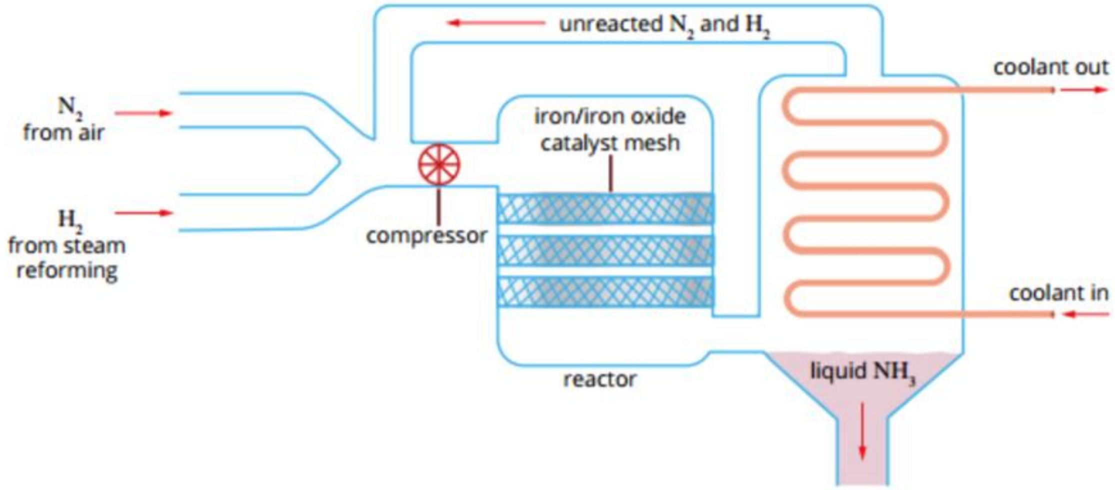
- Ensure high yield
    - Greater productivity in plant
    - Reduces waste
- Higher reaction rate
    - Ensures that the product is generated in a timely manner

Reaction rate increase:

- Temperature is higher
- A catalyst is present
- Higher pressure

Condition	Effect on equilibrium yield	Effect on reaction rate
Catalyst present	No effect	Increased
Increased temperature	Decreased	Increased
Increased pressure	Increased	Increased

- The economic benefits from increased rate and yield outweigh maintaining high pressure (100 to 250 atmospheres)
- High temperature leads to a high reaction rate but also leads to a lower yield
    - Use moderate temperature (350 to 550 *C)
    - Yield is sufficient while maintaining reasonable reaction rate



Alternative Sources of Raw Material:

- Electrolysis of water by using electricity from renewable sources
  - However it costs $600 per tonne of ammonia
  - Methane costs $40
- Cracking to obtain the hydrogen directly from methane

  $CH_{4\,(g)} \rightarrow C_{(s)} + 2H_{2\,(g)}$
  - It causes there to be no CO_2 to be produced
  - However a lot of energy is needed (over 800*C)
  - A catalyst can be used but the soot covers the reactive surface
- Bubbling methane into a bath of molten metal
  - As methane bubbles through it cracks and hydrogen bubbles to the top
  - Its only been done at small scale at 1000*C
  - The issue is that it would produce several cubic kilometres of soot.

Green Chemistry:

It is an overarching philosophy related to sustainable and environmentally friendly chemical practices

Environmental sustainability:

The ability to balance the rates of resources use pollution so they can be continued indefinitely without harm to the environment

Principles of Green Chemistry:

1. Prevent waste
   - Design chemical processes to prevent waste rather than treating it or cleaning it up
2. Maximise atom economy
   - Design synthesis so final product contains the max proportion of the starting material. There should be few atoms wasted
3. Design less hazardless chemical synthesis
   - Design safer methods that use and generate substances with little or no toxicity to humans or the environment
4. Design safer chemicals and products
   - Design chemical products to be fully effective and yet have little or no toxicity
5. Use safer solvents and reaction conditions
   - Avoid using toxic solvents to dissolve reactants or extract products
6. Increase energy efficiency
   - Minimise energy requirements
   - Preform chemical reactions at room temperature and pressure
7. Use renewable raw material
   - Use materials that are derived from renewable resources such as plant material rather than finite material
8. Avoid chemical derivatives
   - When a chemical has to be produced from another chemical before it can be used, additional reagents are used and extra waste is generated
9. Use catalyst, not excess reagents
   - Minimise waste by using small amounts of catalyst that can carry out a single reaction many times
   - Using a catalyst is better due to it not producing waste
10. Design chemicals and products that are biodegradable
    - Substances that breakdown to harmless substances
    - so they do not accumulate in the environment
11. Analyse in real time to prevent pollution
    - Include continuous monitoring and control during the process to minimise or eliminating the formation of by-products
12. Minimise the potential for accidents

- Design chemicals (including state) to prevent chemical accidents, including explosions, fires and releases to the environment

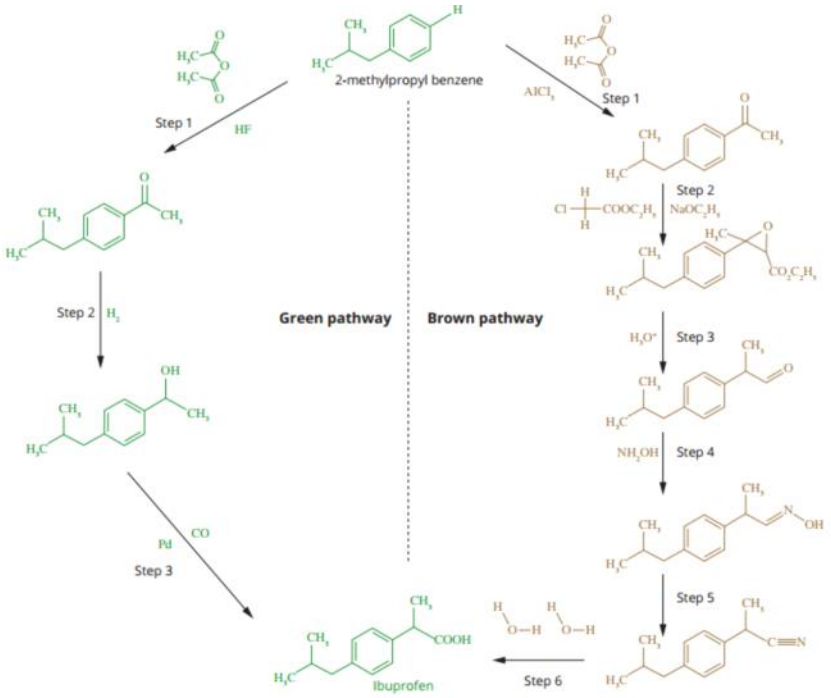
Renewable Source:

Is a source that is replenished naturally at a rate that compensates for its depletion through use

Green Synthesis:

Design efficient methods for converting readily available starting materials into desired products

- with increasing awareness for environmental impact, chemists are trying to develop greener synthesis pathways that minimise side products



Green Chemicals:

Chemists are constantly searching for new, innovative and environmentally friendly chemicals to replace long used ones

Extracting Gold in Western Australia :

The industry standard for gold extraction and refining involves gold cyanidation, where gold is leached from the ore

$$4Au(s) + 8CN^-(aq) + 2H_2O(l) + O_2(g) \rightarrow 4[Au(CN)_2]^-(aq) + 4OH^-(aq)$$

- Once extracted the tailing contains cyanide (toxic)
  - Aqueous solutions degrade into harmless substances
  - These products might persist in the environment for a number of years
- Found a wat of using amino acid (glycine)
  - It its environmentally friendly, cheaper and recyclable
  - Non toxic
  - It is also as accessible

Leaching:

Is the process of extracting certain substances from a solid by dissolving them in a liquid

Waste Minimisation and Remediation:

The key financial losses are:

- Reagents that end up in waste do not end up in marketable product
- Treating and storing waste is expensive

By placing industries and factories near each other

- Reduces transportation cost/ CO_2 produced
- Allows some companies to use others waste

Why not all reusable bags are good for the planet:

3 Things to Consider:

- How the bag is produced
- How can you dispose of it
- How many times you'll use it

Heavy Duty Bag:

- takes more energy
- Use it at least 4 times for it to be beneficial
- They are a thick form plastic
- Most people don't reuse them

Degradable Plastic Bags:

- Not the same as biodegradable bags
- Break into smaller plastic parts
- Worse than a smaller bag due to the small animals being affected by the microplastics

Biodegradable Bags:

- Made with plant materials that degrade into organic components
- Break down into methane, biomass, water and carbon dioxide

Green Bag:

- Plastic that is a biproduct of oil refinery
- Doesn't take that much energy
- Use it 11 times to breakeven
- Breaks down into microplastics

Canvas Tote Bag:

- Energy and water intensive option
- Need to use it at least 131 times
- Very durable, washable and biodegradable

Paper Bag:

- Breaks down easily
- Don't accumulate
- When wet, east to tear
- You'll need to reuse them a few times

Hessian Bag:

- Sustainable choice
- Made from fibres of jute plant
- Most comes from India or Bangladesh
    - There is a carbon cost in transportation
- Carbon neutral
- Biodegradable

Chart

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Name:	Biodegradable Polylactic acid bags (PLA)	Reusable Calcio Bags	High Density Polyethene (HDPE) bags	Oxo-biodegradable plastic bags	Paper Bags
Properties	Light, strong, flexible, compostable	Strong, flexible, durable, washable, reusable	Light, strong, flexible, durable, high chemical resistance, water and bacteria resistant	Light, strong, flexible	Light, strong, flexible, recyclable, compostable
Raw Material:	Plant extract, renewable sources, plasticisers by-product oil refining	Renewable resources, cotton	Non-renewable, ethene, by-product of oil refining	Non-renewable resources plus chemical additive	Renewable Material, wood, managed timber
Manufacture:	• 270MJ energy, • 200L of water • 7kg of CO_2 • 4-5 kgs of material used	• 30MJ • 7600L of water • 3.2kg CO_2 • Less than 1.25 kg materials used	• 200 MJ energy • 4.2L of water • 6.2kj of CO_2 • 1.5-4 kg of material needed	• 230MJ of energy • 76L of water • 10.2kg of CO_2 produced • Around 3 kg materials used	• 865 Mj • 350 L • 61kg of CO_2 • 5 or more kg of materials used
Transportation	USA or Japan	Pakistan	Hong Kong	Hong Kong and Malaysia	Australia
Cost and Usage	• One use • 520 bags used pp • 6c cost to wholesaler • Free to consumer	• Uses per bag 52 • 4 bags used pp • $1.5 cost to wholesaler • $2 to consumer	• One use per bag • 520 bags used pp • 1c cost to whole seller • Free to consumer	• One use per bag • 578 bags used pp • 3c to wholesaler • Free to consumer	• One use per bag • 520 bags used pp • Cost to wholesaler 10c • Free to consumer
Litter	• Moderate marine • 6 month life span	• Low marine • 2 years lifespan	• Extremely high marine impact • 2-20 year life span	• Low/ moderate marine impact • 6 months life span	• Low marine impact • 6 moths life span
Recycling	• Compostable • Not recyclable	• Recyclable • compostable	• Compost no • Recycle no	• Compostable • Not recyclable	• Compostable • Recyclable (60% only gets recycled)

1.1 Reaction Rate

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Measuring Reaction Rate:

The rate of reaction, at some instant is:

- The rate at which reactants are used up
- Or the rate in which products are formed

Factors Affecting Reaction Rate:

- Nature of the reactants
- Concentration of the reactants
- State of subdivision on the reactants
- Temperature
- Presence of a catalyst

1.2 Collision Theory

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Successful Reaction:

- The reacting particles have an appropriate collision orientation
- The reacting particles collide with sufficient energy

The greater the number of successful collisions, the faster the reaction rate

1.3 Changing Reaction Rate

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Nature of Reactants:

- Ionic reactions are rapid
  - They do not involve the breaking of bonds or electron transfer between reacting particles
- Molecular reactions are slow
  - They involve bond breaking and bond formation
  - Collisions are often unsuccessful at room temperature as there is insufficient activation energy

Concentration of Reactants:

- Either solution or gaseous phase
- If the number of particles per unit volume is increased, the number of collisions will also increase

The State of Subdivision of Reactants:

- When something is crushed up it has exposed the particles that couldn't react before
- This increases the surface area
- And hence there is a greater frequency of collisions
- This increases the frequency of successful reactions

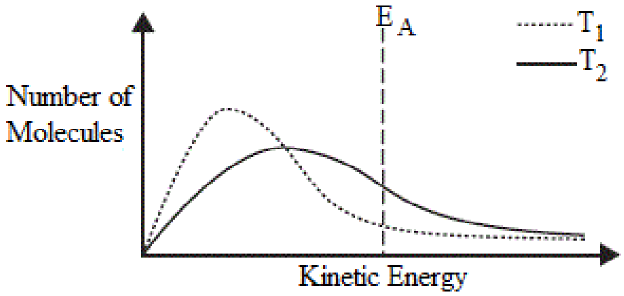
Temperature:

From the kinetic theory we know that as temperature increases, so does the velocity of the particles

- The increase in kinetic energy increases the frequency of collisions
- The force that the collisions occur with
  - Therefore the proportion of particles with sufficient activation energy increases
- This then increase the frequency of successful reactions

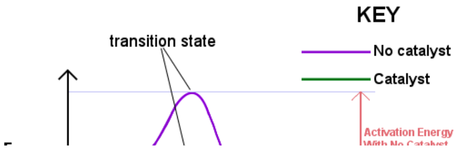
Kinetic Energy Distribution and Temperature:

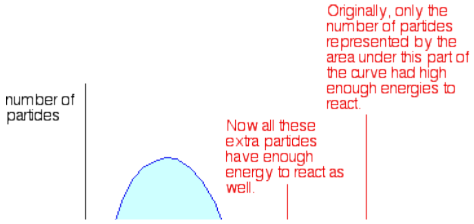
- The diagram shows the typical distribution of molecular kinetic energies at a certain temperature
- If particles exceed the activation energy then they will be able to sufficient energy to react successfully
- When the temperature is increased can increase the proportion of particles with energy greater than the activation energy

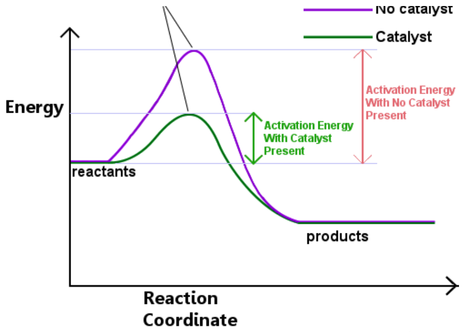


Catalyst:

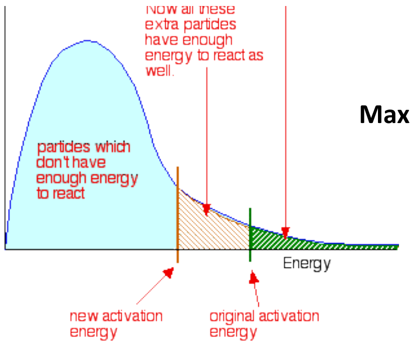
- A substance that does not get used up during a reactions
- It provides an alternate and easier reaction pathway of lower reaction activation energy
- This causes a greater proportion of reactants to have enough energy to exceed the activation energy







Energy Profile Diagram:



Maxwell Bolman Distribution

1.4 Equilibrium

Sunday, 22 September 2019 1:34 PM

Within a closed an equilibrium will always occur between reactants and products in a reversible reaction

- A system that allows energy to exchange with the surrounding
- Not matter

At Equilibrium:

- The forward reaction rate is equal to the reverse reaction rate
- There is no change in the macroscopic properties
  - Pressure
  - Colour
  - Concentration
  - This is how you know equilibrium has been reached

Vapour-Liquid Equilibrium:

$H_2O_{(aq)}$ + heat <-> $H_2O_{(g)}$ $\triangle H = +ve$

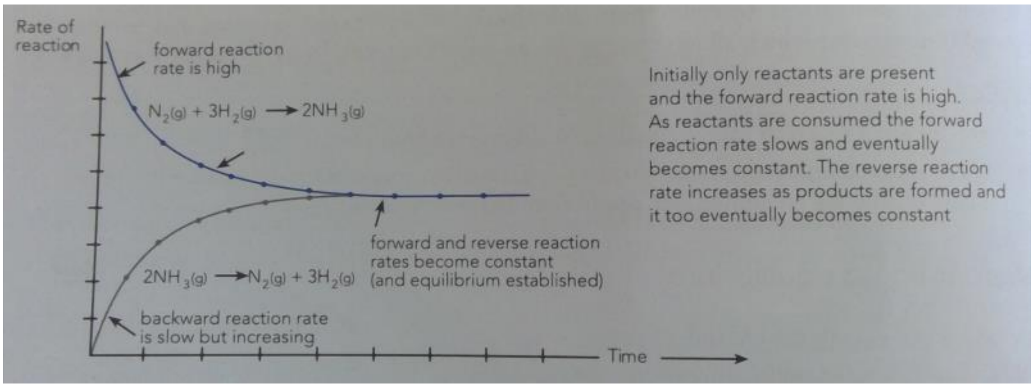
- Assuming dry air initially
- The forward reaction would predominate as there would be no water in gaseous phase
- As the vapour pressure increases the rate of condensation would also increase until it is equal to the rate of evaporation

At equilibrium:

- The rate of evaporation is equal to the rate of condensation
- The vapour pressure and water level are constant

Chemical Equilibrium:

- The concentration will be constant when at equilibrium
- The reverse and forward reaction rate will be equal
- It needs to occur at a closed system and the reaction has to be reversible



Initially only reactants are present and the forward reaction rate is high. As reactants are consumed the forward reaction rate slows and eventually becomes constant. The reverse reaction rate increases as products are formed and it too eventually becomes constant

Equilibrium Constant (K)

In the reaction:

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

- If K> 1 the reaction favours the products
- If K>>1 the reaction very strongly favours the products
- K<1 reaction favours reactants
- If K<<1 reaction very strongly favours reactants

Important Note:

- Solids are not included in the K expression
  - The concentration of a solid does not vary
  - Or water in an aqueous solution
- The value of K does not change if you alter concentration, pressure or volume
- The K value does change when the temperature is changed
  - If the temperature is increases, the value of K will increase for endothermic reaction
  - If temperature is decreased, the value of K will decrease for an exothermic reaction
- K only refers to the equilibrium position

1.5 Le Chatelier's Principle:

Sunday, 22 September 2019 2:36 PM

"if a change in conditions is made to a chemical system in equilibrium, then the system will adjust in such a way to partially counteract the imposed change"

This means:

- Increasing the concentration of a substance will favour the reaction which uses up that substances
- Increasing the pressure of a gas will favour the reaction which decreases the pressure
- Increasing the temperature of the system will favour the reaction which will lower the temperature

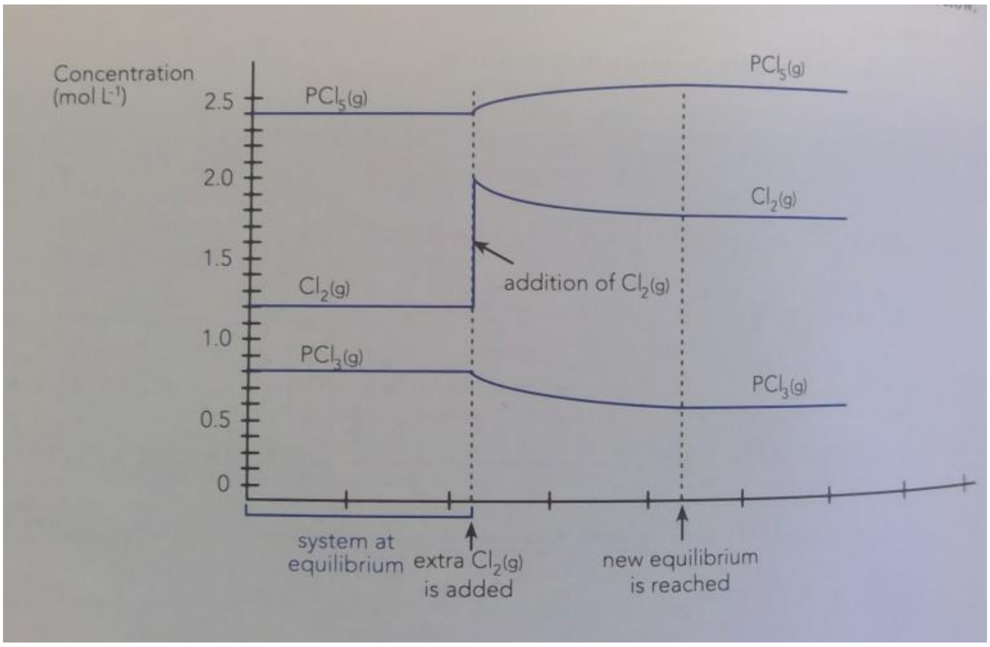
Effect of Changing Concentration:

- When a substance is added it will increase the concertation of the substance and hence the rate of reaction that consumes it

E.g.
$PCL_{3(aq)} + CL_{2\ (g)}$ <-> $PCl_{5\ (g)}$

Suppose that CL_2 is added, then:

- the forward reaction rate would increase while the reverse would not initially be affected (since the concentration of PCl_5 has not changed)
- As more PCl_5 is produced, the reverse reaction rate will also begin to increase
- A new equilibrium would eventually be reached with identical new forward and reverse reaction rates



Effect of Changing Pressure or Volume of a Gas:

- Change in volume can alter the pressure and hence the concentration of all species
- it will cause a change a change in both the forward and reverse reaction rates
- The favoured reaction will depend on the number of gas particles in the reactant and product

e.g. 1
$N_2\ (g) + 3H_2\ (g)$ <-> $2NO(g)$

An increase in pressure will have no effect on the equilibrium position of this reaction

- Both the forward and reverse reactions increase equally
- Since the number of gas particles are the same
- Hence there is no change in equilibrium position
- Just a change in reaction rate

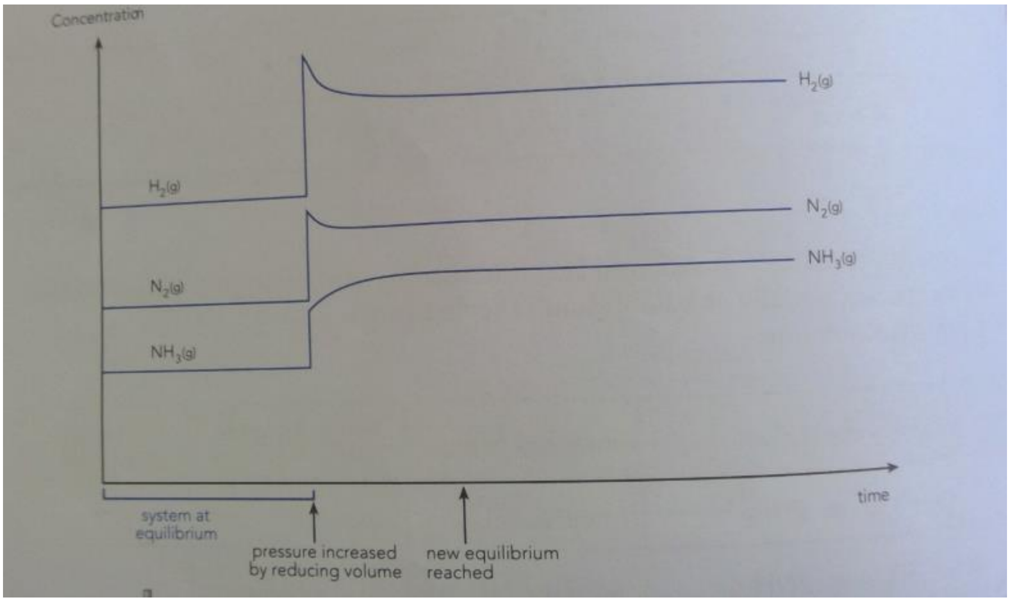
e.g. 2

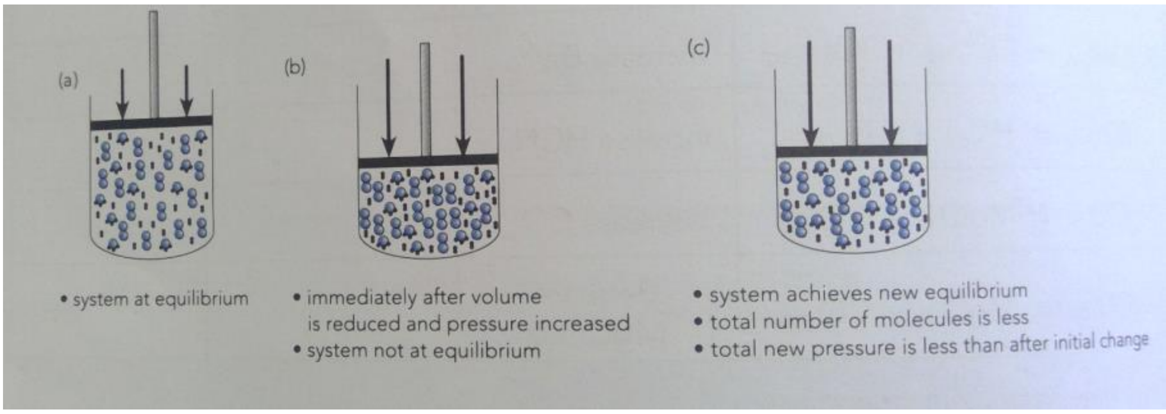
N2 (g) + 3H2 (g) <-> 2NH3 (g)

An increase in pressure will favour the side with the least number of molecules

According to Le Chateliers Principle…

- when the volume is reduced, the pressure will increase
- The system will oppose this change by favouring the reaction which produces the least number of particles
- In this case, it would be right





Effect on Changing Temperature:

- It is best to include the heat of reaction as a part of the equation

e.g.

$2NO_{(g)} + O_{(2)}$ <-> $NO_{(g)}$ +133j

- If heat is added to the system at equilibrium the system reaction will move in the direction that uses u heat
  - In this case the reverse reaction is favoured

- Both the forward and reverse reaction rate increase
- Except the reverse reaction rate increases to a greater extent initially

Effect of using catalyst:

- They provide and a lower activation pathway for a reaction
- Increase both forward and reverse reaction rates
- Hence they do not affect the equilibrium position but they do help reactions achieve equilibrium quicker

2.6 Further Applications of Le Chateliers Principle

Tuesday, 26 February 2019 6:18 PM

Changing Pressure by Changing Volume

The pressure of gases can be changed by an increase or decrease in volume in a container when the temperature is kept constant.

Predicting the Effect of a Change using Le Chatelier's Principle:

Le Chatelier’s principle tells us that that an equilibrium system will respond to an increase in pressure by adjusting to reduce the pressure. Therefore, the position of equilibrium will move towards the direction of the fewest particles.

Introduction of Acids and Bases 4.1

Saturday, 27 April 2019 1:09 PM

Arrhenius Model:

- Acids are substances that dissociate and ionise in water. They produce hydrogen ions H^+
- Bases dissociate in water to produce hydroxide ions OH^-

A limitation is that it only works in aqueous solutions

It is normally the principle used for dissociation reactions

e.g.

$$HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$$

Bronsted-Lowry Theory

- Acids are proton donors
- Bases are proton acceptors
- An acid base reaction involves an exchange of protons from an acid to a base

This theory is used to represent hydrolysis reactions

- Occurs when a molecule or ion in aqueous solution reacts with water, either accepting or donating a proton

e.g.

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Advantages of Bronsted Lowry:

- Solutions are not restricted to aqueous solutions
  - A reaction between two gases can be an acid base reaction

e.g. Salt ammonium chloride can be formed by a reaction between, note that Bronsted Lowry caters for the second one

- solutions of hydrochloric acid and ammonia:

$$HCl(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$$

- gaseous hydrogen chloride and gaseous ammonia:

$$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$$

Limitations of Bronsted Lowry model:

- It cannot be applied to reaction between acidic and basic oxides
  - Under certain circumstances solid calcium oxide, a basic oxide, reacts with gaseous carbon dioxide, to produce the salt calcium carbonate:

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$

Conjugate Acid-Base Pairs:

- When an acid donates a proton, it forms a conjugate base
- When a base accepts a proton is forms a conjugate acid
- Conjugate acid-base pairs are molecules or ions that differ from each by an H^+ ion.

For e.g.

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

- Cl^- can be formed from HCl therefore it is the conjugate base
  - This makes HCl the conjugate acid of Cl^-
- And H_2O and H_3O are the other conjugate acid-base pair

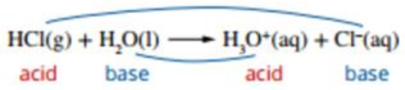


FIGURE 4.1.8 Conjugate acid–base pairs are formed when an acid donates a proton to a base.

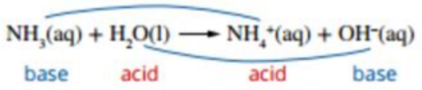
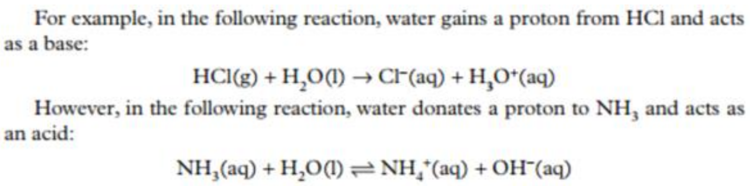


FIGURE 4.1.9 The reaction between ammonia and water, showing the conjugate acid–base pairs

Amphiprotic Substances

Substances that can act as acids or bases due to them being able to accept or donate protons

- For example water can donate or accept protons depending on the reaction



For example, in the following reaction, water gains a proton from HCl and acts as a base:

$$HCl(g) + H_2O(l) \rightarrow Cl^-(aq) + H_3O^+(aq)$$

However, in the following reaction, water donates a proton to NH_3 and acts as an acid:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

- If the solute is a stronger acid than water, then water will act as a base
- If the solute is a stronger base than water, then water will act as an acid

When amphiprotic substances react with water it reacts as both an acid and a base. Although one reaction generally dominates (which can be determined by measuring pH

Monoprotic Acids:

- Donate only one proton per molecule
- e.g. HCl, HF, HNO_3, HCH_3COO
    - ○ HCH_3COO has 4 hydrogens but it can only donate one (the one in the O-H bond) so it's still a monoprotic acid

Acidic Proton:

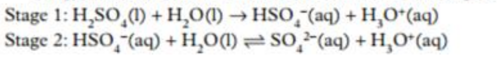
Is the proton that is donated

Polyprotic Acids:

- Acids that can donate more than one proton from each molecule
- The number of protons it can donate depends on the acid's structure
- They do not donate all of their protons at once, but do it in steps.

Diprotic Acids

- Can donate 2 protons
- e.g. Sulphuric acid and carbonic acid



A diprotic acid, such as sulfuric acid, ionises in two stages:

Stage 1: $H_2SO_4(l) + H_2O(l) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$

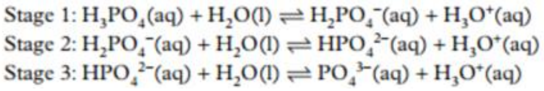
Stage 2: $HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$

- Due to Sulfuric acid being a strong acid, due to it readily donating a proton, so the first stage almost occurs to completion
- Hydrogen sulphate is a weak acid because it only partially ionises, it is an incomplete reaction
- Therefore a solution of sulphuric acid contains hydronium ions, hydrogen sulphate ions and sulphate ions

Triprotic Acids:

- Acids that can donate 3 protons
- The extent of ionisation decreases progressively from stage 1 to stage 3

e.g. Phosphoric acid



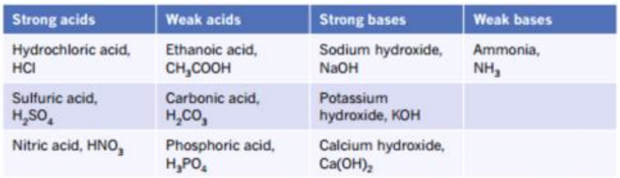
Stage 1: $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + H_3O^+(aq)$

Stage 2: $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$

Stage 3: $HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons PO_4^{3-}(aq) + H_3O^+(aq)$

Strength of Acids and Bases 4.2

Saturday, 27 April 2019 1:26 PM



Strong acids	Weak acids	Strong bases	Weak bases
Hydrochloric acid, HCl	Ethanoic acid, CH_3COOH	Sodium hydroxide, NaOH	Ammonia, NH_3
Sulfuric acid, H_2SO_4	Carbonic acid, H_2CO_3	Potassium hydroxide, KOH	
Nitric acid, HNO_3	Phosphoric acid, H_3PO_4	Calcium hydroxide, $Ca(OH)_2$	

Strong Acids

- Acids that readily donate a proton
- Therefore the ionisation reaction is complete
- With virtually no unreacted acid molecules remaining

e.g.

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$
$$H_2SO_4(l) + H_2O(l) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$$
$$HNO_3(l) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$$

Weak Acids:

- Acid that doesn't readily donate a proton
- It partially ionises
- There is a high portion of the acid molecules and a small portion of the ions

e.g. Ethanoic acid

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$$

- In a 1.0 mol/L solution of ethanoic acid, only a small portion of the ethanoic acid molecules are ionised, and it has a high proportion of ethanoic acid molecules and only some hydronium ions and ethanoate ions

Strong Bases:

- Accept protons easily
- Completely react

e.g.

Sodium Oxide (Na_2O),

- It completely dissociates in water to produce Na^+ ions and O^{2-} ions
- These oxide ions react completely with water, accepting a proton to form hydroxide ions

$$\underset{\text{base}}{O^{2-}(aq)} + \underset{\text{acid}}{H_2O(l)} \rightarrow OH^-(aq) + OH^-(aq)$$

** NaOH is often referred as a strong base, however according to the BL definition of acids and bases, it is more correct to state it as an ionic compound that is the source of the strong base OH^-

- OH^- acts as the strong base

Weak Bases:

- Only a small portion ionises
- There is a large portion of base left and only a small portion of ions

e.g.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

A 1.0 mol/L solution of ammonium contains mostly ammonium molecules together with a smaller number of ammonium ions and hydroxide ions

Relative Strength of Conjugate acid-base pairs:

- The stronger an acid is, the weaker its conjugate base is
- The stronger the base is, the weaker its conjugate acid is

Acid Ionisation Constant:

- The strength of an acid or base can be described in terms of the position equilibrium when the substance donated a hydrogen to, or accepts a hydrogen from water (hydrolysis reaction)
- For example ethanoic is classified as a weak acid because the equilibrium constant for the hydrolysis reaction is small…

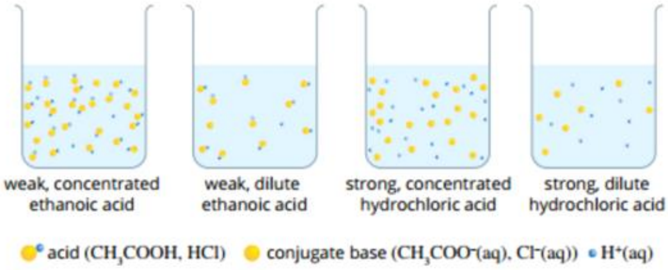
$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq) \qquad K_a = 1.8 \times 10^{-5}$$

- The equilibrium constant for an acid is called the acidity constant
- For ethanoic acid, it would be written as…

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$$

Strength versus Concentration:

- A concentrated acid or base contains more moles of solute per litre than a dilute acid or base
- While strong/ weak acids and bases refers to the relative tendency to accept or donate protons



weak, concentrated ethanoic acid

weak, dilute ethanoic acid

strong, concentrated hydrochloric acid

strong, dilute hydrochloric acid

Acidity of Solutions 4.3

Saturday, 27 April 2019 3:12 PM

Ionic Product of Water:

- Pure water undergoes self-ionisation to a very small extent
- It behaves both as a very weak acid and a very weak base
- It produces a hydronium ion for every hydroxide ion
- It displays amphiprotic properties
- $[H_3O^+]=[OH^-]=1.00\text{x}10^{-7}$ mol/L at 25 * C

And the ionisation constant for water is represented by the symbol K_w

$$K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14} \text{ at } 25°C$$

Acidic and Basic Solutions:

- Pure water and neutral solutions: $[H_3O^+]=[OH^-]=1.00\text{x}10^{-7}$ mol/L
- Acidic solutions: $[H_3O^+]> 10^{-7}$mol/l and $[OH^-]<10^{-7}$ mol/L
- Basic Solutions: $[H_3O^+]<10^{-7}$ mol/L and $[OH^-]>10^{-7}$ mol/L
- The higher the concentration of hydronium ions, the more acidic the solution is

Definition of pH

- It has been developed to measure acidity
- When pH decreases the concentration of hydronium increases

$$pH = -\log_{10}[H_3O^+]$$

It can be rearranged to give…

$$[H_3O^+] = 10^{-pH}$$

pH of Acidic and Basic Solutions:

- Neutral have a pH equal to 7
- Acidic solutions have a pH less than 7
- Basic solutions have a pH greater than 7

Effect of Temperature on pH:

- As temp increases K_w will increase
- As temp decreases K_w will decrease
- Due to self-ionisation of water being endothermic

Dilution of Acids and Bases 4.4

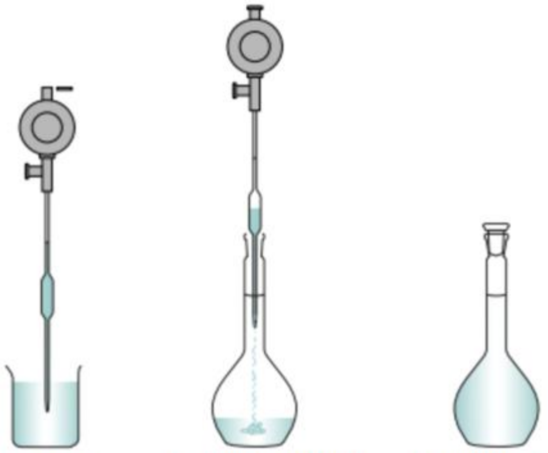
Saturday, 27 April 2019 3:40 PM

Concentration of Acids and Bases

- Molar concentration is the concentration expressed in mol/L
- The amounts of acid or base do not change during dilution
  - The volume increases
  - The concentration decreases
- pH increases when a solution of acid is diluted

c=n/V

To prepare a diluted solution of acid is by mixing concentrated acid with water (dilution)



Measure out 10.0 mL of 10.0 mol L^{-1} HCl with a pipette.

Transfer to a 100.0 mL volumetric flask partly filled with water.

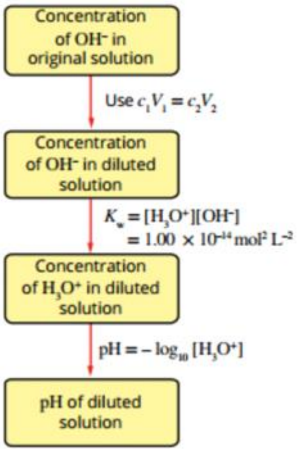
Fill the flask with distilled water to the calibration mark and shake thoroughly.

FIGURE 4.4.1 Preparing a 1.00 mol L^{-1} HCl solution by diluting a 10.0 mol L^{-1} solution. Heat is released when a concentrated acid is added to water, so the volumetric flask is partly filled with water before the acid is added. (Extra safety precautions would be required for diluting concentrated sulfuric acid.)

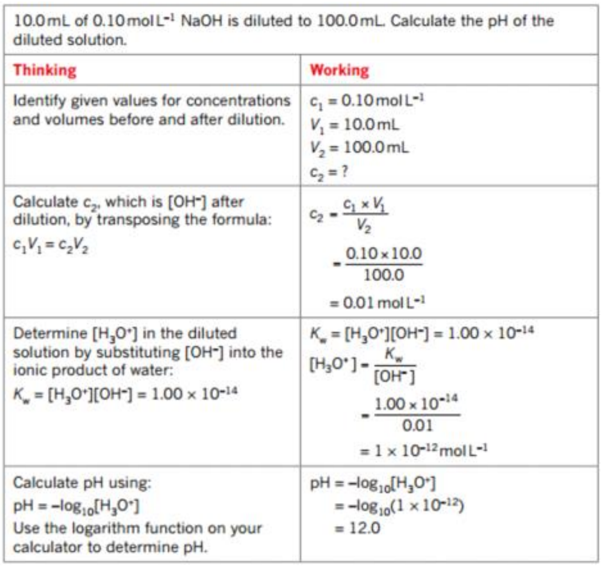
We get the relationship C1V1=C2V2

- This will allow us to calculate the needed concentration of a diluted substance
- Calculate the volume needed to dilute to a specific concentration
- Don't forget the C2 is the total volume, so if you need to calculate the volume added, do C1-C2

Calculation of pH of a base after dilution:



e.g.



10.0 mL of 0.10 mol L^{-1} NaOH is diluted to 100.0 mL. Calculate the pH of the diluted solution.

Thinking	**Working**
Identify given values for concentrations and volumes before and after dilution.	$c_1 = 0.10\ \text{mol L}^{-1}$ $V_1 = 10.0\ \text{mL}$ $V_2 = 100.0\ \text{mL}$ $c_2 = ?$
Calculate c_2, which is $[OH^-]$ after dilution, by transposing the formula: $c_1V_1 = c_2V_2$	$c_2 = \frac{c_1 \times V_1}{V_2}$ $= \frac{0.10 \times 10.0}{100.0}$ $= 0.01\ \text{mol L}^{-1}$
Determine $[H_3O^+]$ in the diluted solution by substituting $[OH^-]$ into the ionic product of water: $K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14}$	$K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14}$ $[H_3O^+] = \frac{K_w}{[OH^-]}$ $= \frac{1.00 \times 10^{-14}}{0.01}$ $= 1 \times 10^{-12}\ \text{mol L}^{-1}$
Calculate pH using: $pH = -\log_{10}[H_3O^+]$ Use the logarithm function on your calculator to determine pH.	$pH = -\log_{10}[H_3O^+]$ $= -\log_{10}(1 \times 10^{-12})$ $= 12.0$

pH of Salt Solutions 4.5

Saturday, 27 April 2019 4:27 PM

Salts

- Ionic compound that contains a cation or a anion
- Formed by neutralisation reactions by the combination of an acid with a base

e.g. Potassium chloride , the potassium ions may have come from the base potassium hydroxide and the chloride ions from hydrochloric acid

$$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$$

Salts of a Strong Acid and a Strong Base:

- Is a neutral salt
- The anion and cation of a neutral salt do not react with water by accepting or donating a proton

e.g. Sodium Nitrate, the salt of the strong acid, HNO_3 and the strong base NaOH:

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

- Sodium ions do not hydrolysis in water
- Nitrate ions, the conjugate base of the strong acid HNO_3, are very weak bases and do not react with water
- Therefore sodium nitrate solution has a pH of 7

Salts of a Strong Acid and a Weak Base:

- Forms an acidic salt
- The anion or cation of an acidic salt reacts with water by donating a proton
- It's an acidic salt due to conjugate acid of the weak base hydrolyses to form hydronium ions

e.g. The salt of Ammonium chloride, which is from the neutralisation of hydrochloric acid and a weak base ammonia

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

5.1 Introducing Buffers:

Thursday, 2 May 2019 9:00 AM

Buffer Solution:

- Able to resist a change in pH when a small amount of acid or base is added
- Consists of a weak conjugate acid- base pair
- Made up of:
  - A weak acid and its conjugate base
  - A weak base and its conjugate acid

Acidic Buffer:

- Buffers can be made up of a weak acid and one of its salts

Example:

A mixture of ethanoic acid and sodium ethanoate solution

- Produces CH_3COOH/CH_3OO^- buffer

Preparation:

- By dissolving approximately equal molar amounts of ethanoic acid (CH_3CHOOH) and sodium ethanoate (CH_3COONa) in water
- The sodium ethanoate dissociates completely in water, producing ethanoate ions and sodium ions

$$CH_3COONa_{(s)} \text{ -> } CH_3CHOO^-_{(aq)} + Na^+_{(aq)}$$

- At the same time only a small proportion of ethanoic acid molecules will ionise , producing ethanoate (CH_3COO^-) and hydronium (H_3O^+) ions. The vast majority of the ethanoic acid molecules remain as molecules.

$$CH_3COOH_{(aq)} + H_2O_{(l)} \text{ <-> } CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

- Therefore a buffer solution contains a significant amount of both weak acid, CH_3COOH, and its conjugate base, CH_3COO^- . The equilibrium system

Basic Buffer:

- Can be made up of a weak base and one of its salts

Example:

A mixture of ammonia solution and ammonium chloride

- Produces NH_3^{+}/NH_4^+

Preparation:

- Can be made from dissolving approximately equal molar amount of ammonia solution, and an ammonium salt, such as ammonium chloride (NH_4Cl) in water
- The ammonium chloride dissociates completely in water, producing ammonium ion and chloride ions:

$$NH_4Cl_{(s)} \text{ -> } NH_4^+_{(aq)} + Cl^-_{(aq)}$$

- At the same time, only a small proportion of ammonia molecules will ionise, producing ammonium ions (NH_4^+) and hydroxide ions (OH^-)
- The resulting solution is an equilibrium mixture of NH_3, molecules, OH^- ions and NH_4^+ ions.

$$NH_{3\,(aq)} + H_2O_{(l)} \text{ <-> } NH_4^+_{(aq)} + OH^-_{(aq)}$$

- The buffer solution contains a significant amount of both the weak base, NH_3, and its conjugate acid, NH_4^+. This equilibrium system can resist changes in pH when a small amount of acid or base is added.

5.2 How Buffers Work

Thursday, 2 May 2019 12:14 PM

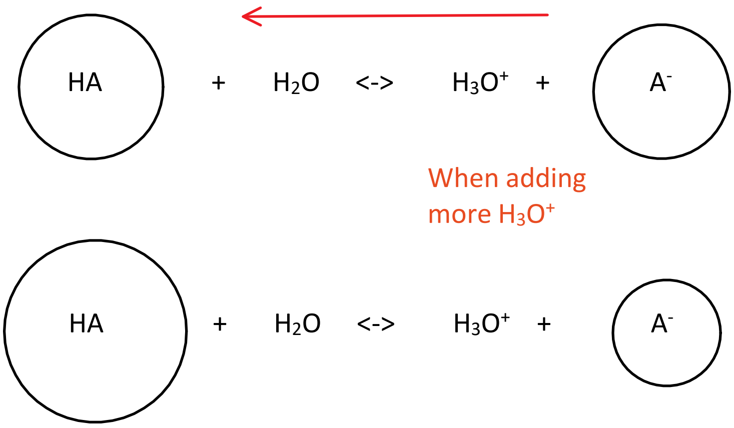
Adding an Acid to a Buffer:

When HCl is added to the ethanoic acid/ ethanoate buffer, The pH will decrease to a small extent.

When you add HCl

- The added H_3O^+ ions will disturb equilibrium
- LCP, tell us that the system will oppose the change and restore equilibrium
- Some of the additional H_3O^+ will react with the CH_3COO^- ions in the buffer
- This produces more CH_3COOH molecules, decreasing $[H_3O^+]$ in solution

Initial Equilibrium:



Adding a Base to a Buffer:

When a strong base is added to the ethanoic acid/ ethanoate buffer, the OH^- ions will react with the CH_3COOH molecules

- Generates more CH_3COO^- ions
- Consumes most of extra OH^- ions

$$CH_3COOH_{(aq)} + OH^-_{(aq)} \text{<->} CH_3COO^-_{(aq)} + H_2O_{(l)}$$

$$\longrightarrow$$

Buffer Capacity:

Is a measure of the effectiveness of a buffer solution at resisting a change in pH when either a strong acid or strong base is added

- **High concentration of weak acid & its conjugate base**
- **The concentration of the acid and its conjugate base are equal**

6.1 Characteristics of Indicators

Thursday, 2 May 2019 12:35 PM

Indicators:

Are large molecules that change colour in solution at different pH values

- Used to distinguish between acids and bases
- Determine pH of a solution
- Exist in two forms (**a weak acid and its conjugate base**)
    - Each has a different colour

Properties of Indicators:

In solution, the acidic form of the indicators is in equilibrium with its conjugate base

$$Hin_{(aq)} + H_2O_{(l)} <-> In^-_{(aq)} + H_3O^+_{(aq)}$$

- The position of equilibrium depends on the pH
- Therefore changing the pH of an indicator solution changes the relative concentrations of the acidic and basic forms
- Therefore the colour of the solution can change

6.2 Common Indicators

Thursday, 2 May 2019 12:44 PM

Universal Indicator:

- It estimates the pH
- It is a mixture of several indicators
- Therefore it changes through a range of colours
- Not very accurate, due to it not having an exact change..

Bromothymol Blue: **(6.0-7.6)**

Can be expressed:

$HBB_{(aq)} + H_2O_{(l)} <-> BB^-_{(aq)} + H_3O^+_{(aq)}$

- The indicator colour depends upon the relative concentrations of HBB and BB^-

Example:

When bromothymol blue is added to HCl

- The additional H_3O^+ ions from HCl will cause indicator equilibrium to shift left
- Due to it wanting to oppose the increase of H_3O^+

$$\longleftarrow$$

$HBB_{(aq)} + H_2O_{(l)} <-> BB^-_{(aq)} + H_3O^+_{(aq)}$

Blue Yellow

- Therefore the concentration of HBB molecules becomes much greater than the concentration on BB^- ion
- Therefore the solution becomes yellow

When Added to a Basic Solution:

When an indicator is added to a solution of a base, the system shifts to the right to oppose the increase in the concentration of OH^- ions

$$\longrightarrow$$

$HBB_{(aq)} + H_2O_{(l)} <-> BB^-_{(aq)} + H_3O^+_{(aq)}$

Blue Yellow

OR $HBB_{(aq)} + OH^-_{(aq)} <-> BB^-_{(aq)} + H_2O_{(l)}$

The concentration of BB^- ions becomes greater than the concentration of HBB molecules and therefore the solution changes colour

Transition Point:

When the solution appears a colour in between the colours on the weak acid and its conjugate base

- The midpoint of the indicator or colour change

e.g. At pH 7, $[HBB] = [BB^-]$

- The solution appears to be green, a mixture of the blue and yellow

Methyl Orange: **(3.2-4.4)**

- **Red** in acidic solution
- **Yellow** in basic solution
- Due to it having a colour change between pH 3.1 and 4.4, it is used for weak bases
- It's a synthetic indicator

]

Phenolphthalein: **(8.2 -10.0)**

- In acidic solution it is **colourless**
- In basic solution it is a **pink** colour
- Due to it having a colour change between pH 8.3- 10.0 it is used for the analysis of weak acids

6.3 pH Range of an Indicator

Thursday, 2 May 2019 5:15 PM

Indicator Range:

The range of pH values over which an indicator changes colour

Using Indicators:

Equivalence point:

Is the point during a neutralisation reaction when the stoichiometric amount of the acid and base are equal

e.g. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
The equivalence point during this reaction is when the amount (in moles) of HCl and NaOH are equal in the titration

End Point of Indicators:

Is the point in a titration when the indicator changes colour. At this point, the colour of the indicator will be intermediate between its colour in acidic solution and its colour in alkaline solution (**transition point**)

7.2/7.3 Calculations Involving Acids and Bases and Standard Solutions

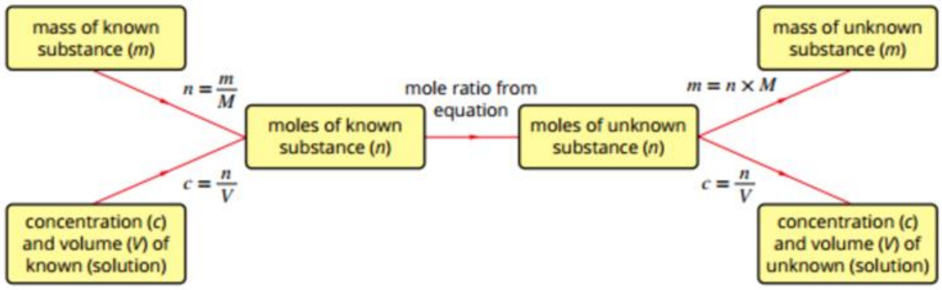
Thursday, 2 May 2019 8:36 PM

7.2 -Calculations Involving Acids and Bases

Reacting Quantities of Acids and Bases:

Steps:

1. Write a balanced equation for the reaction
2. Identify the substance that is 'known'. This is the substance for which there is enough information (normally V and C) to calculate the number of moles
3. Use the mole ratios from the equation to calculate the amount, in mol, of the 'unknown' substance
4. Calculate the volume or concentration from the number of moles



7.3 -Standard Solutions:

Volumetric Analysis:

Can be used to accurately determine the concentration of solutions of acids and bases

- Involves reacting the solution of unknow concentration with a solution of accurately knows concentration (a standard solution)
- It is an example of chemical quantitative analysis

Primary Standard:

A primary standard is used to standardise secondary standards and other reagents

e.g Anhydrous Sodium Carbonate (Na_2CO_3)
Hydrated Oxalic Acid ($H_2C_2O_4$.$2H_2O$

A substance is suitable for use as a primary standard if it:

- Is readily available in pure form
- Has a known chemical formula
- Is easy to store without deteriorating or reacting with the atmosphere
- Has a high molar mass to minimise the effect of weighing errors

Secondary Standard:

It is made specifically for a certain analysis

- Not very pure
- Comparatively more reactive
- Somewhat hydroscopic

Anhydrous:

No water present in the compound

Hydroscopic:

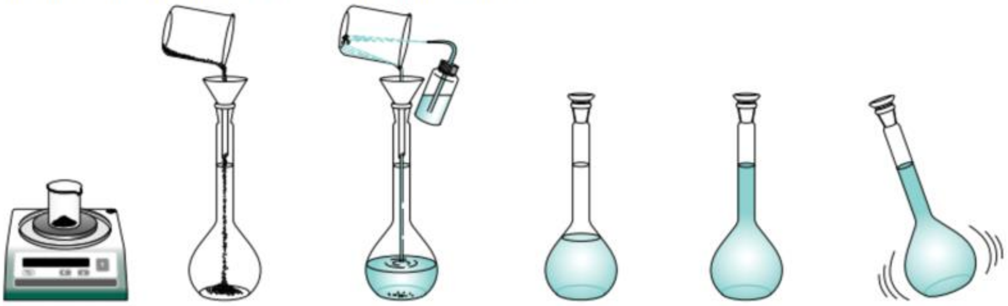
Absorbs H_2O

Deliquescence:

Absorbs H_2O and it dissolves in it

Preparing a Standard Solution:

To prepare a standard solution from a primary standard, you need to dissolve an accurately known amount of the substance in distilled water to produce a solution of known volume. The steps in this process are shown in Figure 7.3.5.



Weigh the pure solid on a balance. → Transfer the solid into the volumetric flask using a clean, dry funnel. → Rinse any remaining solid particles into the flask using deionised water. → Half-fill the flask with deionised water, stopper and swirl vigorously to dissolve the solid. → Add deionised water up to the calibration line on the neck of the flask. The bottom of the meniscus of the solution should be on the mark when viewed at eye level. → Stopper and shake the solution to ensure an even concentration throughout.

Standard Solution:

Is a solution of an accurately known concentration and volume

- The concentration , in $molL^{-1}$, of a prepared standard solution can be determined by measuring the mass of the solid dissolved and the volume of the solution prepared

7.4 Volumetric Analysis

Thursday, 2 May 2019 9:15 PM

Equivalence point:

When the reactants are present in the same stoichiometric amounts

- Hence, the amounts indicated by the coefficients in the equation for the reaction

End point:

Is the point during titration at which the indicator changes colour

- The colour will be at the transition point
- For an accurate analysis, the end point should be very close to the equivalence point

Equipment:	**Visual Reference:**	**Use:**
Conical Flask:		It is used to prepare a standardised solution (e.g. sodium carbonate). An accurately weighed sample of sodium carbonate is placed in the flask and dissolved in distilled water to form a specific volume and concentration of solution.
Pipette		Is used to accurately measure a specific volume of HCl. This known volume or aliquot, is then poured into a conical flask ready for analysis
Burette		The standard solution of sodium carbonate is placed in a burette, which delivers accurate known, but variable volumes. The volume of the liquid delivered by the burette is called titre.
Conical Flask		Is what the tire and aliquot is mixed in. We use it instead of a beaker due to it mixing the solution better.

Using a Burette:

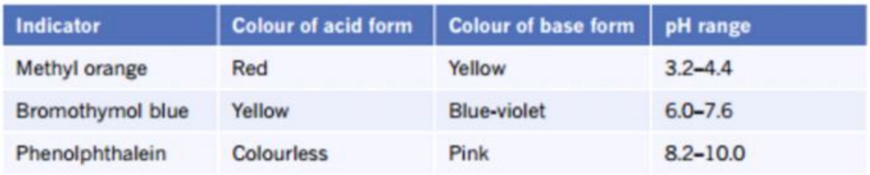
- Usually calibrated in intervals of 0.10mL
- Usually 3 concordant titres are used to find the average titre

Concordant:

The readings are in a 0.2mL range of each other

- Dismiss any that are not (outliers)

Indicators:



Indicator	Colour of acid form	Colour of base form	pH range
Methyl orange	Red	Yellow	3.2–4.4
Bromothymol blue	Yellow	Blue-violet	6.0–7.6
Phenolphthalein	Colourless	Pink	8.2–10.0

Characteristics of Indicators:

- Indicators are large organic molecules
- Colour represents a change in pH of the solution in which they are dissolved in
- They are either a weak acid or a weak base
- In solution, the acid form of the indicator is in equilibrium with its conjugate base

  $Hin_{(aq)} + H_2O_{(l)} <-> In^{-}_{(aq)} + H_3O^{+}$
- The position of equilibrium depends on the pH
- The colours of its acid and base forms are different
- The acid or base colours of an indicator is visible at low indicator concentrations

pH Change During a Titration:

Titration Curve/ pH Curve:

A graph of the pH against the volume of acid/ base added

Graphing:

The equivalence point occurs when the gradient of the pH is the steepest (inflection point)

- Near the equivalence point the addition of a very small amount of acid or base, produced a large change in pH

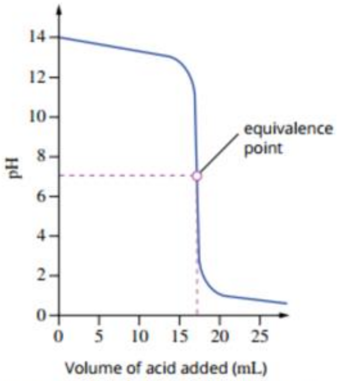


FIGURE 7.4.5 Titration curve for a strong acid being added to a strong base

- Near the equivalence point, the addition of a very small volume of HCl produces a large change in pH
- In this reaction the pH changes from 10 to 4 with one drop pf acid
- By using an indicator that changes colour in this range (bromothymol blue range: 6.0-7.6), one drop will cause a colour change
- It is important to know the range of an indicator to ensure a good end point

Example:

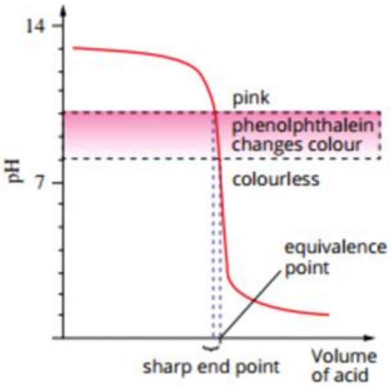
For a reaction between a strong acid and a strong base, the pH at the equivalence point is 7.

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

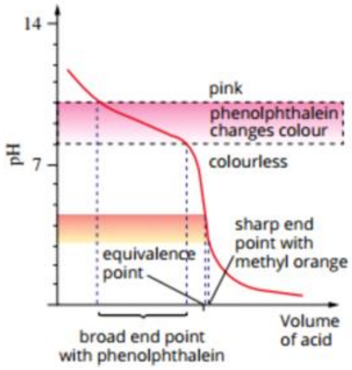
Only $H_2O_{(l)}$ and $NaCl_{(aq)}$ are present at the equivalence point making the solution neutral

** other indicators, including phenolphthalein (pH 8.3-10.0) could be used for this titration because they would also produce a sharp end point**

Strong Acid
Strong Base



Strong acid
Weak Base



Example Question:

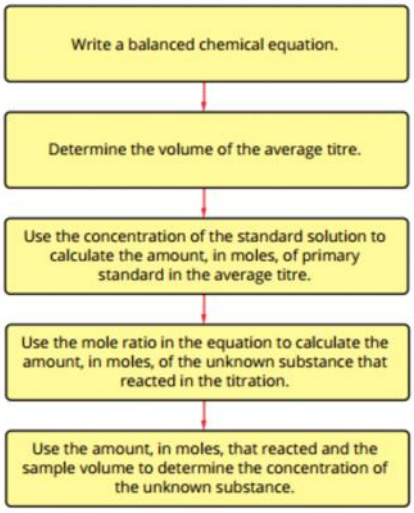
"Why is it important to select an indicator with an end point close to the equivalence point for the reaction?"

Near the equivalence point, a very small addition of either base or acid in the burette can cause a very large change in pH. A sharp end point is one where the indicator changes colour (due to a lrage change in pH) with just one additional drop of the solution being added from the burette. This causes the amount of titre to be more accurate.

7.5 Calculations in Volumetric Analysis

Thursday, 2 May 2019 10:13 PM

Titrations:



Write a balanced chemical equation.

Determine the volume of the average titre.

Use the concentration of the standard solution to calculate the amount, in moles, of primary standard in the average titre.

Use the mole ratio in the equation to calculate the amount, in moles, of the unknown substance that reacted in the titration.

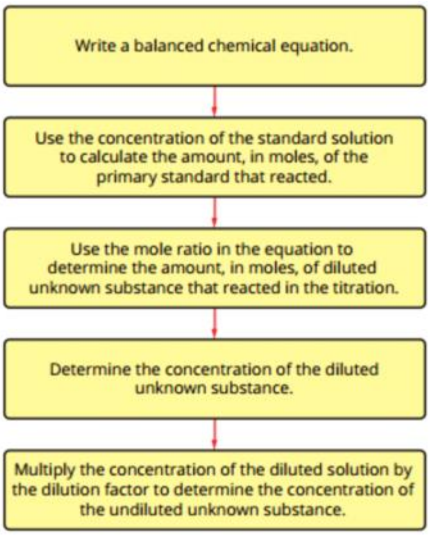
Use the amount, in moles, that reacted and the sample volume to determine the concentration of the unknown substance.

Titrations that Involve Dilution:

$V_1C_1 = V_2C_2$

I personally to use C1V1 = C2V2 when there is dilution

**Don't forget the amount added is (V2-V1)



Write a balanced chemical equation.

Use the concentration of the standard solution to calculate the amount, in moles, of the primary standard that reacted.

Use the mole ratio in the equation to determine the amount, in moles, of diluted unknown substance that reacted in the titration.

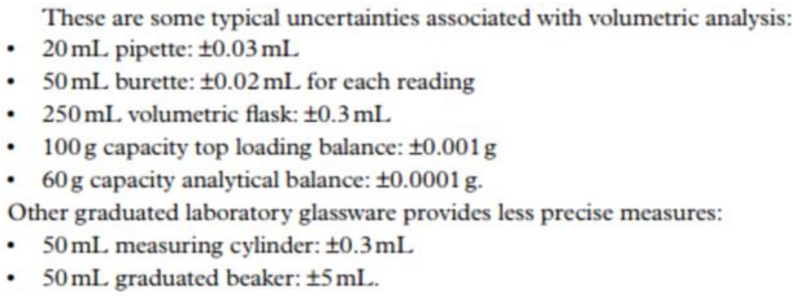
Determine the concentration of the diluted unknown substance.

Multiply the concentration of the diluted solution by the dilution factor to determine the concentration of the undiluted unknown substance.

Uncertainty:

** Uncertainty is in the course nut according to teachers, we wont explicitly get us to calculate it unlike physics, Instead you are more likely to be questioned about how it is created and so…

I included the amounts just to get a rough understanding



These are some typical uncertainties associated with volumetric analysis:

- 20 mL pipette: ±0.03 mL
- 50 mL burette: ±0.02 mL for each reading
- 250 mL volumetric flask: ±0.3 mL
- 100 g capacity top loading balance: ±0.001 g
- 60 g capacity analytical balance: ±0.0001 g.

Other graduated laboratory glassware provides less precise measures:

- 50 mL measuring cylinder: ±0.3 mL
- 50 mL graduated beaker: ±5 mL.

Precision and Accuracy:

Precise Measurement:

When the measurements of the same quantity yield are in close agreement

Accurate Measurement:

When the average of a set of measurements of quantity is very close to the true/ accepted value

Random Error:

It is normally due to the precision limitations of the measurement device and there is no regular patterns
[Are usually a result from the experimenter's inability to take the same measurement in exactly the same way to get the same number].

Causes:

- Where the meniscus sits (pipette)
- Difficulty judging between the analogue scaling on the burette (0.1mL)
- Uncertainty in the last value after the decimal place when using a balance

Systematic Error:

Produces constant bias in measurement and cannot be reduced by repeating measurements

Causes:

- Wrong indicator
- Primary standard is inflated because it was not dried
- Not precise equipment
- Faulty equipment
- Constant parallax error
- Solution is left in container

8.1/8.2 Oxidation and Reduction & Oxidising Numbers

Tuesday, 26 February 2019 6:20 PM

Redox:

'Oxidation and reduction are linked processes'

Definitions:

Oxidation:

- Gain of electrons
  e.g. $2Mg+O_2\text{->}2MgO$
  (Mg is oxidised)
- Donation of electrons
- Increases oxidation numbers

Reduction:

- Substance loses oxygen
  e.g. $Fe_2O_3+3CO\text{->}2Fe+3CO_2$
  (Fe is reduced)
- Accepts electrons
- Decreases oxidation number

Oxidising Agent (oxidant):

Is the species that is reduced

Reducing Agent (reductant):

Is the species that is oxidised

O- oxidation
I - is
L - losing

R - Reduction
I - Is
G - Gaining

Disproportionation:

When a species is oxidised
and reduced at the same time

Example:

$\overset{+1}{2H_2}\overset{-1}{O_2}{}_{(aq)} \text{ -> } \overset{+1}{2H_2}\overset{-2}{0}{}_{9(aq)}\ \overset{0}{O_2}{}_{(g)}$

🟦 Loss electrons
Therefore gets reduced
Oxidant or the oxidising agent

🟥 Gains electrons
Therefore gets oxidised
Reductant or the reducing agent

Transfer of electrons:

Redox reactions involve the transfer of electrons from one species to another

Examples:

Reaction between Zinc and hydrochloric acid

Molecular Equation:

$Zn_{(s)}+2HCl_{(aq)} \text{ -> } ZnCl_{(aq)}+H_{2\,(g)}$

Ionic Equation:

$Zn_{(s)}+2H^+\text{-> } Zn^{2+}{}_{(aq)}+H_{2\,(g)}$

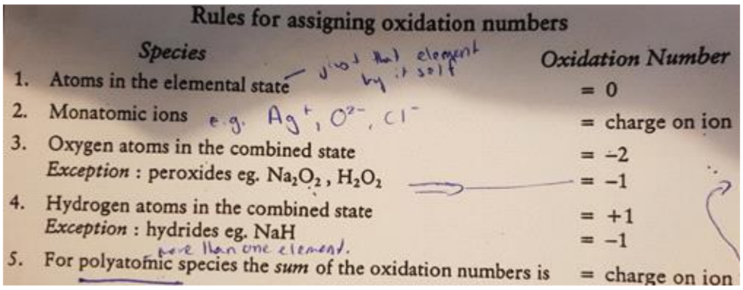
Gains
Therefore reduction

Lost electrons
Therefore oxidation

Half equations:

$Zn_{(s)}\text{-> } Zn^{2+}+2e^-$
(loss of electrons, so its oxidation)
$2e^-+2H^+{}_{(aq)}\text{->}H_{2\,(g)}$
(gains of electrons, so it is reduction)

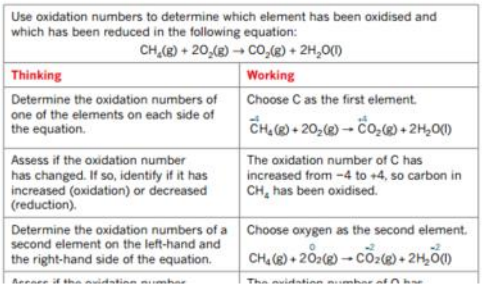
Oxidation Numbers:



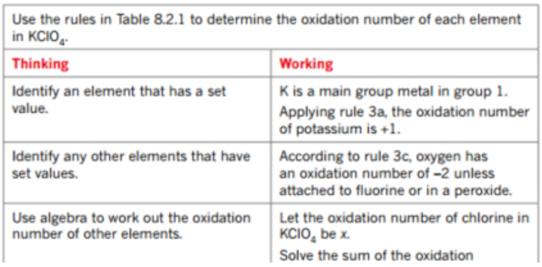
Rules for assigning oxidation numbers

	Species	Oxidation Number
1.	Atoms in the elemental state – just that element by itself	= 0
2.	Monatomic ions e.g. Ag^+, O^{2-}, Cl^-	= charge on ion
3.	Oxygen atoms in the combined state	= –2
	Exception : peroxides eg. Na_2O_2 , H_2O_2 ⇒	= –1
4.	Hydrogen atoms in the combined state	= +1
	Exception : hydrides eg. NaH	= –1
5.	For polyatomic (more than one element.) species the *sum* of the oxidation numbers is	= charge on ion

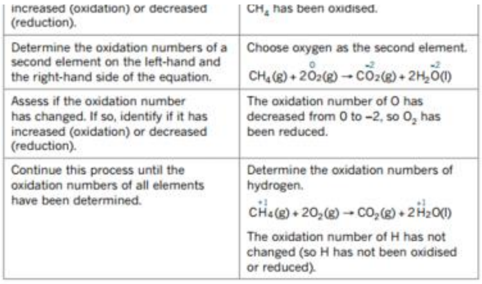
Examples:



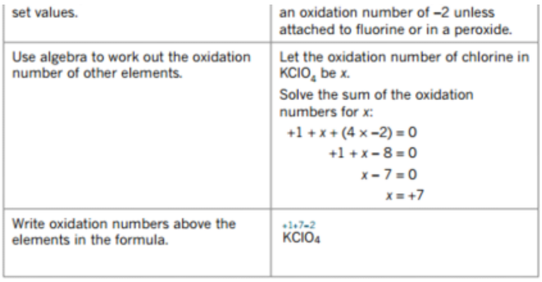
Use oxidation numbers to determine which element has been oxidised and which has been reduced in the following equation: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	
Thinking	**Working**
Determine the oxidation numbers of one of the elements on each side of the equation.	Choose C as the first element. $\overset{-4}{C}H_4(g) + 2O_2(g) \rightarrow \overset{+4}{C}O_2(g) + 2H_2O(l)$
Assess if the oxidation number has changed. If so, identify if it has increased (oxidation) or decreased (reduction).	The oxidation number of C has increased from −4 to +4, so carbon in CH_4 has been oxidised.
Determine the oxidation numbers of a second element on the left-hand and the right-hand side of the equation.	Choose oxygen as the second element. $CH_4(g) + 2\overset{0}{O_2}(g) \rightarrow C\overset{-2}{O_2}(g) + 2H_2\overset{-2}{O}(l)$
Assess if the oxidation number	The oxidation number of O has



Use the rules in Table 8.2.1 to determine the oxidation number of each element in $KClO_4$.	
Thinking	**Working**
Identify an element that has a set value.	K is a main group metal in group 1. Applying rule 3a, the oxidation number of potassium is +1.
Identify any other elements that have set values.	According to rule 3c, oxygen has an oxidation number of –2 unless attached to fluorine or in a peroxide.
Use algebra to work out the oxidation number of other elements.	Let the oxidation number of chlorine in $KClO_4$ be x. Solve the sum of the oxidation



increased (oxidation) or decreased (reduction).	CH_4 has been oxidised.
Determine the oxidation numbers of a second element on the left-hand and the right-hand side of the equation.	Choose oxygen as the second element. $CH_4(g) + 2\overset{0}{O}_2(g) \rightarrow C\overset{-2}{O}_2(g) + 2H_2\overset{-2}{O}(l)$
Assess if the oxidation number has changed. If so, identify if it has increased (oxidation) or decreased (reduction).	The oxidation number of O has decreased from 0 to −2, so O_2 has been reduced.
Continue this process until the oxidation numbers of all elements have been determined.	Determine the oxidation numbers of hydrogen. $C\overset{+1}{H}_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2\overset{+1}{H}_2O(l)$ The oxidation number of H has not changed (so H has not been oxidised or reduced).



set values.	an oxidation number of −2 unless attached to fluorine or in a peroxide.
Use algebra to work out the oxidation number of other elements.	Let the oxidation number of chlorine in $KClO_4$ be x. Solve the sum of the oxidation numbers for x: $+1 + x + (4 \times -2) = 0$ $+1 + x - 8 = 0$ $x - 7 = 0$ $x = +7$
Write oxidation numbers above the elements in the formula.	$\overset{+1}{K}\overset{+7}{Cl}\overset{-2}{O}_4$

8.3 More Complex Redox Equations:

Monday, 29 April 2019 5:43 PM

Balancing half equations with hydrogen and oxygen in acidic conditions

Steps:	**Example:** Permanganate is <u>reduced</u> to manganese ions in acidic solution
1. Balance all elements except for H and O	$MnO_4^-{}_{(aq)} \rightarrow Mn^{2+}$
2. Balance oxygen by adding H_2O	$MnO_4^-{}_{(aq)} \rightarrow Mn^{2+} + \underline{4H_2O}_{(aq)}$
3. Balance hydrogen by adding H^+	$MnO_4^-{}_{(aq)} + \underline{8H^+} \rightarrow Mn^{2+} + 4H_2O_{(aq)}$
4. Balance charge by adding electrons	$MnO_4^-{}_{(aq)} + 8H + \underline{5e^-} \rightarrow Mn^{2+} + 4H_2O_{(aq)}$

<u>Example:</u>

Write a balanced redox equation to show the reaction occurring when a strip of lead reacts vigorously when placed into a concentrated nitric acid solution. A brown gas forms as the metal dissolves to give a colourless solution

$Pb_{(s)} \rightarrow Pb^{2+}{}_{(aq)}$

$Pb_{(s)} \rightarrow Pb^{2+}{}_{(aq)} + 2e^-$

$HNO_{3(aq)} \rightarrow NO_{2\,(g)}$

$HNO_{3(aq)} + H^+ + e^- \rightarrow NO_{2\,(g)} + H_2O_{(l)}$

<u>To combine the number of electrons must be the same</u>

$HNO_{3(aq)} + H^+ + e^- \rightarrow NO_{2\,(g)} + H_2O_{(l)}$

$Pb_{(s)} \rightarrow Pb^{2+}{}_{(aq)} + 2e^-$

$2(HNO_{3(aq)} + H^+ + e^- \rightarrow NO_{2\,(g)} + H_2O_{(l)})$

$Pb_{(s)} + 2HNO_{3(aq)} + 2H^+ + 2e^- \rightarrow 2NO_{2\,(g)} + 2H_2O_{(l)}) + Pb^{2+}{}_{(aq)} + 2e^-$

$Pb_{(s)} + 2HNO_{3(aq)} + 2H^+ + \cancel{2e^-} \rightarrow 2NO_{2\,(g)} + 2H_2O_{(l)}) + Pb^{2+}{}_{(aq)} + \cancel{2e^-}$

$\underline{Pb_{(s)} + 2HNO_{3(aq)} + 2H^+ \rightarrow 2NO_{2\,(g)} + 2H_2O_{(l)}) + Pb^{2+}{}_{(aq)}}$

Write a half equation for the reduction of nitrate ions in acidic solution forming dinitrogen tetroxide gas

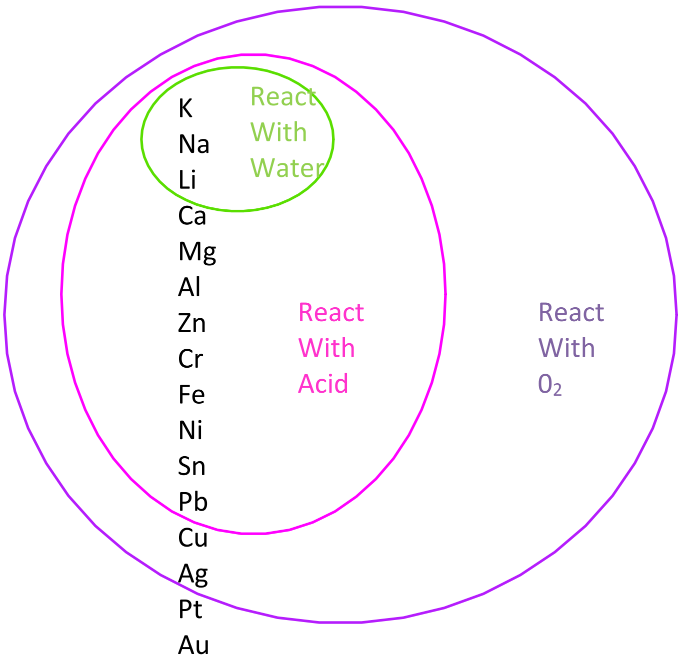
$NO_3^-{}_{(aq)} \rightarrow N_2O_{4\,(g)}$

$\underline{2}NO_3^-{}_{(aq)} \rightarrow N_2O_{4\,(g)}$

$2NO_3^-{}_{(aq)} + 4H^+{}_{(aq)} + 6e^- \rightarrow N_2O_{4\,(g)} + 2H_2O_{(l)}$

8.4 The Reactivity Series of Metals

Tuesday, 7 May 2019 9:27 AM



K
Na
Li
Ca
Mg
Al
Zn
Cr
Fe
Ni
Sn
Pb
Cu
Ag
Pt
Au

React With Water

React With Acid

React With O_2

Most Reactive

Least Reactive

In metal displacement reactions, the more reactive metals will form ions.

<u>Example:</u>

Zinc is placed in $Cu(NO_3)_{2\,(aq)}$

$Zn_{(s)} \rightarrow Zn^{+2}_{(aq)} + 2e^-$

$\underline{Cu^{+2}_{(aq)} + 2e^- \rightarrow Cu_{(s)}}$

$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

-Metals form positive ions

Halogen Reactivity:

F_2

Cl_2

Br_2

I_2

Most Reactive

Least Reactive

Displacement reactions can also occur with halogens

8.5 Competition for Electrons:

Sunday, 22 September 2019 4:32 PM

- Redox reactions involve a competition for electrons
- The species being reduced has a greater ability or potential to gain electrons than the substance being oxidised

Standard Reduction Potentials (E* values):

- Are measured using the hydrogen half-cell as a reference cell
- Apply to solutions at STP (1 mol/l concentration)
- Are a measure of the relative tendency of a species to be reduces
- Can be used to predict
    - Electrochemical cell voltages
    - Whether a particular redox reaction could occur

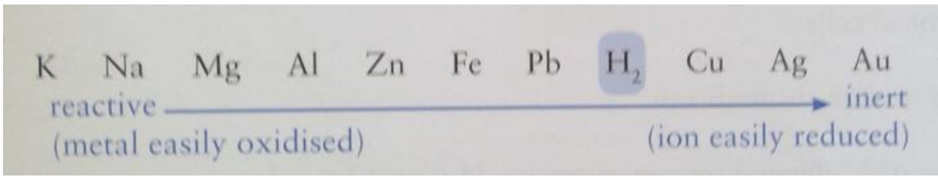
Predicting the Direction of Redox Reactions:

The E* values for the two half equations are added

- An overall +E* means the reaction may occur as written
- An overall -E* means that the reaction will not occur as written
- In general, substances listed high on the list of reduction potentials will oxidise those lower listed

Metals and Metal Ions - Displacement reactions:

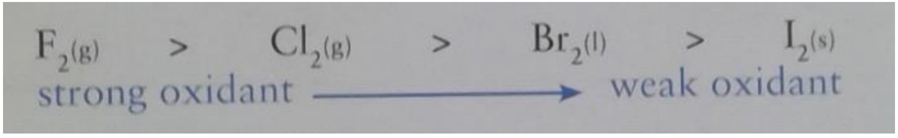
- Metal displacement reactions will occur if a more reactive metal is placed in a solution of a less reactive metal



- for examples $Mg_{(s)}$ will react with $CuSO_{4\ (aq)}$ but $Cu_{(s)}$ will not react with $MgSO_{4\ (aq)}$

Halogens and Halide ions - Displacement Reactions:

- all halogens are good oxidising agents with fluorine being the strongest



- This means that $F_{2\ (g)}$ will displace halide ions (e.g. Cl^-) of any other halogens

Limitations of the use of E* table:

- The values of E* depend on concentration
- It applies only to aqueous solutions
- The emf of a cell can depend on temperature, pressure and acidity
- The E* values give no indication of likely reaction rate

8.6 Electrochemical Cells:

Monday, 23 September 2019 11:53 AM

There are two types:

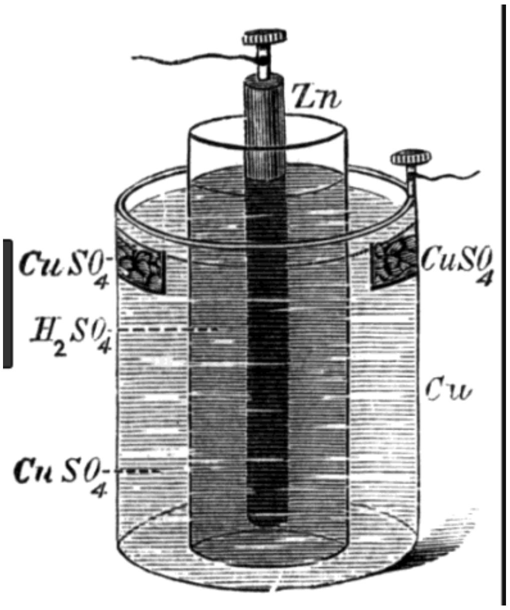
- Galvanic cells
    - Ones that power a torch or a laptop
    - Produce an electric current due to the competition for electrons between two different materials
    - Reaction is spontaneous
- Electrolytic cells
    - Used for the electrolysis of solutions
    - Require an electric current to produce a chemical reaction
    - The process is not spontaneous

Galvanic Cells:

- The reactants are separated
- Electrons are forced along an external path

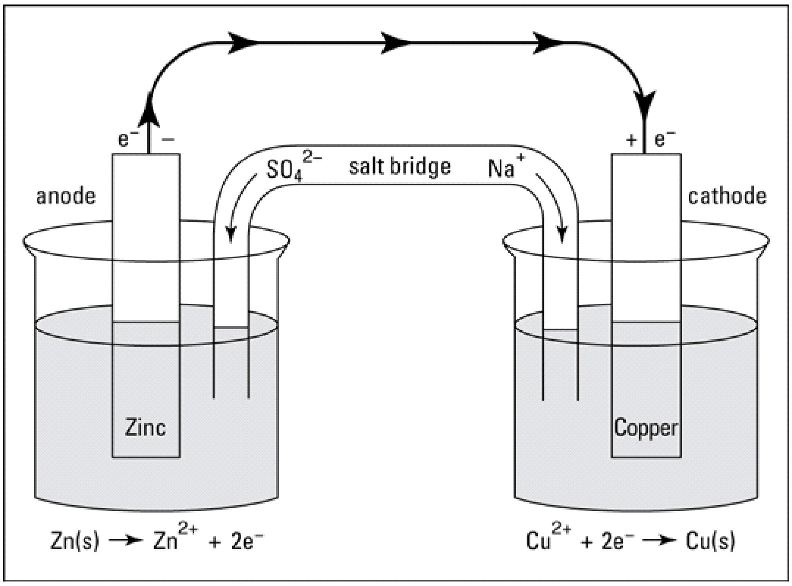
Daniel Cell:

- Consists of copper can filled with copper sulphate solution
- It which was immersed a porous pot containing a zinc rod in a zinc sulphate solution
- The porous pot prevented the solutions from mixing but allowed ions to flow between the solutions
- If the zinc and copper were connected by a wire then an electrical current would flow through the wire



- In a lab we two beakers and a salt bridge
- Zinc is oxidised and electrons flow through the external circuit to the copper
    - Copper ions in the Cu/Cu^{2+} cell are reduced
- The salt bridge
    - Filter paper soaked in ammonium nitrate solution
    - Allows ions to migrate between the two half cells, so that each cell remains electrically neutral
    - Also allows the ions to flow to complete the circuit
- The cell will stop working when:
    - Reactants have been used

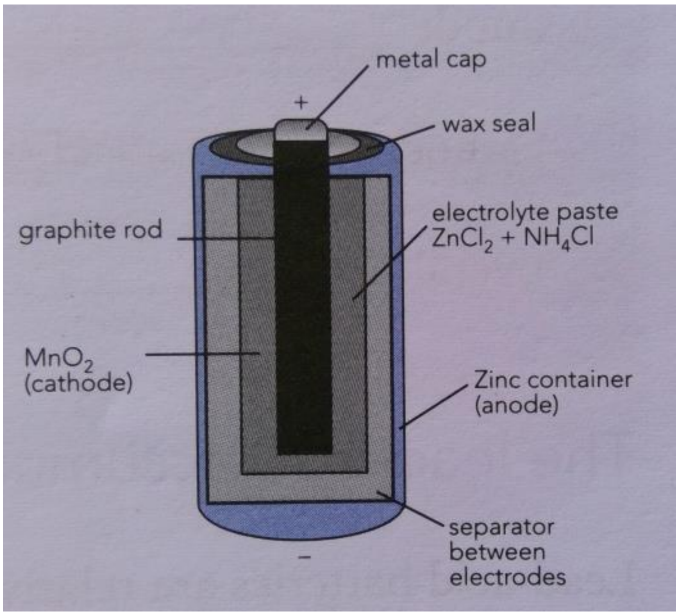
- Chemical equilibrium has been reached



The Dry Cell: (Leclanche Cell):

- Inexpensive
- Quite portable
- Uses e.g. torched, portable radio and cameras
- Consists of:
    - An outer case of zinc (anode)
    - A carbon rod surrounded by a paste of $MnO_{2\,(s)}$ (cathode)
    - An electrolyte paste of NH_4Cl and $ZnCl_2$

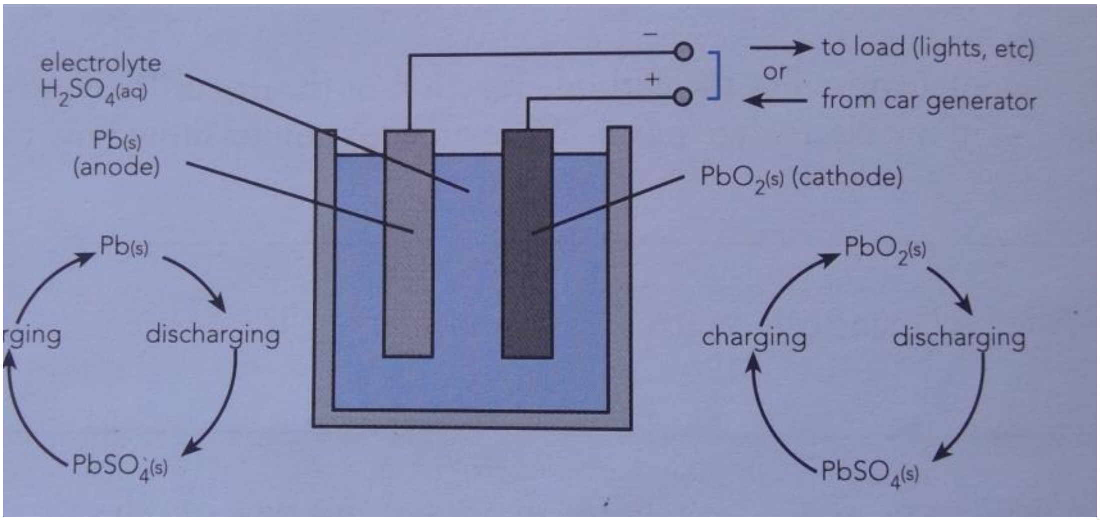
Anode reaction: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$
Cathode reaction: $2MnO_{2\,(s)} + 2H^+_{(g)} + 2e^- \rightarrow Mn_2O_{3\,(s)} + H_2O_{(l)}$



Lead-Acid Accumulator:

- Relatively inexpensive and can store large quantities of charge
- They can be recharged
- They are bulky

- Used for cards
- Important feature:
    - Electrode
        - Anode - spongy lead- large surface
        - Cathode - lead (IV) oxide packed on a metal grid
    - Electrolyte is concentrated sulfuric acid
    - A typical car battery consists of 6 cells placed in series
    - It can be recharged (**secondary cell**)
    - The density of the electrolyte indicates the state of charge



The Fuel Cell:

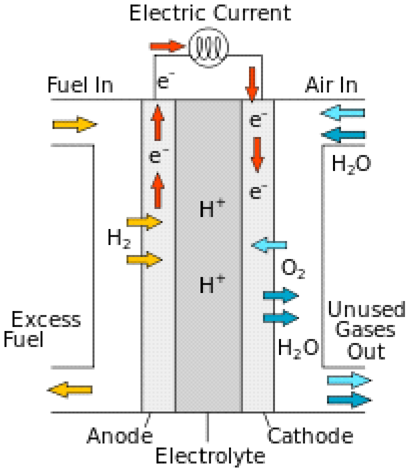
- It does not store the reactants or products
- Converts the energy of a chemical reaction directly and continuously into electrical energy

Important Features:

- Electrodes consist of porous platinum or graphite
- Electrolytes can be either basic or acidic
- Reactants usually gaseous
- They supply electricity as reactants are fed in

Advantage:

- Highly efficient
- Can generate electricity for a long time



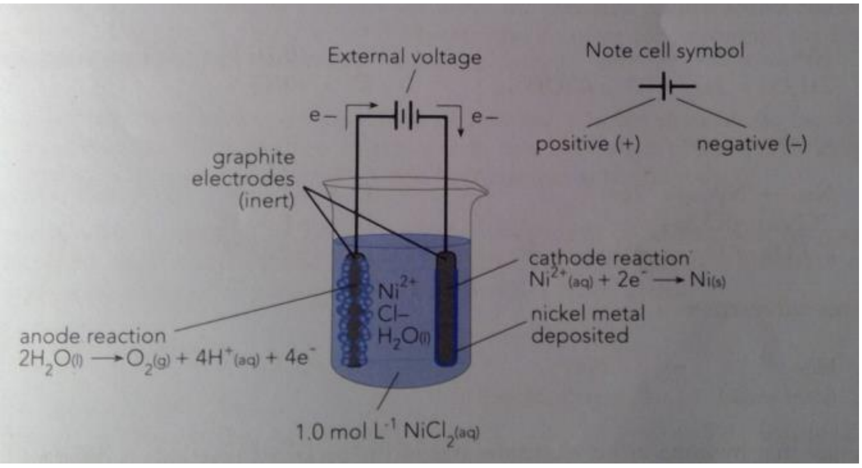
8.7 Electrolysis:

Tuesday, 24 September 2019 9:02 PM

The chemical changed when an electrical current is passed through a molten substance or solution

- It is a forced reaction
    - Not spontaneous
- By applying a voltage, electrical energy is converted to chemical energy

Electrolytic Cells:



Predicting Electrode Reactions:

- For each electrode we need to consider all substances present and whether the electrode is inert or reactive
- We use the E^O value to predict the reaction
    - This E* value is assuming the reactants are in 1.0 M solution

Considering the above reaction:

Possible Cathode reactions (reduction):
$NI^{2+}_{(aq)} + 2e^- \rightarrow NI_{(s)}$ E*=-0.24V Therefore this is the reduction reaction
$2H_2O_{(l)} + 2e^- \rightarrow N_{2\,(g)} + 2OH^-_{(aq)}$ E*= -0.83V

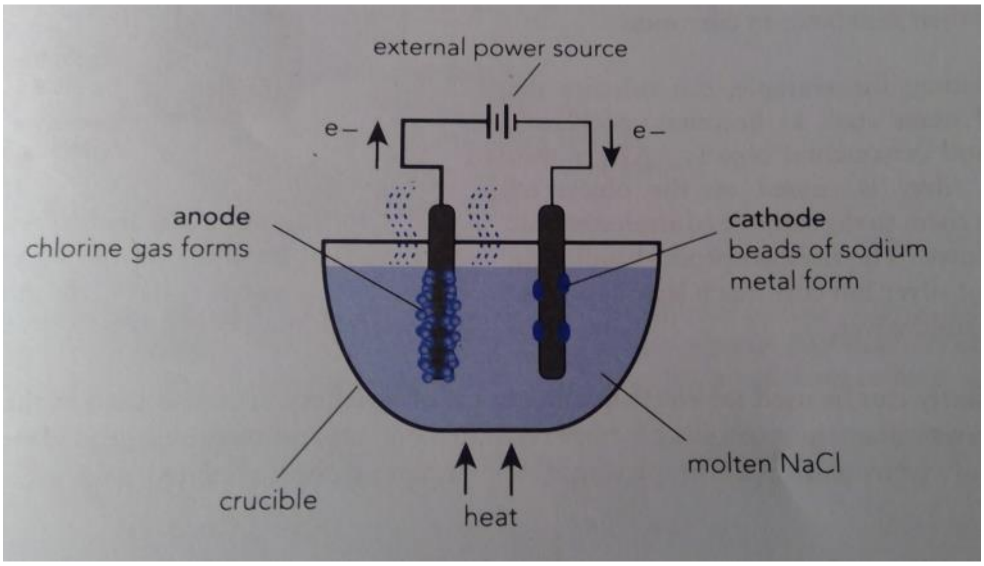
Possible anode reactions (oxidation):
$2Cl^-_{(aq)} \rightarrow Cl_{2\,(g)} + 2e^-$ E*=-1.36V
$2H_2O_{(l)} \rightarrow O_{2\,(g)} + 4H^+_{(aq)} + 4e^-$ E*= -1.23V Therefore this reaction is favoured

Note:

- The least negative reaction is favoured
- Graphite electrodes can be considered inert and do not react

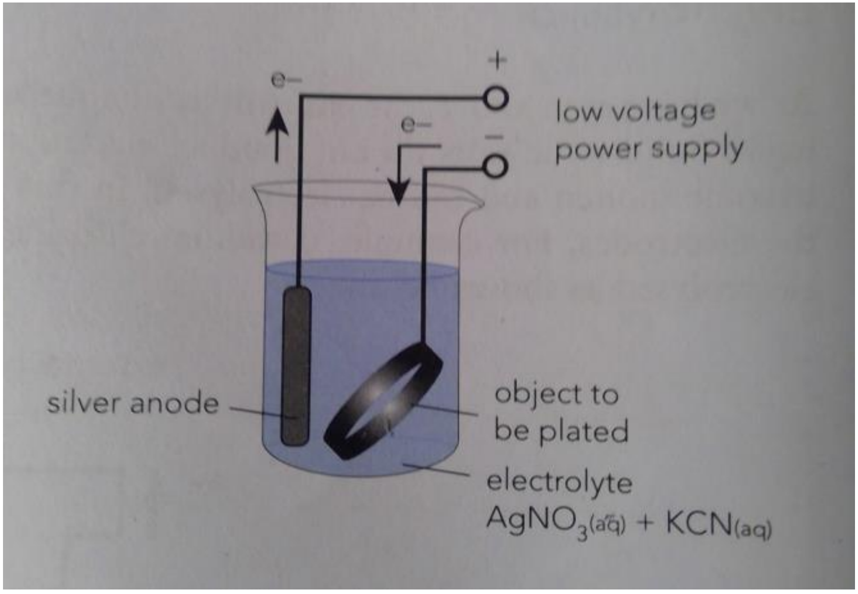
Electrolysis of Molten Salts:

- Solid ionic salts do not conduct electricity
- When heated, to a molten state and can be electrolysed



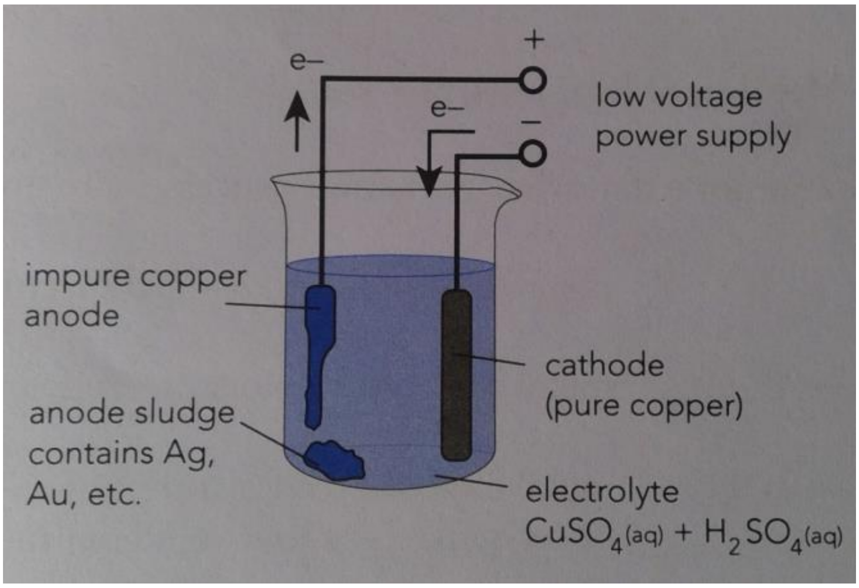
Electroplating:

- Improves appearance of material and their resistance to corrosion
- A very thin layer of metal is coated on an object
    - By placing the object in the cathode
- It will look like the coated material but would be much cheaper



Electrolytic Refining of Copper:

- Blister copper is refined
- The copper and other reactive metals within the anode are oxidised
    - Become part of the electrolyte solution
- The cost of this is offset by the recovery of valuable materials (e.g. gold)
- They use a low voltage
    - It ensures that only copper is deposited in the cathode
    - The less reactive metal (e.g. gold) are left in the sludge


e–
+
e–
–
low voltage
power supply
impure copper
anode
cathode
(pure copper)
anode sludge
contains Ag,
Au, etc.
electrolyte
$CuSO_{4(aq)} + H_2SO_{4(aq)}$

8.8 Corrosion of Metals:

Tuesday, 24 September 2019 10:02 PM

Corrosion is an electrochemical process that occurs when metals are oxidised by substances in their environment

Anode (metal oxidise):

- Metal solid becomes ions

Cathode (reduction):

$2H^+ + 2e^- \rightarrow H_2$	Metal exposed to moist, acidic conditions
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	Metal exposed to moisture and oxygen (very common)
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	Metal exposed to moisture but a low concentration of oxygen

Oxide Layer:

- When some metals oxidise they form an oxide later
  - It is tough and protective
  - It limits the ability of the oxidising agent to come in contact with the metal
  - e.g. Aluminium

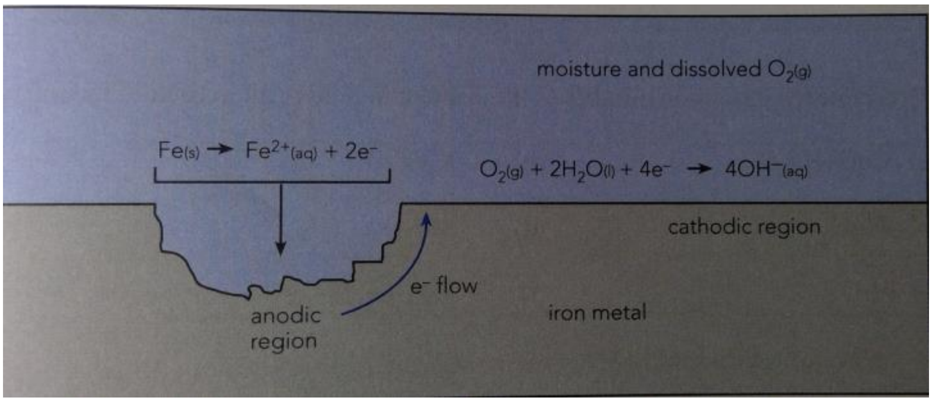
Rust - A Special Example of Corrosion

Oxidation of iron by the action of oxygen and water vapour in the air

- The initial oxidation of iron
  $Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$ (anodic reaction)
  $O_{2\,(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-$ (cathodic reaction)

- The further oxidation of the $Fe(OH)_2$ formed
  $4Fe(OH)_{2\,(s)} + 2H_2O_{(l)} + O_{2\,(g)} \rightarrow 4Fe(OH)_{3\,(s)}$
  Pale green red brown

- The partial dehydration of the $Fe(OH)_{3\,(s)}$ to rust
  $2Fe(OH)_3 \rightarrow Fe_2O_3.H_2O_{(s)} + 2H_2O_{(l)}$



- Areas of stress in the iron become anodic
- Areas of high oxygen concentration become cathodic
- Electrons flow thought the metal from the anode to the cathode
- Moisture acts as the electrolyte

Corrosion Prevention:

- Excluding air and/or water from the metal surface
  - Protecting the iron surface with paint, grease, plastic

  - Plating the iron surface with metals such as chromium or metallic tin
- Using a sacrificial anode (more reactive metal) by
  - Galvanising iron with zinc- zinc corrodes in preference
  - Attaching magnesium and aluminium to ships
- Using cathodic protection
  - So that jetties are rendered negative by a low DC voltage
  - The anode may be made of scrap iron

11.1

Wednesday, 12 June 2019 7:46 PM

Organic Compounds:

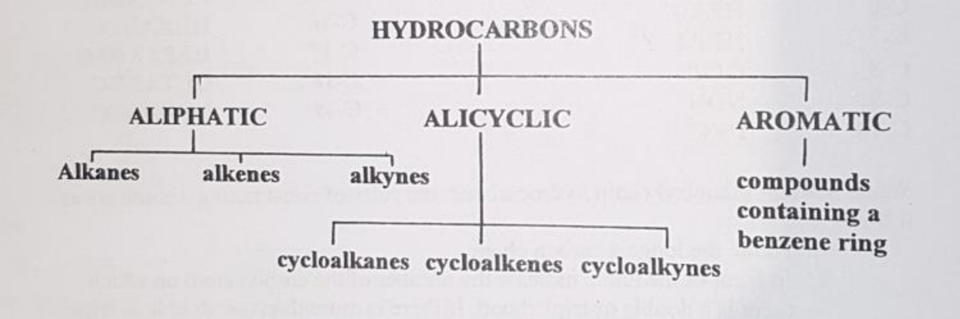
- Are derived from living materials
- Includes sugars, fossils, fuels, oils, plastics… (all are organic compounds)

Hydrocarbons:

Are compounds that consist of only carbon and hydrogen

- Made up of carbon chains or rings
- Have hydrogen atoms **covalently** bonded to the carbon atoms
- Each carbon has 4 valence electrons therefore it can form 4 covalent bonds with other carbons or hydrogens.

They can be classified as:



Alkanes:

Are hydrocarbons that contain only C-C (single bond)

- Their general formula is $\mathbf{C_nH_{2n+2}}$
- Their names end with **ane**
- Known as saturated hydrocarbons

Alkenes:

Are hydrocarbons that contain one C=C (double bond).

- Their general formula is $\mathbf{C_nH_{2n}}$
- Their names end with **ene**
- They are unsaturated hydrocarbons

Alkynes:

Are hydrocarbons containing one C≡C (triple bond)

- Their general formula is $\mathbf{C_nH_{2n-2}}$
- Their names end with **yne**
- They are unsaturated hydrocarbons

Cycloalkanes:

Ring compounds containing three or more carbon atoms

- Their general formula is $\mathbf{C_nH_{2n}}$
- Their name starts with **cyclo-** and ends with **ane**

Cycloalkenes:

Ring compounds containing three or more carbon atoms and a double bond

- Their general formula is **C_nH_{2n-2}**
- Their name begins with **cyclo-** and ends with **ene**

Cycloalkynes:

Ring compounds containing four or more carbon atoms and a triple bond

- Their general formula is **C_nH_{2n-4}**
- Their name stays with **cyclo-** and ends with **yne**

Aromatic Compounds:

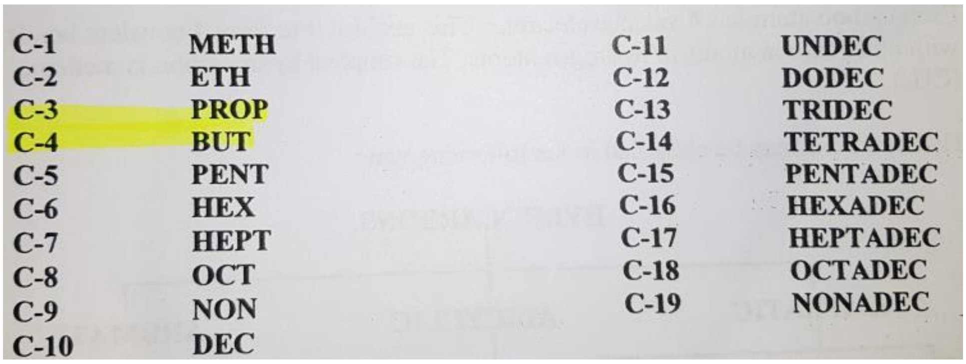
Contains a benzene ring

- If the benzene ring forms the main part of the compound its name begins with **benz-**
- If the benzene ring is a substitute group on a larger hydrocarbon its name begins with **benz-** (the substitute)

Naming Hydrocarbons:

The systematic IUPAC naming method is used

The names of compounds with 1-19 carbon atoms will begin as follows:



C-1	**METH**	**C-11**	**UNDEC**
C-2	**ETH**	**C-12**	**DODEC**
C-3	**PROP**	**C-13**	**TRIDEC**
C-4	**BUT**	**C-14**	**TETRADEC**
C-5	**PENT**	**C-15**	**PENTADEC**
C-6	**HEX**	**C-16**	**HEXADEC**
C-7	**HEPT**	**C-17**	**HEPTADEC**
C-8	**OCT**	**C-18**	**OCTADEC**
C-9	**NON**	**C-19**	**NONADEC**
C-10	**DEC**		

Steps:

1. Name the longest carbon chain
2. In front of the name indicate the number of carbon atom on which there is a double or triple bond
3. Name the substituent groups (e.g. methyl…) indicating their position on the carbon chain by a number

Isomers:

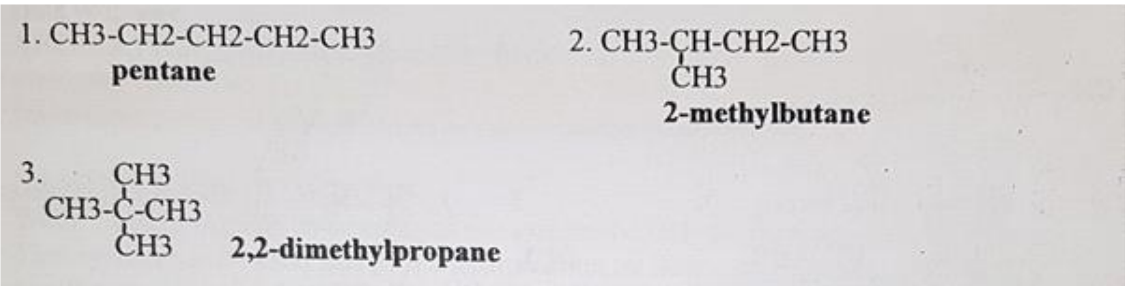
Are compounds that have the same molecular formula but a different structural formula.\

- They might be **structural** or **geometric**

Structural Isomers:

Are isomers in which the length of the carbon chain differs

e.g. the isomers of pentane (C_5H_{12}): are



1. $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$

pentane

2. $CH_3\text{-}\underset{CH_3}{CH}\text{-}CH_2\text{-}CH_3$

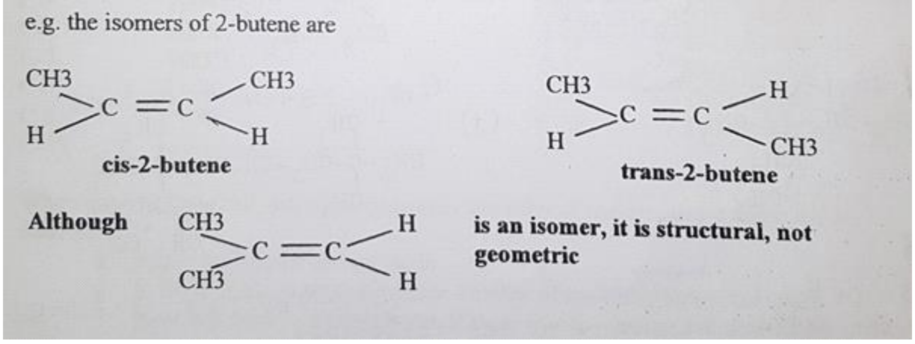
2-methylbutane

3. $CH_3\text{-}\underset{CH_3}{\overset{CH_3}{C}}\text{-}CH_3$ **2,2-dimethylpropane**

Geomatical Isomers:

Are some isomers of alkenes.

- The structure around the carbon atom in a double bond is a triangular planar
  - Double bonds are rigid and the carbon atoms cannot rotate
  - The substituent groups on the carbon atoms od the double bond are therefore in fixed positions.
- Depending on whether substituent groups are on the same side or different sides of the double bond, geometric isomers are formed .
- These isomers will have different physical and chemical properties



e.g. the isomers of 2-butene are

cis-2-butene

trans-2-butene

Although **is an isomer, it is structural, not geometric**

13.1 Diversity of Carbon Compounds

Wednesday, 17 July 2019 11:30 AM

Homologous series:

Have:

- Similar structures
- Similar chemical properties
- The same general formula
- A pattern to their physical properties

Alkanes and alkenes are the most common hydrocarbon homologous series. The chain gros by the addition of a -CH_2- unit.

Representing Organic molecules:

- Molecular formulae
- Structural formulae
- Condensed (or semi structural) formulae

Molecular formulae:

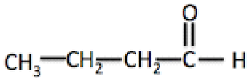
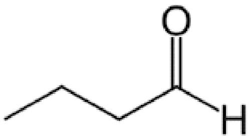
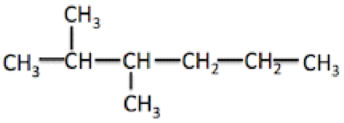
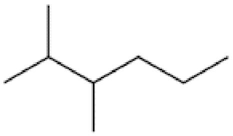
- Indicate the number and type of each atoms of each elements present in the molecule
- Do not indicate how atoms are arranged
- e.g. C_2H_6O

Structural Formula:

- Show the relative location of atoms relative to one in another in a molecule, as well as the number and location of covalent bonds.

Condensed Formula:

- Is used to indicate the connection in the structure of a compound without the three dimensional arrangements of atoms.
- The carbon atoms in the chain, and the atoms attached to each of them are listed in order that they appear in the structural formula
- Groups of atoms that form branches in a molecule are written in brackets after the attached carbon atom.
- e.g.

Compound	Condensed Structural Formula	Skeletal Structural Formula
C_4H_8O Butanal	 $CH_3-CH_2-CH_2-\overset{O}{\overset{\|}{C}}-H$	
C_8H_{18} 2,3-dimethylhexane	 $CH_3-\overset{CH_3}{\overset{\mid}{C}H}-\underset{CH_3}{\underset{\mid}{C}H}-CH_2-CH_2-CH_3$	

Alkanes:

Should remember from last year

Alkenes:

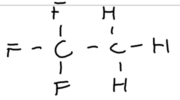
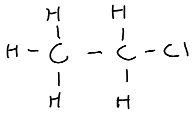
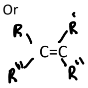
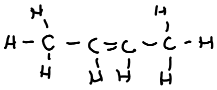
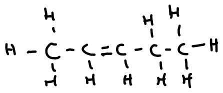
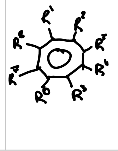
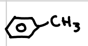
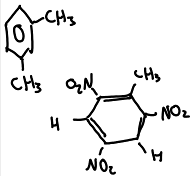
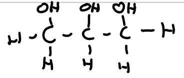
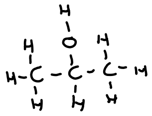
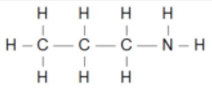
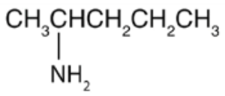
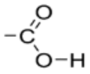
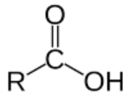
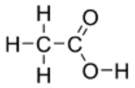
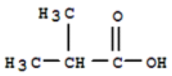
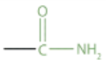
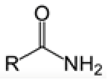
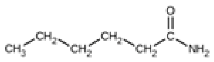
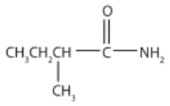
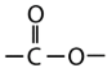
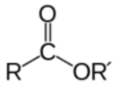
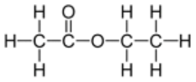
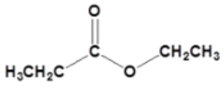
Remember from last year

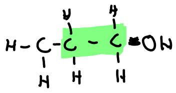
Benzene ring:

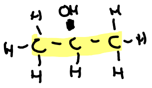
- Draw as a hexagon with the circle in the centre
- The electrons that make up the double bond are not in fixed positions; they are delocalised and can move around the ring
- It is quite stable compared to other unsaturated hydrocarbons

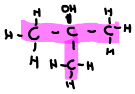
13.2 Functional Groups

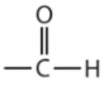
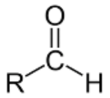
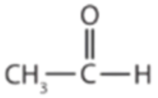
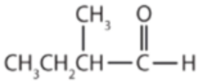
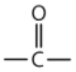
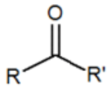
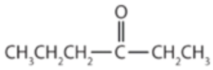
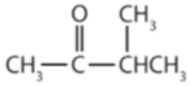
Wednesday, 17 July 2019 12:36 PM

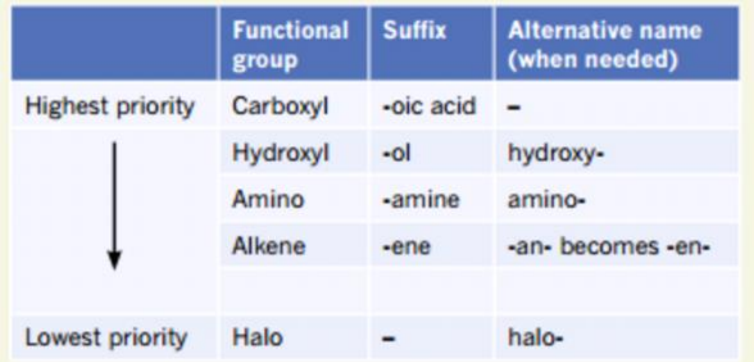
Class	Suffix	Functional Group	General Formula	Example	Name of Example	Other Facts
haloalkane	Prefix: (…oro) Suffix: …ane	Halogens: • F • Cl • Br • I	R-X e.g. CH_3-Cl	 	2-Chloro-1,1-difluoroethane Chloroethane	
alkene	ene	C=C	C_nH_{2n} Or 	 	Propene Trans-but-2-ene	Can have geometric isomers: • Cis (same side) • Trans (opposite) The double bond gets preferred
aromatic	Suffix: …Benzene Prefix: Phenyl… (if added to a more complex group)	Benzene	 or 	 	Methyl Benzene 1,3-dimethyl-benzeme 2-methyl-1,3,5-dinitrobenzeme	Contains benzene
alcohol	…ol Prefix: Hyroxy… (when in more complex group)	-OH (hydroxyl)	R-OH Number from end Closest to OH group	 	Propane-1,2-diol Or 1,2-propandiol Propan-2-ol	Start from end that is closest to -OH More than one OH then di, tri… **Primary Alcohol:** Only has 1 C attached to the C bonded to OH **Secondary Alcohol:** Two Cs attached to C bonded to OH **Tertiary:** Three Cs attached to C bonded to OH
amine	Amine Prefix: Amino (if more complex group)	$-NH_2$ (amino)	R-NH_2	  $CH_3\underset{\substack{\vert \\ NH_2}}{CH}CH_2CH_2CH_3$	Propan-amine 3-pent-2-amine	• Number from closest end to the NH_2 • If not first, then state it • e.g. propane-2-amine • Primary is 1 C connected to N • (secondary and so on are not in the syllabus)
Carboxylic acid	-oic acid	 (carboxylic group)		 	Ethanoic acid 2-methyl-propanoic acid	• Number from end closest to the acid
amide	-amide			 	Hexamide butanamide	• Like with amines, primary amides have only one C attached to N… • Number from end with primary amide on it
ester	Akyl-oate		 O	 	Ethyl-ethanoate Ethyl-propanoate	• Esters are made by a carbonic acid and alcohol • The first part of the name comes from the alcohol and the second part from carbonic acid







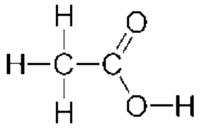
aldehyde	-al	(=O must be on first C in chain) 		 $CH_3-\overset{\overset{O}{\|}}{C}-H$  $CH_3CH_2\overset{\overset{CH_3}{\vert}}{C}H-\overset{\overset{O}{\|}}{C}-H$	Ethanal Ethylbutananal	
ketone	-one	(=O is on any C except first or last one) 		 $CH_3CH_2CH_2-\overset{\overset{O}{\|}}{C}-CH_2CH_3$  $CH_3-\overset{\overset{O}{\|}}{C}-\overset{\overset{CH_3}{\vert}}{C}HCH_3$	Hexan-3-one 4-methylbutan-2-one	• Number from the end closest to =O group • Number position of =O



	Functional group	Suffix	Alternative name (when needed)
Highest priority	Carboxyl	-oic acid	–
↓	Hydroxyl	-ol	hydroxy-
	Amino	-amine	amino-
	Alkene	-ene	-an- becomes -en-
Lowest priority	Halo	–	halo-

Questions:

"Draw and name an isomer of $HCOOCH_3$"
Ethanoic acid:



13.3 Properties of Organic Compounds

Wednesday, 17 July 2019 1:37 PM

Physical Properties of Alkanes and Alkenes:

Boiling Point of Alkanes/ Alkenes:

- Alkanes are non-polar
  - Only intermolecular force is dispersion
- As the chain length increases the increase in dispersion forces
  - Because of the increased strength in temporary dipoles within the molecule
- Shape also affects
  - When straighter, more molecules can fit more closely together
  - Therefore giving a greater strength

** alkenes have a relatively smaller boiling point than alkanes

Solubility in Water:

- non polar therefore insoluble in water
  - Water is held together by hydrogen bonds
  - The weak dispersion forces between water molecules and hydrocarbon molecules are not strong enough to overcome the strong attraction between water molecules

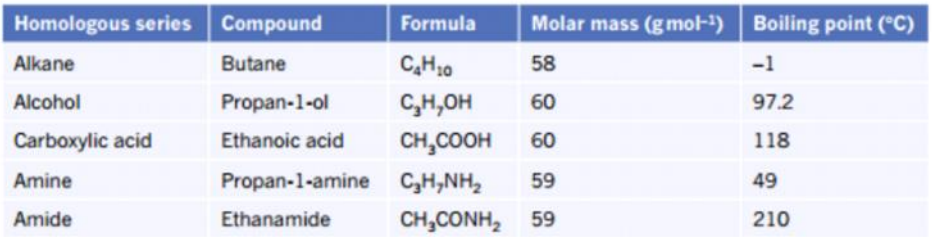
Solubility in Organic Solvents:

- Mix with other non-polar liquids
  - The forces of attraction between the molecule of these liquids are also weak dispersion forces of similar strength to the alkane-alkane forces of attraction.
- Therefore these liquids are miscible
  - (they are soluble in each other)

Physical Properties of Alcohols, Carboxylic acid, Amines and Amides:

All these substances can form hydrogen bonding and why they are placed together

Boiling Point:



Homologous series	Compound	Formula	Molar mass (g mol⁻¹)	Boiling point (°C)
Alkane	Butane	C_4H_{10}	58	–1
Alcohol	Propan-1-ol	C_3H_7OH	60	97.2
Carboxylic acid	Ethanoic acid	CH_3COOH	60	118
Amine	Propan-1-amine	$C_3H_7NH_2$	59	49
Amide	Ethanamide	CH_3CONH_2	59	210

Boiling Points of Alcohols:

- The higher boiling point are due to the presence of hydrogen bonds between neighbouring alcohol molecules
- Oxygen has a greater electronegativity than hydrogen
  - Therefore it is a polar bond

Boiling Points of Amines and Amides:

- Presence of highly polar nitrogen-hydrogen bonds means that they can also form hydrogen bonding
- In amines the hydrogen bonding forms between the non-bonding pair of electrons on the electronegative nitrogen atom and the partially positive hydrogen atom
- In amides, hydrogen bonding occurs between the non-bonding electron pairs on the oxygen atom of one of the molecule and the partially positive hydrogen atom on a neighbouring

molecule.

Boiling Point of Carboxylic acid:

- undergoes hydrogen bonding as well
- But unlike the other they can form **dimmers**
    - 2 hydrogen bonds form between molecules
    - A dimmer is stable with a molecular mass that is double that of a single carboxylic acid
- The larger mass creates larger dispersion forces
- Therefore a higher boiling point when compared to other organic
- molecules of similar size

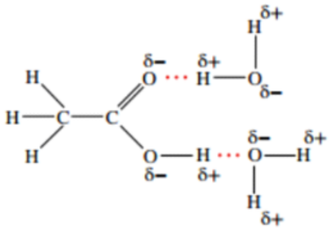
Effect of chain length on boiling point:

- Boiling point increases as molar mass increases
    - As the length of the hydrocarbon increases the molar mass increases
    - Therefore the dispersion forces become strong
- The 3-d structure of molecules can also affect the boiling point
    - For example with primary, secondary and tertiary alcohols
        - The hydroxyl group becomes increasingly 'crowded' from the primary alcohol to the tertiary isomers.
        - The presence of the alkyl groups restricts a molecule's ability to form hydrogen bonds with other molecules

Solubility:

Solubility in Water:

- Small alcohols and amines can dissolve well in water because hydrogen bonds can form between the polar functional groups of the molecules and adjacent water molecules
- When amines interact with water, hydrogen bonds form between the lone pair of electrons on the nitrogen and the partial positive hydrogen of a water molecule
- Amides and carboxylic acid molecules with short carbon chains are also soluble in water. When carboxylic acids dissolve in water, hydrogen bonding occurs between the water molecules and both the C=O group and the -OH group
    - Making these compound more soluble in water than alcohols



Solubility and Chain Length:

- Decreases as chain length increases
- The longer chain disrupt the hydrogen bonding between water molecules
- As the chain increases the non-polar nature of the molecule also increases and the alcohol becomes less soluble

Properties and Uses of Alcohols:

- Can be used as fuel or mixed with petrol
- Boiling point is quite high
- And due to strong forces, kept as a liquid in room temperature

Properties and Uses of Carboxylic Acids:

- Are organic acids
- They give the sour taste to lemons and vinegar or the sting when an ant bites you

- They are weak acids
- When food goes bad it is produced

Boiling Points of Aldehydes, Ketones and Esters:

- Forms polar bonds
  - Due to the oxygen being more electronegative than the carbon
- Therefore having a permanent dipole
- And so dipole-dipole forces can occur

Solubility in Water:

- They are soluble in water but to a lesser extent
  - Due to them forming dipole-dipole forces instead of hydrogen bonding

Properties and Uses of Esters:

- Have a characteristic sweet, fruity odour
- Occur naturally in fruits and flowers
- They are polar however how no free hydroxyl groups, so they cannot form hydrogen bonds with each other
  - Therefore they have a low boiling point compared to the others

13.4 Isomer Overview

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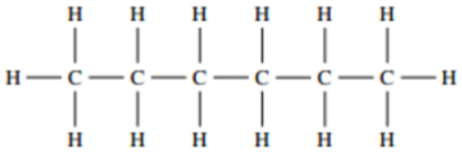
Are molecules that contain the same number and type of atoms, arranged in different ways.
They have the same molecular formula, but they have different physical and chemical properties and so behave differently.

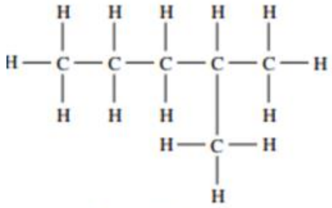
There are two main types of isomers:
- Structural (positional and chain) isomers
- Geometric (cis-trans) isomers

Chain Isomers:

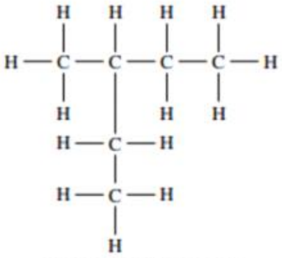
- Form because of the branching that is possible in the carbon chains that for the backbone of any large organic molecule
- e.g. hexane



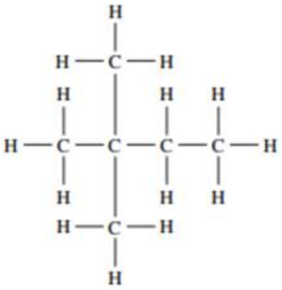
Three isomers of hexane are shown below. Each isomer has a different name that represents its exact molecular structure.



$CH_3CH_2CH_2CH(CH_3)_2$



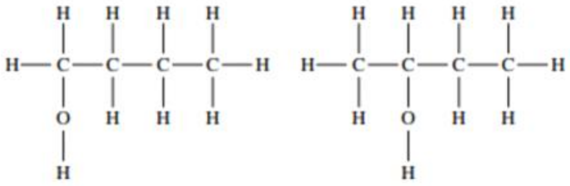
$CH_3CH_2CH(CH_3)CH_2CH_3$



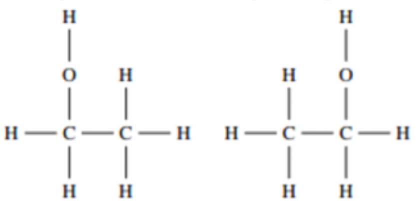
$(CH_3)_3CCH_2CH_3$

Position Isomers:

- Occur in organic molecules that contain functional groups
- Two molecules with the same with the sane carbon chain and the same functional group, but the functional group in a different location in the molecule
- Each positional isomer is given a different name
  - This does include alkenes
- e.g.



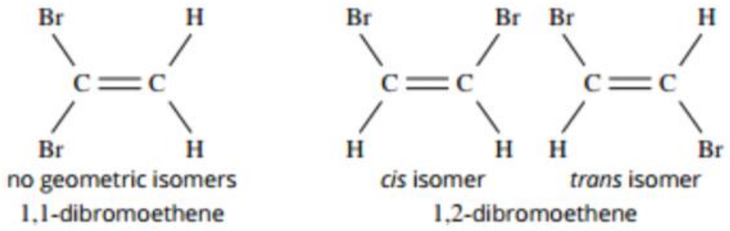
- However the chain has to be long enough
  - For example these are not isomer…



Geometric (cis-trans) Isomers:

Occur when there is restricted rotation somewhere in a molecule

- Can only occur about a carbon-carbon double bond or within a ring
- In a single bond, atoms can rotate freely around the single bond
- In a double bond, because of the arrangement of the electrons, groups attached to carbons on either side are unable to rotate freely
- Cis-trans isomers can occur when there are two different groups attached to each carbon involved in the double bond.
    - If the groups are on the same side, the isomer is called the cis-isomer
    - If the groups are on opposite sides, the isomer is called the trans-isomer

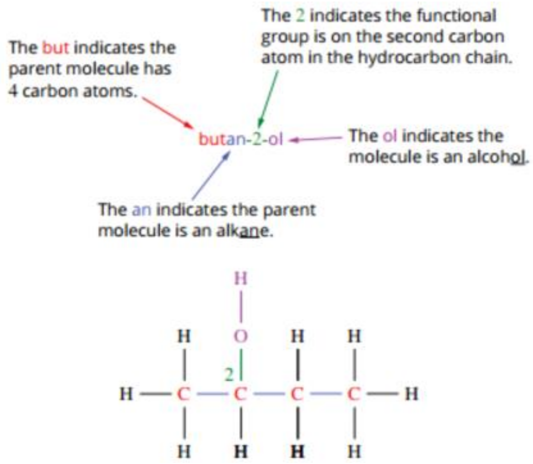


13.5 IUPAC Nomenclature Overview:

Wednesday, 17 July 2019 3:57 PM

- all organic molecules can be thought as being derived from a hydrocarbon parent molecule, which provides the basis for the name of the molecule, Part of the IUPAC name reflects which alkane is the parent molecule
- It also indicated which functional groups are present in the molecule by adding a suffix to the end of the name or a prefix to the beginning.
  - The position of functional groups are indicated by numbers.

e.g.

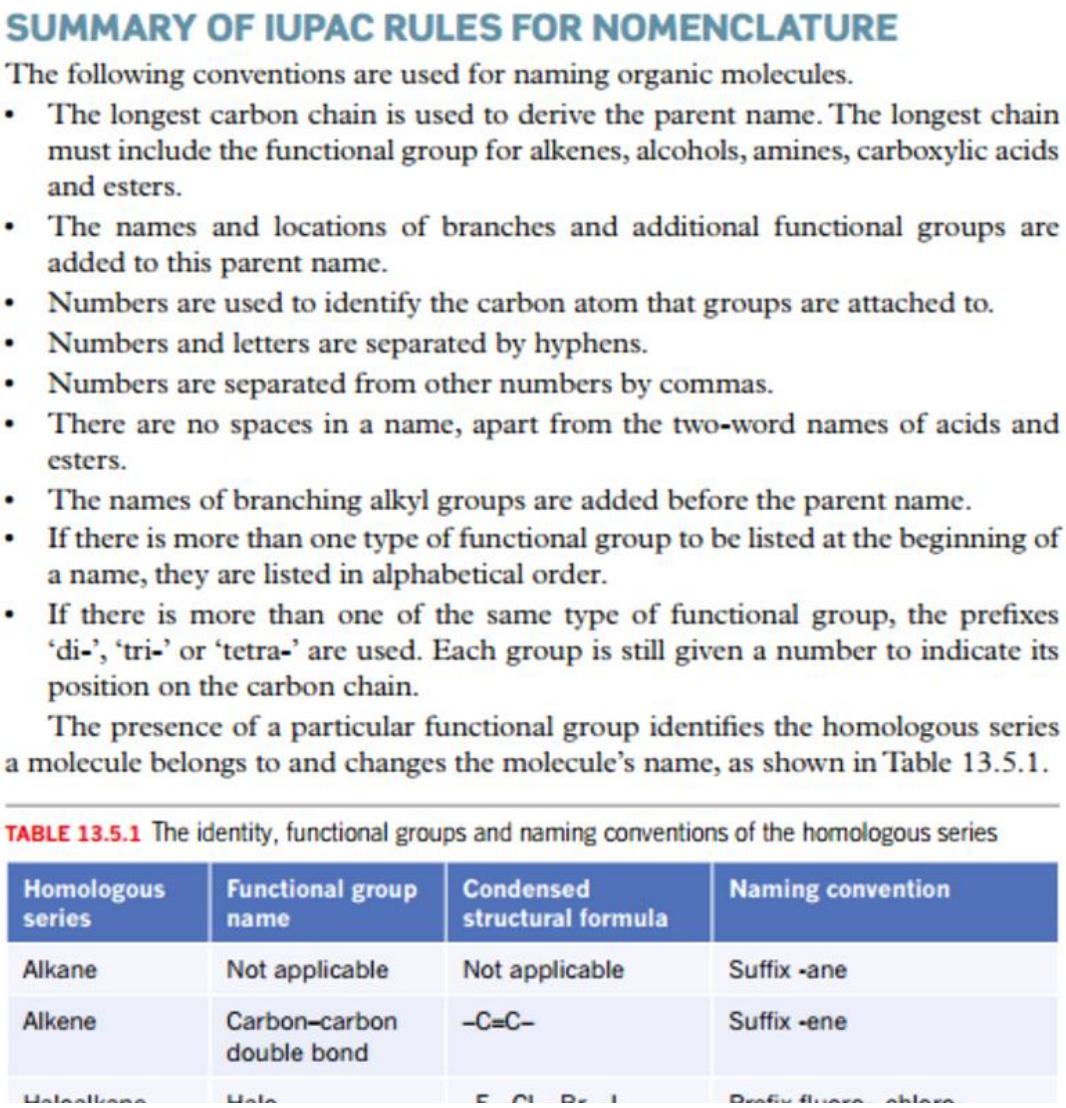


The but indicates the parent molecule has 4 carbon atoms.

The 2 indicates the functional group is on the second carbon atom in the hydrocarbon chain.

The ol indicates the molecule is an alcohol.

The an indicates the parent molecule is an alkane.



SUMMARY OF IUPAC RULES FOR NOMENCLATURE

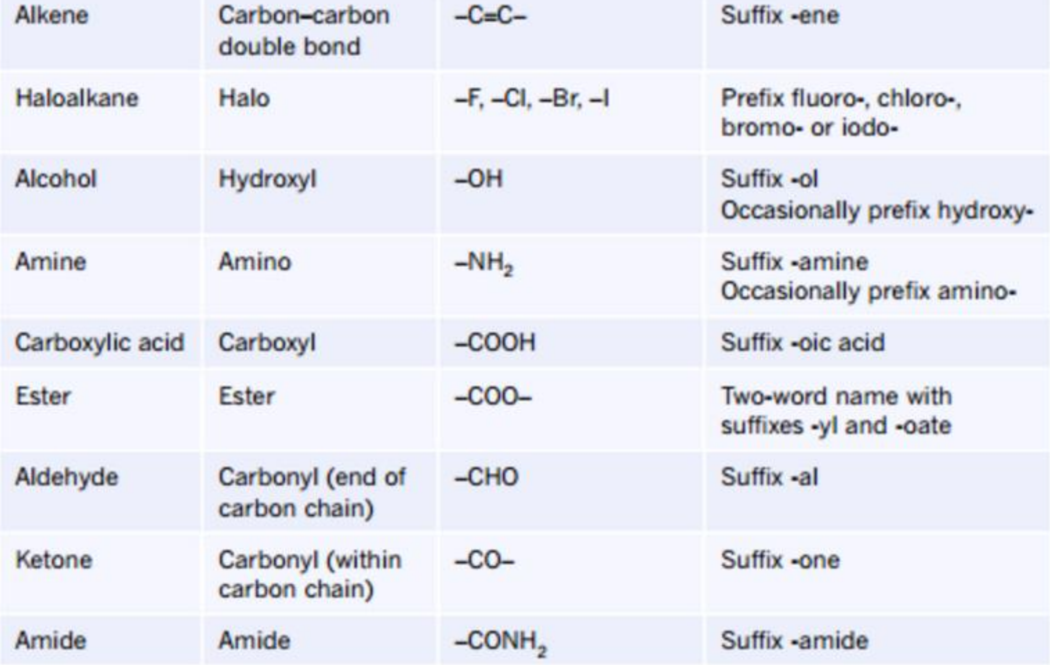
The following conventions are used for naming organic molecules.

- The longest carbon chain is used to derive the parent name. The longest chain must include the functional group for alkenes, alcohols, amines, carboxylic acids and esters.
- The names and locations of branches and additional functional groups are added to this parent name.
- Numbers are used to identify the carbon atom that groups are attached to.
- Numbers and letters are separated by hyphens.
- Numbers are separated from other numbers by commas.
- There are no spaces in a name, apart from the two-word names of acids and esters.
- The names of branching alkyl groups are added before the parent name.
- If there is more than one type of functional group to be listed at the beginning of a name, they are listed in alphabetical order.
- If there is more than one of the same type of functional group, the prefixes 'di-', 'tri-' or 'tetra-' are used. Each group is still given a number to indicate its position on the carbon chain.

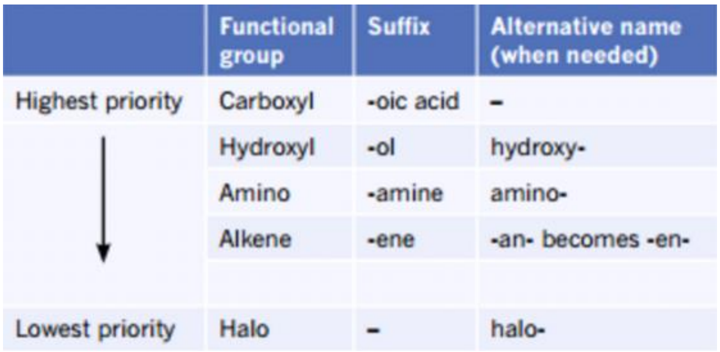
The presence of a particular functional group identifies the homologous series a molecule belongs to and changes the molecule's name, as shown in Table 13.5.1.

TABLE 13.5.1 The identity, functional groups and naming conventions of the homologous series

Homologous series	Functional group name	Condensed structural formula	Naming convention
Alkane	Not applicable	Not applicable	Suffix -ane
Alkene	Carbon–carbon double bond	–C=C–	Suffix -ene
Haloalkane	Halo	–F, –Cl, –Br, –I	Prefix fluoro-, chloro-

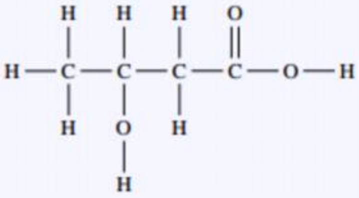
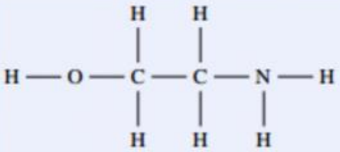
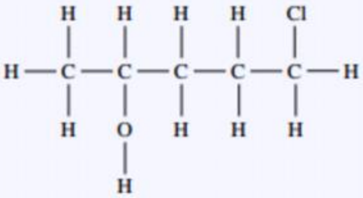


Alkene	Carbon–carbon double bond	–C=C–	Suffix -ene
Haloalkane	Halo	–F, –Cl, –Br, –I	Prefix fluoro-, chloro-, bromo- or iodo-
Alcohol	Hydroxyl	–OH	Suffix -ol Occasionally prefix hydroxy-
Amine	Amino	$-NH_2$	Suffix -amine Occasionally prefix amino-
Carboxylic acid	Carboxyl	–COOH	Suffix -oic acid
Ester	Ester	–COO–	Two-word name with suffixes -yl and -oate
Aldehyde	Carbonyl (end of carbon chain)	–CHO	Suffix -al
Ketone	Carbonyl (within carbon chain)	–CO–	Suffix -one
Amide	Amide	$-CONH_2$	Suffix -amide



	Functional group	Suffix	Alternative name (when needed)
Highest priority	Carboxyl	-oic acid	-
↓	Hydroxyl	-ol	hydroxy-
	Amino	-amine	amino-
	Alkene	-ene	-an- becomes -en-
Lowest priority	Halo	-	halo-

e.g.

Structure	Name
	3-Hydroxybutanoic acid
	2-Aminoethanol
	5-Chloropentan-2-ol

13.6 Determining Formulae of Organic Compounds:

Saturday, 3 August 2019 10:56 AM

Percentage Composition

$$\% \, comp \, X = \frac{molar \, mass \, of \, X}{molar \, mass \, of \, compound} \times 100$$

e.g. Find the percentage composition of ethanoic acid
M(CH_3OOH)= 60.032

$\frac{2\times 12.01}{60.032} \times 100$ =40%

Empirical Formula:

The empirical formula of a compound is the simplest whole number ratio of the number of atoms of each element in the compound

Substance:	**Molecular Formula**	**Empirical Formula**
Hydrogen Peroxide	H_2O_2	HO
Ethane	C_2H_6	CH_3
Ethyne	C_2H_2	CH
Benzene	C_6H_6	CH
Glucose	$C_6H_{12}O_6$	CH_20

Steps to Finding Empirical Formula:

Step 1:
Find the mass of each element in the compound. If percentages, assume you have 100g of the substances

Step 2:
Convert masses into moles for each element (n=m/M)

Step 3:
Find a whole ratio (simplest) of all the elements
** try dividing all the numbers by the smallest number
** The ratio doesn't have to be perfect

Step 4:
Write empirical formula

Example:
A chemical analysis of glucose indicated its composition to be 40.0% carbon, 6.7% hydrogen and 53.3% oxygen. Calculate the empirical formula of glucose:

Element	C	H	O
%	40.0	6.7	53.3
Mass (in 100g)	40.0	6.7	53.3
Moles (n=m/M)	40.0/12.01	6.7/1.008	53.5/16.0
	=33.33	=6.65	3.33
Find Ratio:	3.33/3.33	6.65/3.33	3.33/3.33
	=1	=2	=3

Therefore empirical formula is = CH_2O

Trickier Example:

From the following data, determine the structural formula and name of the compound

- The compound contains carbon, hydrogen and oxygen only
- when 1.24g of the unknown compound is burnt in pure oxygen, 2.73g of CO2 and 1.49g of H2O are produced
- 0.67 grams of the compound was vaporised and occupied 0.317L at 77.0*C and 100kP
- When the compound was treated with Na, hydrogen gas was evolved

Empirical Formula -> Molecular Formula -> Structural Formula -> Name

Organic compound + O_2 -> CO_2 + H_2O

M(CO2) = 2x16 + 12.01
= 44.01

n(C02) = 2.73/44.01
= 0.062031356
Therefore: n(C) = 0.062031356

Therefore m(C) = 0.062031356x12.01
= 0.744996585

M(H20)= 2X1.008+16
=18.016

n(H2O) = 1.49/18.016
=0.082704262

Therefore n(H) = 2x 0.082704262
= 0.165408524

m(H) =0.165408524x1.008
= 0.166731792

And m(O) = 1.24 - 0.744996585 - 0.166731792
= 0.328271622
n(O) = 0.020516976

Substance:	C	H	O
Moles:	0.062031356	0.165408524	0.020516976
Ratio	0.062031356/0.020516976	0.165408524/0.020516976	0.020516976/0.020516976
	=3	=8	=1

Therefore empirical formula: $C_3H_8O_1$

PV=nRT

T= 77+273.15 = 350.15
R = 8.4314
V= 0.3171
P= 100kPA

$$n = \frac{pv}{RT} = \frac{100\times0.371}{8.4314\times350.15}$$

n(substance) = 0.012566666

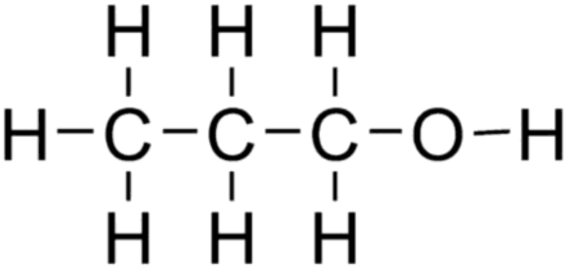
M(empirical formula) = 12.01x3 + 8x1.008 + 16
= 60.094

M (substance) [from gas calculations] = m/n = 0.767/ 0.012566 = 61.037721

Hence Ratio = $\frac{61.03480665}{60.094}$ = 11

Therefore C_3H_8O

Alcohols reacts with Na (can't be carboxylic acid, not enough Oxygen atoms)



14.1 Chemical Properties of Alkenes

Thursday, 18 July 2019 10:30 AM

Reaction of Alkenes:

- Alkenes are described as unsaturated
    - Because they contain a carbon, carbon double bond
- Alkanes are described as saturated

Combustion in Air:

- Alkanes are normally unreactive
- This combustion reaction releases energy and therefore alkanes are a good fuel source
- Alkenes also do a combustion reaction

When burned in an excess of oxygen, alkanes/alkenes produce carbon dioxide, water and energy.

e.g. Combustion of ethene

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$

When there is a limited supply of oxygen, incomplete combustion occurs and carbon monoxide is produced instead of carbon dioxide

e.g. Incomplete combustion of ethene:

$$C_2H_4(g) + 2O_2(g) \rightarrow 2CO(g) + 2H_2O(g)$$

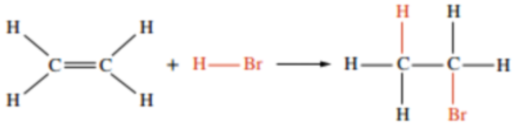
Addition Reactions of Alkenes:

When two reactants combine to give a single bond

- It involves the addition of a small molecule across the double bond

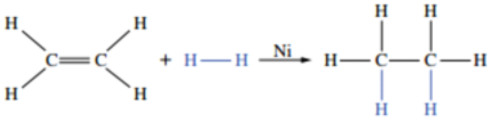
During addition reactions:

- Two reaction molecules combine to form one product molecule
- The carbon-carbon bond becomes a single bond
- An unsaturated compound becomes saturated
- The atoms of the small molecule adding to the alkene are 'added across the double bond'
    - The small molecule splits into 2 parts
    - They add to either end of the original double bond



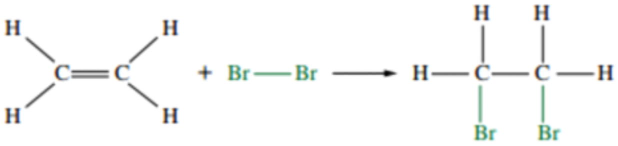
Reactions of Alkenes with Hydrogen:

- Alkenes react with hydrogen gas in the presence of a metal catalyst, such as nickel
- It is knows as hydrogenation reaction and forms a saturated alkane
- The activation energy for this reaction is too high for the reaction to proceed at room temperature without a catalyst



Reaction of Alkenes with Halogens:

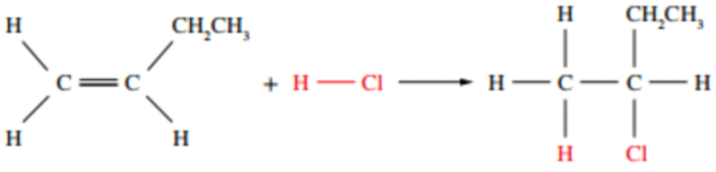
- This reaction proceeds at room temperature without a catalyst
- Other halogens such as Cl_2 and I_2 also undergo addition reactions
    - they form the corresponding haloalkanes
- Bromine is often used to test for the presence of a carbon-carbon double bond because of the ease and speeds with which it reacts with an alkene
    - The orange colour of the bromine quickly disappears when it is mixed with an alkene



Reaction with Hydrogen Halides:

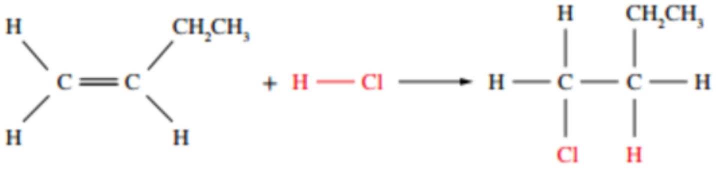
- A hydrogen atom adds to one of the carbon atoms in the carbon-carbon double bond and a halogen atom adds to the other carbon atom
- Markovnikov's Rule pretty much states that, the hydrogen will bond to the carbon that has more hydrogens
    - e.g. most likely the carbon at the end
- Both reaction take place however the one that defies Markovnikov's rule has a greater proportion

  e.g.



2-chlorobutane

This product is in greater proportion



1-chlorobutane

Reaction of Alkenes with Water:

Reactions that involve water as a reactant are referred to as **hydration reactions**

- Alkenes react with water under specific conditions to form the corresponding alcohol
- They normally need a strong acid as a catalyst and at high temperatures
- The water is added across the double bond
- The reaction is used for the commercial manufacture of ethanol because it is a one step process that uses little energy, apart from the initial heating
  e.g.

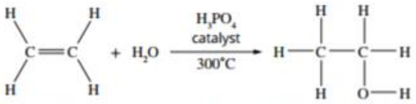
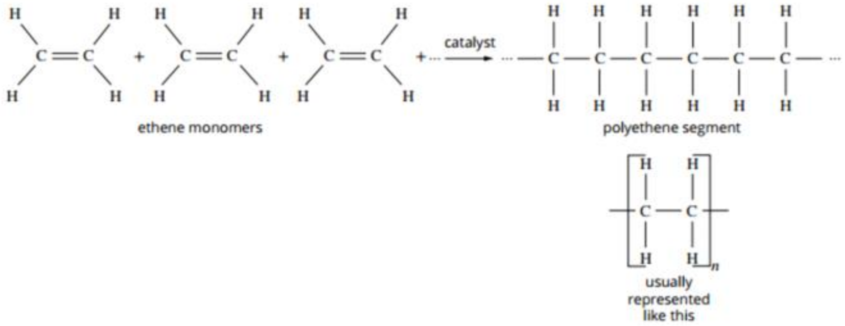


FIGURE 14.1.8 The addition reaction of ethene with water in the presence of a phosphoric acid catalyst produces ethanol.

Addition Polymerisation:

The process is called **an addition polymerisation process**

- Alkenes can also react with each other in addition reaction to form polymers
- The small molecule that that undergoes the addition reaction is called a **monomer**
  e.g.



14.2 Chemical Properties of Alcohols:

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Combustion of Alcohols:

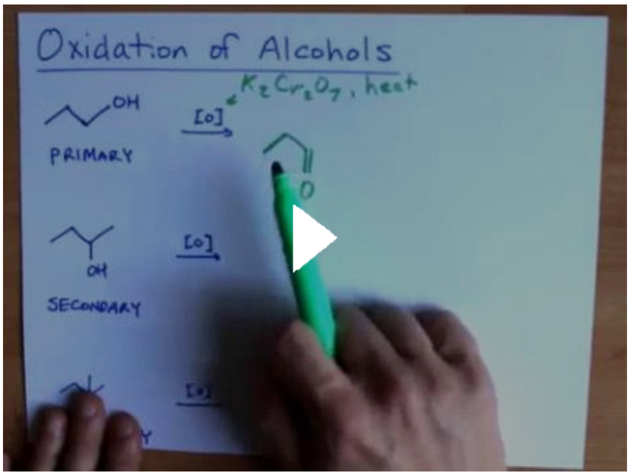
- Alcohols burn readily in air to form carbon dioxide and water as products
- These are highly exothermic reaction
    - Therefore ethanol is used as a fuel
    - For things like methanol spirits, they are made up of around 95% ethanol and used for camp stoves

e.g.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$$

Oxidation of Alcohols:

- The combustion of alcohols and other be classifies as a type of redox reaction.
- Alcohols can also be oxidised by strong inorganic oxidising agents such as acidic solutions of potassium dichromate ($K_2Cr_2O_7$) and potassium permanganate ($KMnO_4$)

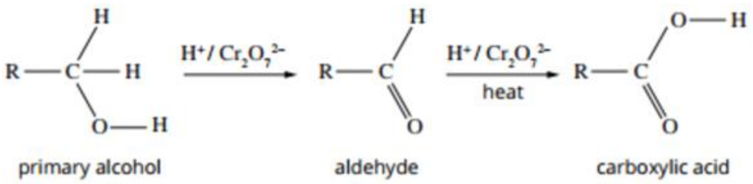


Oxidation of Primary Alcohols:

- Primary alcohols have the -OH group bonded to a carbon that is attached to only one alkyl group
- These alcohols first oxidise to form **aldehydes** and then further oxidation forms the corresponding **carboxylic acid**

Process:

- First, the alcohol is oxidised to an aldehyde when in the presence of a strong oxidising agent and at a high temperature
- In the second stage further heating of the reaction mixture in the presence of the oxidising agent oxidises the aldehyde to a carboxylic acid
- If the required product is an aldehyde
    - Production must occur under milder conditions (lower temperatures and shorter reaction times)
    - The aldehyde can be distilled from the reaction mixture as it forms, so it doesn't oxidise further



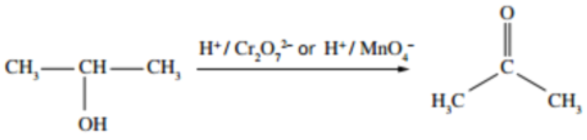
Oxidation of Secondary Alcohols:

- Secondary alcohols have the -OH group bonded to a carbon that is attached to only two alkyl groups
- These alcohols oxidise to form ketones

Process:

- They are oxidised by strong oxidising agents such as solutions of acidified potassium dichromate ($K_2Cr_2O_7$) or potassium permanganate ($KMnO_4$)
- The corresponding ketones are produced

e.g.



Tertiary Alcohols and Oxidising Agents:

- Tertiary alcohols are resistant to reaction with solutions of acidified potassium dichromate ($K_2Cr_2O_7$) or potassium permanganate ($KMnO_4$)
- In tertiary alcohols, the carbon attached to the hydroxyl group does not have a C-H bond to break, so oxidation cannot occur at that carbon atoms

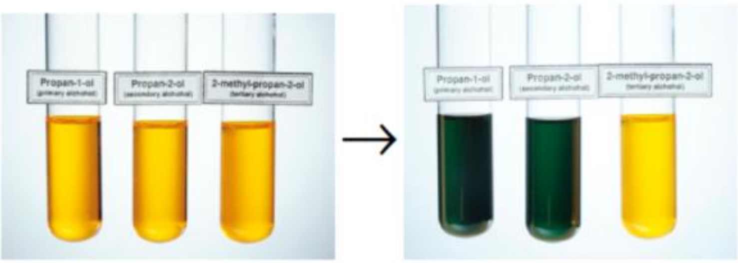
Colour Changes in Oxidation Reactions:

Potassium permanganate and potassium dichromate are both highly coloured due to the presence of the elements chromium (Cr) and manganese (Mn)

Potassium Dichromate:

- A solution of dichromate ions in water is orange
- When mixed with a primary/secondary alcohol the solution is turned to green
  - This is due to the dichromate ions (orange) being reduced to the chromium ions (Cr^{3+}) (green)
- This colour change can be used as a qualitive test to indicate that oxidation an organic compound has taken place
- The rate of reaction may also help to distinguish a primary alcohol from a secondary alcohol
  - A primary alcohol will usually react faster than a secondary alcohol

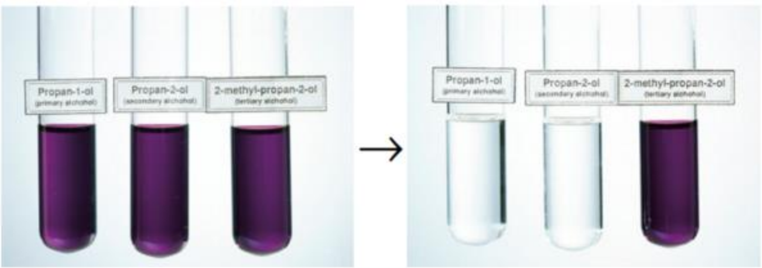
e.g.



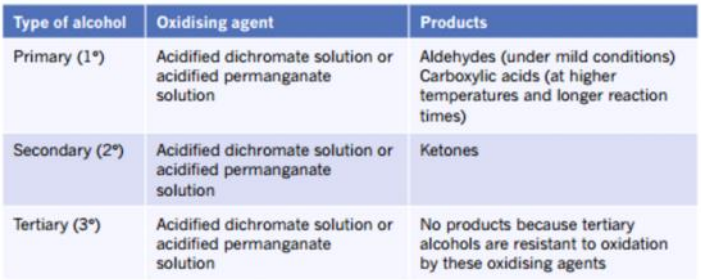
Potassium Permanganate:

- A solution of acidified potassium permanganate is a deep purple colour
- When mixed with a primary/secondary alcohol the solution is turned to an extremely pale pink solution (practically colourless)
  - This is due to the manganese in the permanganate ion (MnO_4^-) is recued to Mn^{2+}
- Tertiary alcohols do not react, there is no change in the colour of the solution
- Like potassium dichromate the reaction rate of the primary alcohol is much faster than the reaction rate of the secondary alcohol

e.g.



Summary:

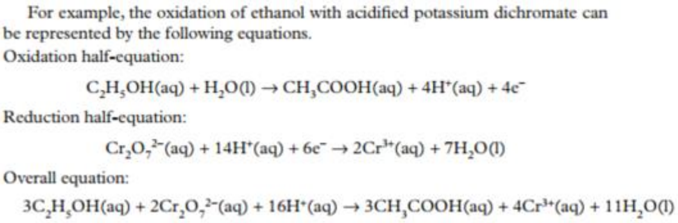


Type of alcohol	Oxidising agent	Products
Primary (1°)	Acidified dichromate solution or acidified permanganate solution	Aldehydes (under mild conditions) Carboxylic acids (at higher temperatures and longer reaction times)
Secondary (2°)	Acidified dichromate solution or acidified permanganate solution	Ketones
Tertiary (3°)	Acidified dichromate solution or acidified permanganate solution	No products because tertiary alcohols are resistant to oxidation by these oxidising agents

Writing Equations for Oxidation of Alcohols:

- Redox reaction occur when alcohols react with oxidising agents
- To write balanced equations for the reactions, you write the oxidation and reduction half-equations and then combine them to make an overall equations for these reaction

e.g.



For example, the oxidation of ethanol with acidified potassium dichromate can be represented by the following equations.

Oxidation half-equation:

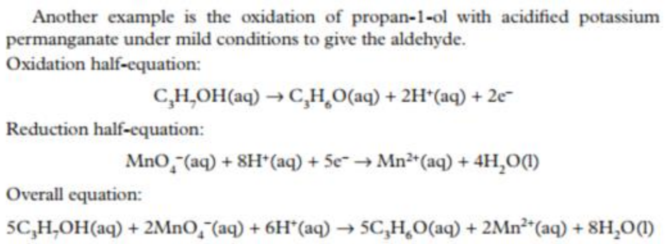
$$C_2H_5OH(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$$

Reduction half-equation:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Overall equation:

$$3C_2H_5OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \rightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$$



Another example is the oxidation of propan-1-ol with acidified potassium permanganate under mild conditions to give the aldehyde.

Oxidation half-equation:

$$C_3H_7OH(aq) \rightarrow C_3H_6O(aq) + 2H^+(aq) + 2e^-$$

Reduction half-equation:

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

Overall equation:

$$5C_3H_7OH(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 5C_3H_6O(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$$

14.3 Chemical Properties of Carboxylic Acids

Friday, 19 July 2019 1:37 PM

Ionisation in Water:

- Most carboxylic acids are weak acids
    - Therefore they ionise to a small extent to form hydronium ions
- The reaction of a carboxylic acid with water is a reversible process
    - Therefore you have to use the equilibrium arrows

Acid	Formula	K_a at 25°C
Nitric acid	HNO_3	2.4×10^{1}
Hydrochloric acid	HCl	1.3×10^{6}
Ethanoic acid	CH_3COOH	1.8×10^{-5}
Methanoic acid	HCOOH	1.8×10^{-4}

Reactions of Carboxylic Acids with Metals and Their Compounds:

Carboxylic acids undergo reactions typical with any other type of acids

Metal Oxides and Hydroxides:

- React with metal oxides or metal hydroxides to give metal salts and water
- When writing these as ionic equations, the carboxylic acid is shown in its molecular form because most of the molecules are not ionised in the original solution

  e.g.

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Metal Carbonates and Hydrogen carbonates:

- React with metal carbonates and hydrogencarbonates to give a salt, water and carbon dioxide

  e.g.

$$Na_2CO_3(s) + 2CH_3CH_2COOH(aq) \rightarrow 2CH_3CH_2COONa(aq) + H_2O(l) + CO_2(g)$$

Or ionic equation:

$$Na_2CO_3(s) + 2CH_3CH_2COOH(aq) \rightarrow 2CH_3CH_2COO^-(aq) + 2Na^+(aq) + H_2O(l) + CO_2(g)$$

Reactive Metals:

- React with reactive metals, such as sodium and magnesium, to give a salt and hydrogen gas

  e.g.

$$2HCOOH(aq) + Mg(s) \rightarrow (HCOO)_2Mg(aq) + H_2(g)$$

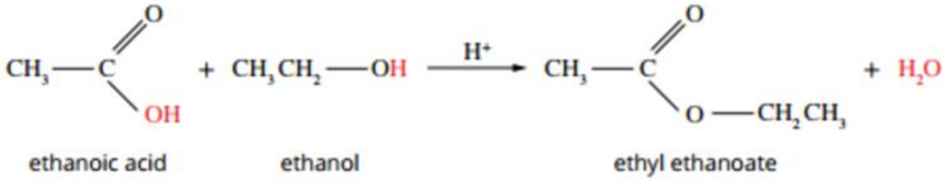
Or ionic equation:

$$2HCOOH(aq) + Mg(s) \rightarrow 2HCOO^-(aq) + Mg^{2+}(aq) + H_2(g)$$

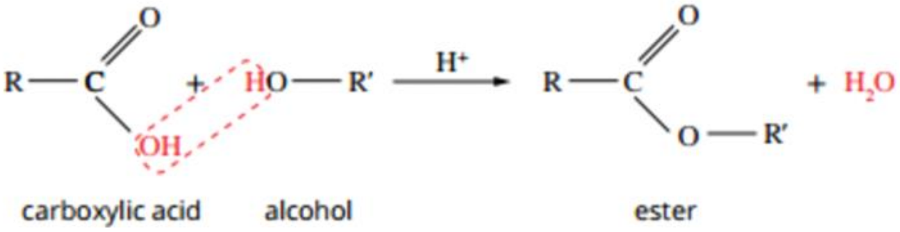
Reactions of Carboxylic Acids with Alcohols:

- the combination of two reactants and the elimination of a small molecule, such as water are called **condensation reactions**
- Esters are made by a condensation reaction between a carboxylic acid and an alcohol
- A condensation reaction in which an ester is formed is also knows as an **esterification reaction**
- **The hydrogen ion comes from the hydroxyl group of the alcohol**

- **The -OH comes from the carboxylic acid**
  e.g. The ester ethyl ethanoate can be produced by gently heating a mixture of ethanol and pure ethanoic acid with sulfuric acid (as a catalyst). Water is also produced.



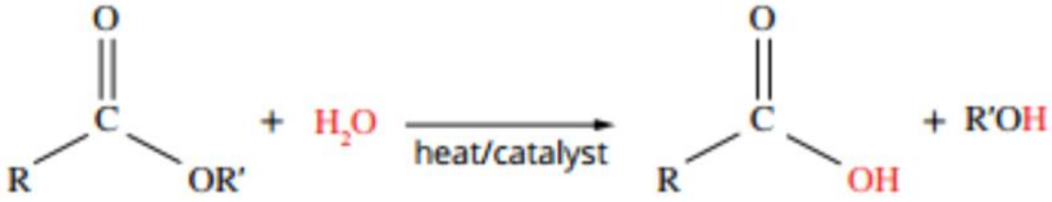
General Equation:

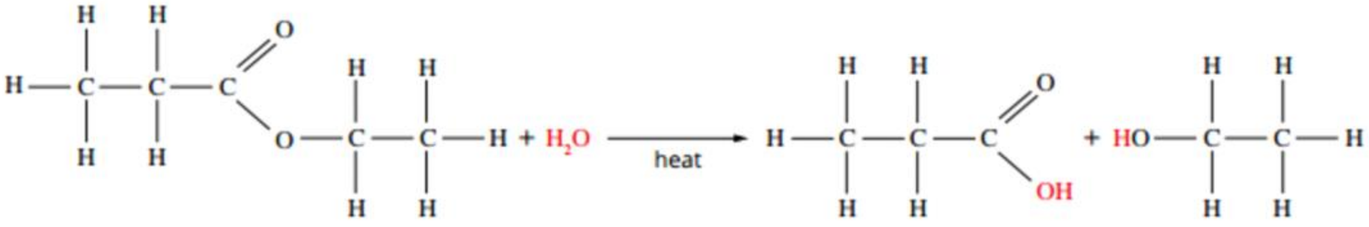


Hydrolysis of Esters:

- The esterification reaction is reversible
- Esters can react with water to form a carboxylic acid and an alcohol
- This reaction is also referred to as **hydrolytic reactions** or simply **hydrolysis**
- This reaction is catalysed by an alkali or dilute acid
- When the hydrolysis of an ester is catalysed by an alkali (e.g. sodium hydroxide) the products are an alcohol and the sodium salt of the carboxylic acid
  - The sodium salt can be easily converted to the carboxylic acid by adding dilute solution, such as HCl

General Equation:



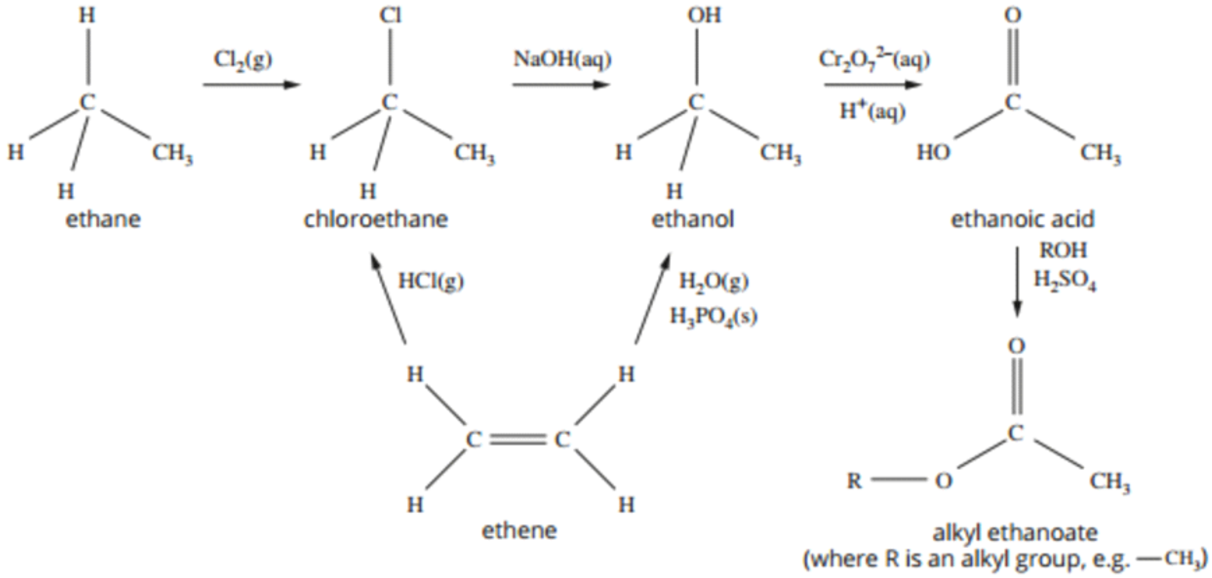


14.4 Creating Molecules: an Introduction to Organic Synthesis

Friday, 19 July 2019 3:03 PM

Simple Reaction Pathways:

- A reaction pathway is a series of one or more stops/ reaction that can be used to convert a reactant containing certain functional groups to a desired product with different functional groups
- The same inorganic reactants and reaction conditions can be applied to different hydrocarbon starting points to produce the same functional groups on the product molecules



Reaction Sequences: Production of Ethyl Ethanoate:

- It can be used as artificial fruit essences and flavours, solvent in the decaffeination of tea and coffee, also used in the manufacture of printing and perfumes
- Ethanol is an alcohol containing two carbon atoms
  - Can be synthesised from ethene by an addition reaction with water or by fermentation of sugars by yeast
- Ethene is a good choice because it can be readily available through the cracking of hydrocarbon fractions form the distillation of natural gas and oil

The manufacture of Ethyl Ethanoate:

1. Ethanol is synthesised directly by the hydration of ethene in the presence of the catalyst phosphoric acid:

$$CH_2{=}CH_2(g) \xrightarrow{H_2O(g),\ H_3PO_4} CH_3CH_2OH(l)$$

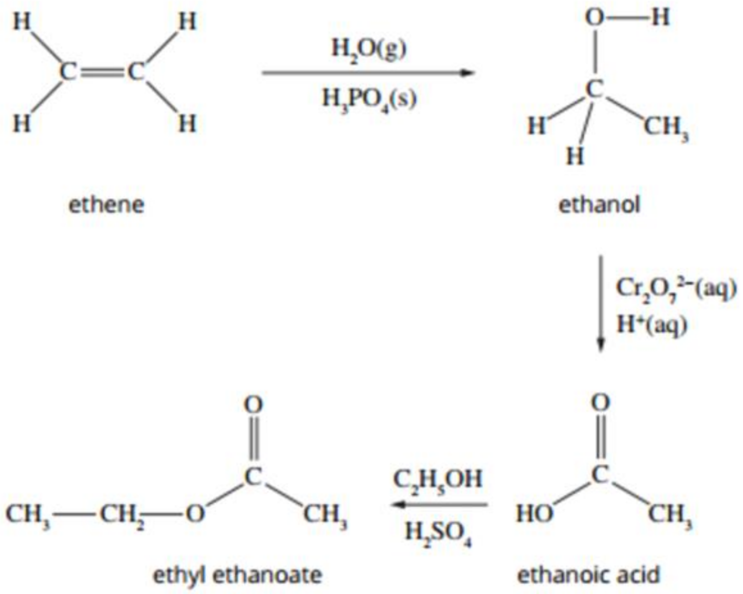
2. Ethanoic acid is synthesised by oxidising some of the ethanol produced in step 1:

$$CH_3CH_2OH(l) \xrightarrow{Cr_2O_7^{2-},\ H^+} CH_3COOH(l)$$

3. Ethyl ethanoate is produced by the condensation reactions between ethanoic acid and ethanol in the presence of sulfuric acid catalyst:

$$CH_3CH_2OH(l) + CH_3COOH(l) \xrightarrow{H_2SO_4} CH_3COOCH_2CH_3(l)$$

Structural Formula:



Considerations in Devising a Synthesis:

- Some desired products can be synthesised by a number by a number of routes, so different possible pathways may also need to be considered
- Chemists also consider yield, rate, cost, safety and sustainability
- The final product needsd to be purified and the purity evaluated

15.1 Polymers: a diverse class of materials

Saturday, 31 August 2019 3:10 PM

Polymer Structure:

- Are covalent molecular substances composed of many small molecules joined together to form a long chain of atoms
- Polymers are formed by the joining together thousands of smaller molecules called monomers
- Polymer chains are made up of identical segments that are repeated along the length of the molecule

Natural Polymers:

- For example carbohydrates are made from sugar monomers (glucose and fructose)
- Proteins are formed from amino acid monomers

Synthetic Polymers:

- Bakelite was the first synthetic polymer
  - Hard, brittle plastic that is used for guitars and telephones

Structural Properties of Polymers:

The properties of a polymer are determines primarily by the type of monomers used to produce it. However structural features also affect the properties of the polymer

- The length of the polymer molecules
- Branching of the polymer chains
- Cross-linking between polymer chains

Length:

- As the polymer gets longer the dispersion forces between neighbouring polymer chains increases
  - This means that the resulting polymer is more rigid and harder
- For example ultra-high molecular weight polyethene
  - It consists of extremely long polymer molecules
  - This makes it a tough polymer that can be used to make artificial hip joints and so on…

Branching:

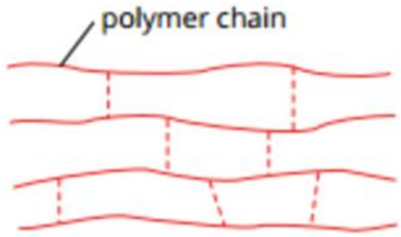
- when polymers are formed, monomers can join together in a linear fashion or with a degree of branching
- Branched polymers are formed when some monomers react with sites on the side of the polymer chain instead of the end
- When the monomer joins to the side of the chain it begins a new chain growing in a different direction
- Branching can cause the polymer molecule to be spaced further apart
  - Resulting in a less dense material
  - With a greater distance between the polymer chains, the intermolecular attraction between neighbouring chain is weekend
    - This can increase the flexibility of a polymer but decrease its strength

straight-chain polymer

branched-chain polymer

Plastics:

- Is a property of a material
- A substance is a plastic if it can be easily moulded
- **Thermoplastic** polymers soften when heated
    - They can be remoulded or recycled
- Polymers are only thermoplastics if the bonds between the long polymer are hydrogen bonds, dipole-dipole bonds ore weak dispersion forces rather than covalent bonds
- When heated the molecules in thermoplastic materials have enough energy to overcome the intermolecular forces and become free to move and slip fast one another



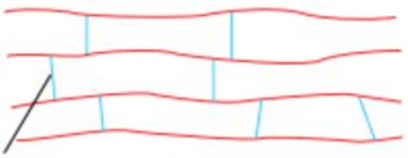
Heat causes the molecules to move enough to overcome the weak forces between molecules.

Cross linking:

- The polymer are covalently bonded to neighbouring polymer chains
- Polymers of this type cannot be liquids because the polymer chains are held in place by the cross linking and are unable to flow

Thermosetting Polymers:

- Cross-linked polymers typically exist as thermosetting polymers
- They normally decompose or burn when heated, rather than melting
- They are also very hard and rigid
- They do not soften because the bonds between the chains are very strong
- If the temperature is high enough to break the covalent bonds
    - The bonds may break at any point, causing the polymer to decompose
- They are used for items such as saucepan handles, bowling balls…

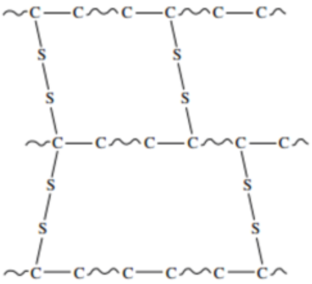


The heat required to break the cross-links is also sufficient to break the bonds within the molecules themselves.

Elastomers:

Are formed when only occasional cross-links are present

- The chains in these polymers can still move past each other when stretched
- But the crosslinks return the chains to their original positions once the force causing the stretching is released
- The cross-links stop elastomers from completely melting when heated, which makes recycling difficult



15.2 Addition Polymerisation

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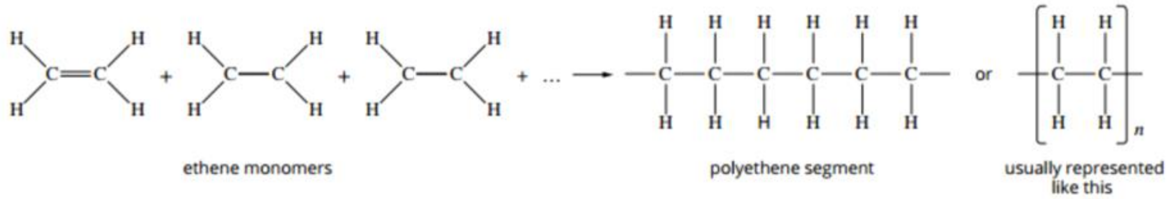
- Addition reactions involve the reaction of an alkene with another molecule
- Under some conditions alkenes undergo a reaction with themselves to produce long chains.
- Addition polymerisation requires monomers that are unsaturated (contain a double or triple carbon-carbon covalent bond). During the polymerisation process, the double or triple bond is broken single C-C bonds are formed between monomers.



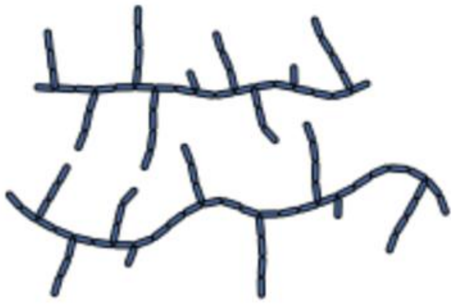
Large square brackets and the subscript *n* are used to simplify the drawing of long polymers

Low Density Polyethene:

- It requires high pressure and temperature
- The process is called free-radical polymerisation
  - Free radicals are highly reactive atoms, molecules or ions with unpaired electrons
  - The free radicals break the double in the ethane monomers to start the polymerisation reaction
  - However the free radicals also attach the sides of the polymer chain, resulting in significant branching
- The presence of these branches affect the properties of the polymer because they cannot pack closely together
  - The dispersion forces between the molecules are weaker when the molecules are further apart
  - The structure can be described as non-crystalline
- It is normally used for plastic bags and plastic layers in cartons of milk or juice

Properties:

- Low density
- Relatively soft
- Low melting point
- Non-crystalline
- Non-conductor



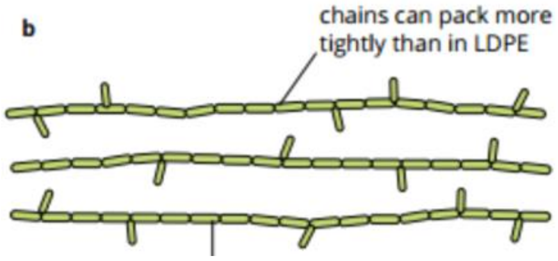
High-Density Polyethene (HDPE):

- It requires lower heat
  - Highly specialised metal catalysts are used to avoid the need for high pressures
- The lack of branching allows the molecule to pack together tightly increasing the density and hardness of the polymer formed

- The structure of the polymer is more ordered, resulting in crystalline sections
- It is normally used for food containers, plastic bottles water pipes…

Properties:

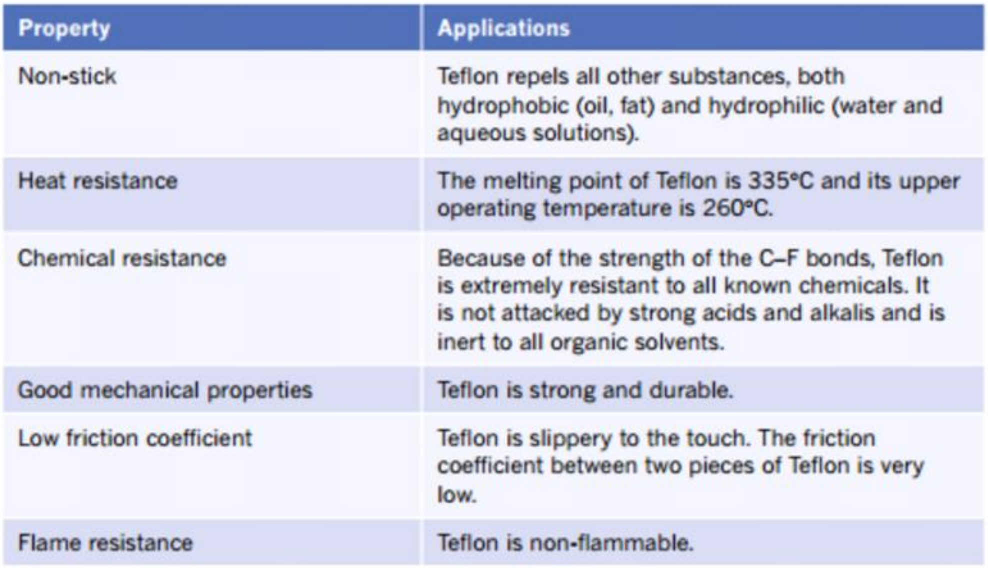
- High density
- Hard
- Relatively high melting point
- Crystalline sections
- Non-conductor



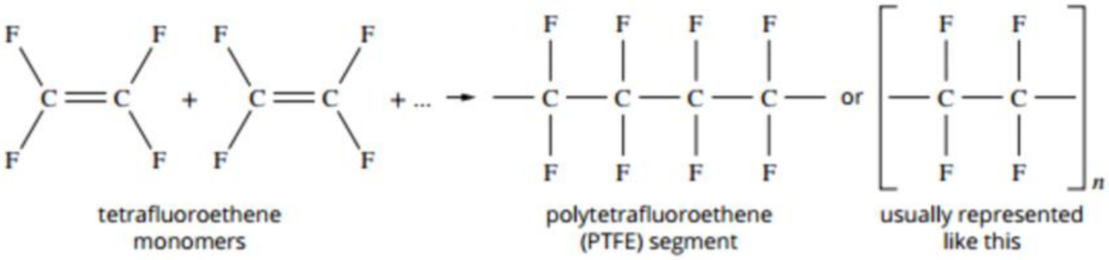
Polytetrafluoroethene (PTFE):

- Is formed from the monomer tetrafluoroethene $CF_2{=}CF_2$
- It is more commonly known as Teflon
- It can be used as non-stick cookware, artificial hips and bullet proof armour

Properties:



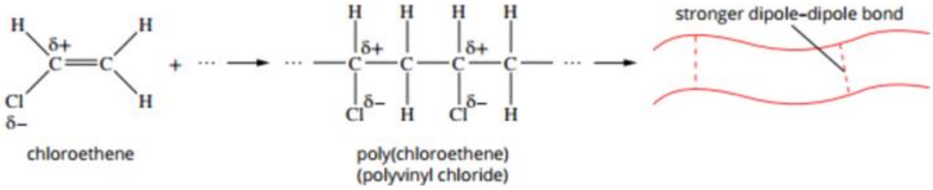
Property	Applications
Non-stick	Teflon repels all other substances, both hydrophobic (oil, fat) and hydrophilic (water and aqueous solutions).
Heat resistance	The melting point of Teflon is 335°C and its upper operating temperature is 260°C.
Chemical resistance	Because of the strength of the C–F bonds, Teflon is extremely resistant to all known chemicals. It is not attacked by strong acids and alkalis and is inert to all organic solvents.
Good mechanical properties	Teflon is strong and durable.
Low friction coefficient	Teflon is slippery to the touch. The friction coefficient between two pieces of Teflon is very low.
Flame resistance	Teflon is non-flammable.



Polyvinylchloride (PVC):

- Polyvinyl chloride (PVC) is made from the polymerisation of chloroethene ($CHCl{=}CH_2$)
- The carbon-chlorine bonds in PVC molecule are polar and allow dipole-dipole attractions to form between polymer chains
    - Because of this PVC is harder and more rigid

- It is mostly used for piping.



15.3 Condensation Polymerisation:

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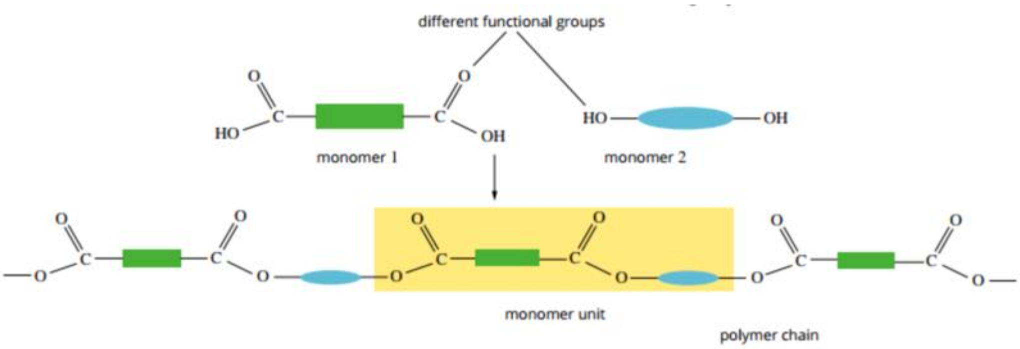
- For it to occur the monomers must have two functional groups, one on each end of the monomer
  - These functional groups react chemically with the functional groups on neighbouring monomers
- Normally small molecules like water are formed

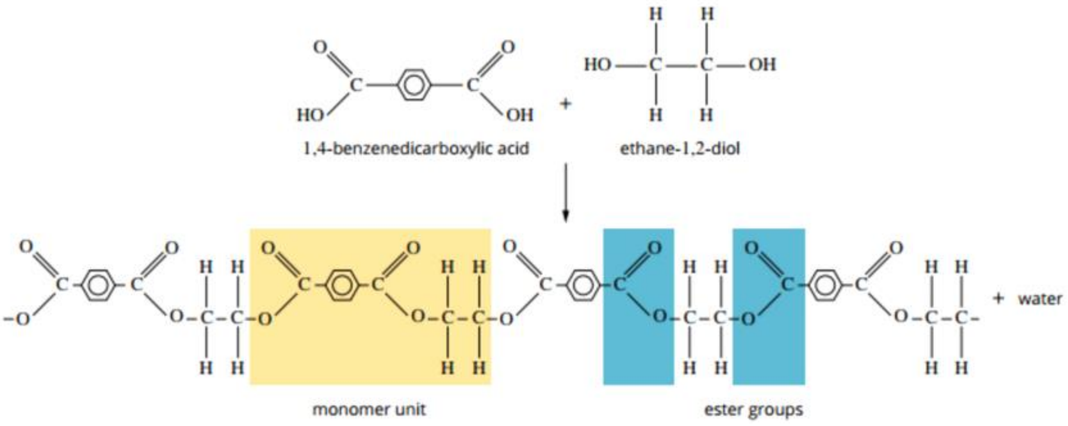


Polyesters:

- Polyesters are typically formed by combining a dicarboxylic acid monomer with a diol monomer in a condensation polymerisation reaction
  - Water molecules are also produced

Polyethylene terephthalate (PET):

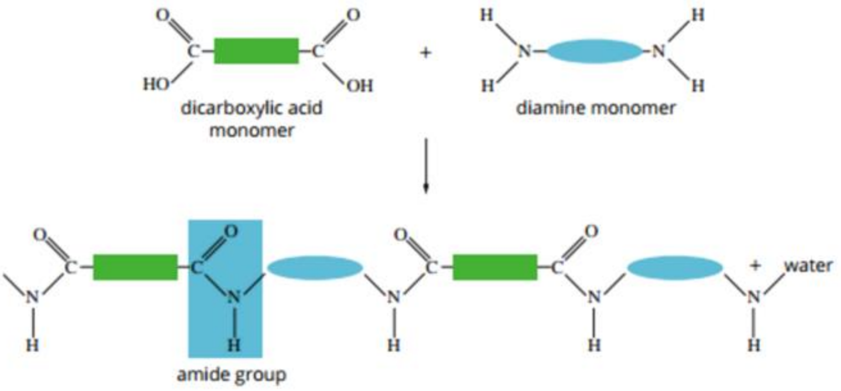
- Most common polyester
- It is used mostly in fabrics, recyclable drink bottles and food packaging
- It is a strong material because the ester groups are polar
  - Therefore PET has dipole-dipole attraction between polymer chains
- Synthesised by reacting 1,4-benzenedicarboxylic acid monomers with ethane-1,2-diol monomers



Polyamides:

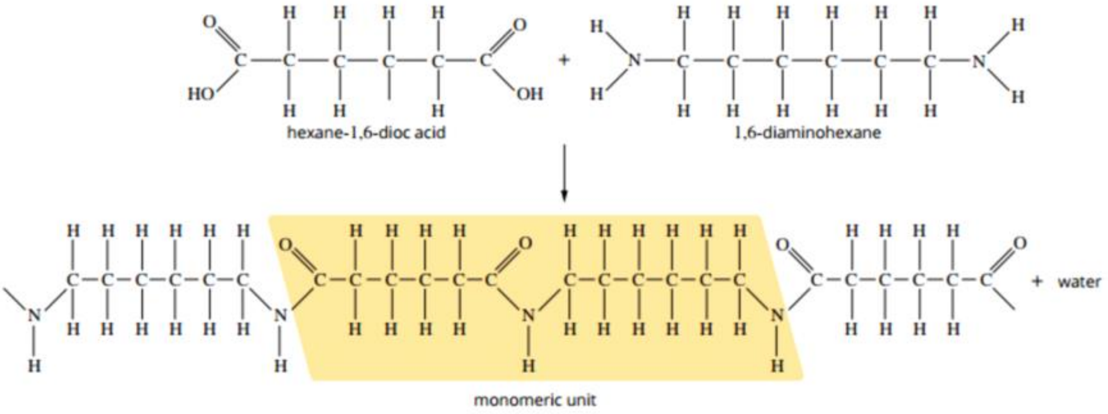
- Polyamides are typically formed by combining a dicarboxylic acid monomer with a diamine monomer in a condensation polymerisation reaction
  - Water is also produced
- Polyamides are normally than polyesters of similar structure
  - Because hydrogen bonding can form between the amide groups on neighbouring

polymer chains



Nylon:

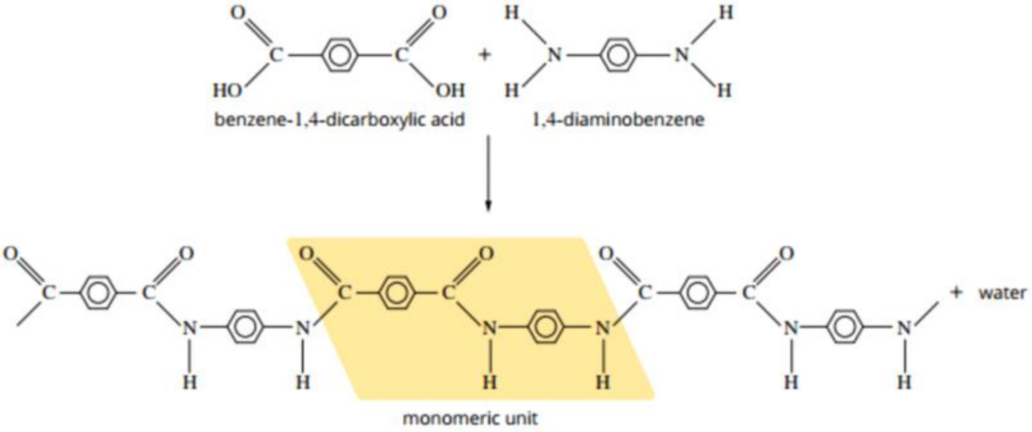
- Is a common example of a polyamide
- It refers to a group of polyamides in which the monomers contain linear carbon chains
- It is easily drawn into fibres with a high tensile strength
    - It is normally used to produce strong, lightweight materials for clothes…
- Can also be used to make hard, rigid plastics



nylon-6,6

Kevlar:

- Is an extremely strong material which Is also very lightweight
    - e.g. used for bulletproof vests
- The benzene rings make the polymer chains rigid and align closely together
    - As a result there is strong hydrogen bonding between the amide groups in these molecules



Kevlar

16.1 Fats and Oils

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Lipids:

Are naturally occurring organic molecules that are insoluble in polar solvents like water
- Fats belong to lipids

Structure of Fats and Oils:

- Fats and oils contain large non-polar molecules known as triglycerides
- Fats and oils have very similar chemical structure, however:
  - Fats are solid at room temperature
  - Oils are liquids at room temperature
- Due to triglycerides being non polar
  - They are unable to form hydrogen bonds with water
  - So fats and oils are insoluble in water

Triglycerides:

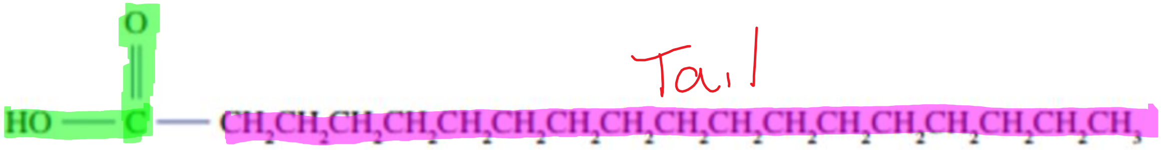
is an ester derived from glycerol and three fatty acids.

General structure of a Fatty Acid and Glycerol:

- Triglycerides are synthesised by condensation reactions between a glycerol molecule and three fatty acids

Fatty acids:

- Are carboxylic acids with chain lengths of at least eight carbon atoms
- They have a carboxyl functional group attached to a long unbranched hydrocarbon chain, which is also known as the "tail"
  - This tail makes up the bulk of the molecule



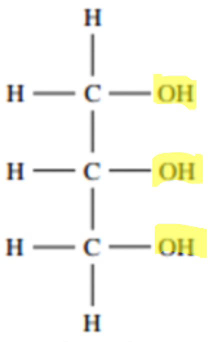
$HO-\overset{\overset{O}{\|}}{C}-CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

fatty acid (stearic acid)

Head

Glycerol:

- Is a relatively small molecule with three hydroxyl functional groups
- It is also known as propan-1,2,3-triol

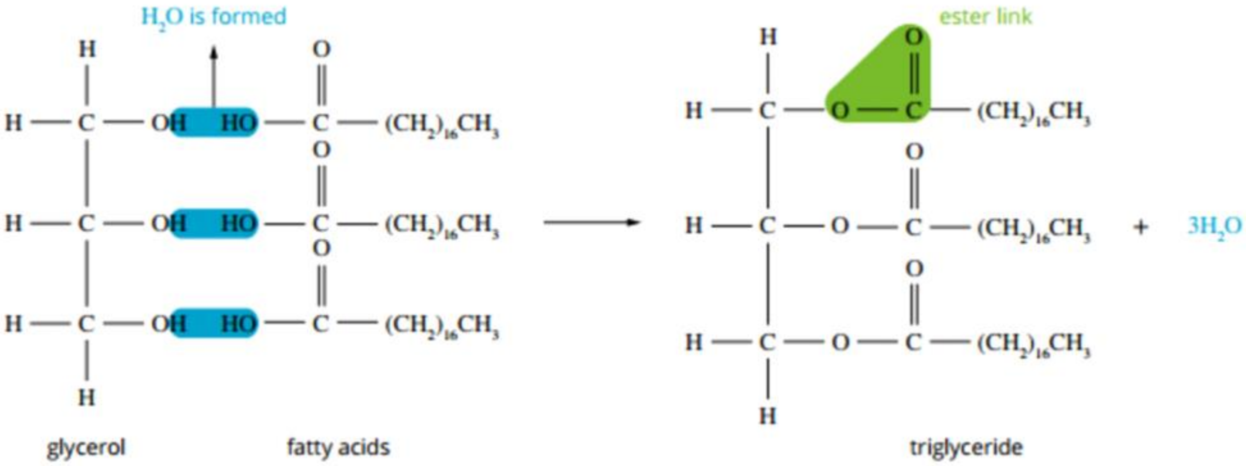


glycerol

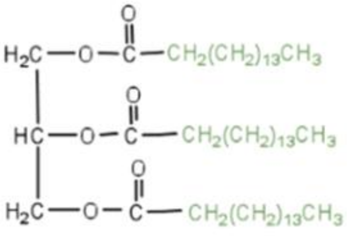
Condensation Reactions to form Triglycerides:

- A triglyceride is formed by a condensation reaction
  - involves the carboxyl group of a fatty acid
  - The hydroxyl group of glyceride
- Forming an ester link

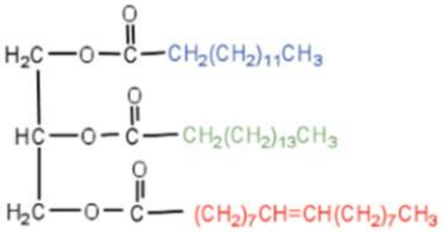
- This reaction needs:
  - One glycerol molecule
  - Three fatty acids
- It forms:
  - Three ester links (one molecule)
  - Three water molecules
- The three chains in the triglyceride are not always identical
  - One with identical chains is called a **simple triglyceride**
  - One with different chains is called a **mixed triglyceride**



Examples:


Tristearin

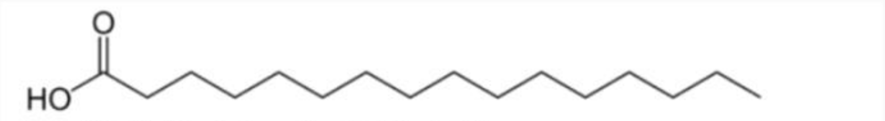
a simple triglyceride


a mixed triglyceride

Saturated and Unsaturated Fatty Acids:

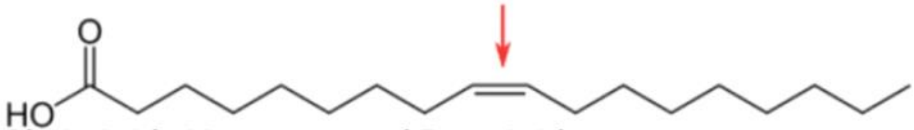
Saturated Fatty Acids:

- Have hydrocarbon chains that only contain single carbon-carbon bonds.


Palmitic Acid - Saturated Fatty Acid

Mononsaturated Fatty Acids:

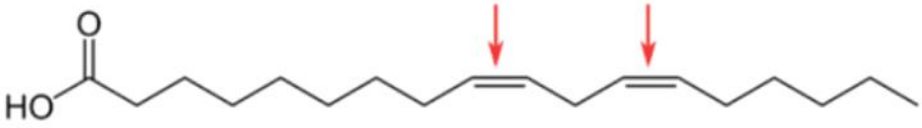
- Contain one carbon-carbon double bond in their hydrocarbon chain
- They are normally plant based oils


Oleric Acid - Monosaturated Fatty Acid

Polyunsaturated Fatty Acids:

- Contain more than one carbon-carbon double bond in their hydrogen chain

- Fish and vegetable oils are mostly polyunsaturated fatty acids



Linoleic Acid - Polyunsaturated Fatty Acid

Uses of Fats and Oils:

- they have a wide variety of uses
- 75% is in food
    - Such as ingredients or cooking oils
- The Other 25% is as a raw material to make new substances
    - e.g. soaps and biodiesels

16.2 Production of Soaps

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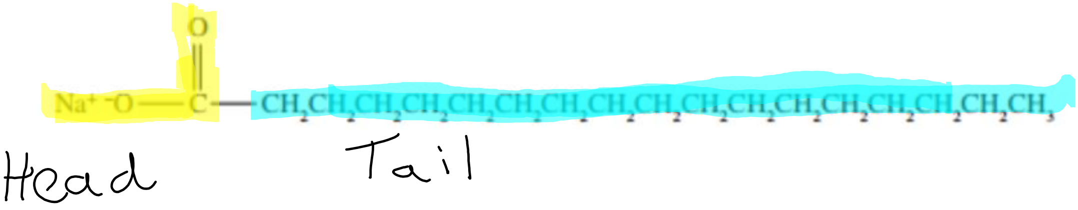
Saponification:

Soap molecules contain a long hydrocarbon chain attached to a charged end

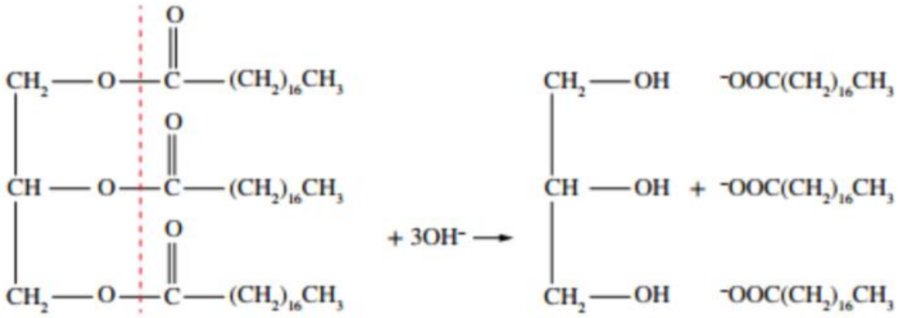


Saponification:

When base hydrolysis is applied specifically to esters

Synthesis:

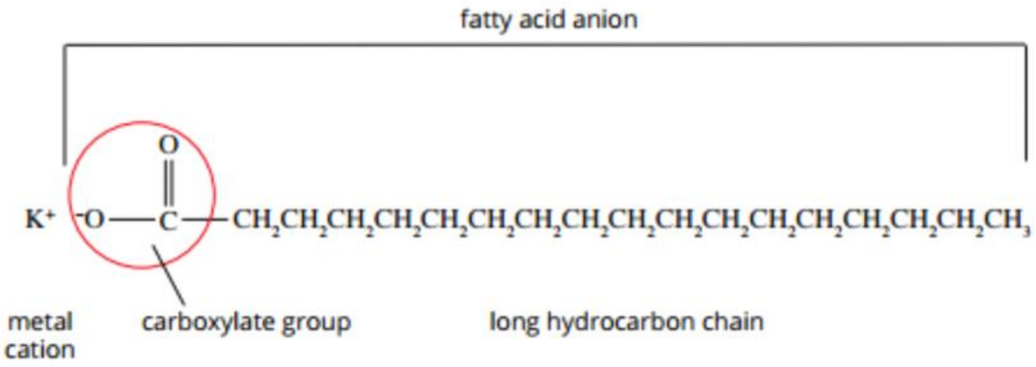
- To synthesise soap from a triglyceride the ester bonds must be broken
- We can use a hydrolysis reaction
  - Water is reacted with the ester
  - However this reaction is very slow
- In practice we use base hydrolysis
  - We use a strong base
    - Such as sodium hydroxide or potassium hydroxide



- It is the fatty acid ion combined with the metal ions from the base that makes up the soap

For example:

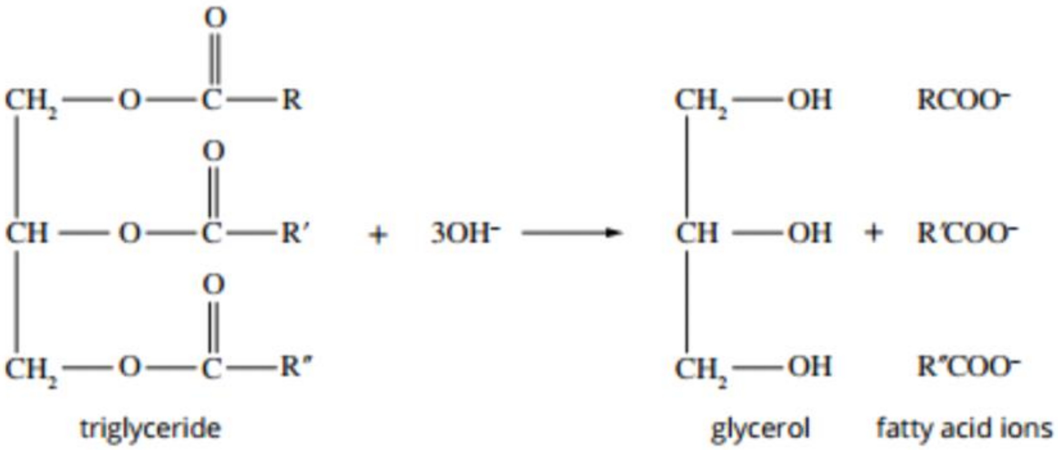
The soap potassium stearate is formed when triglyceride reacts with potassium hydroxide



Structure of Soaps:

- Long hydrocarbon chain (normally referred to the tail)
  - This part of the soap is non-polar
  - In potassium stearate it is an alkyl group (the hydrocarbon is saturated)

- A **carboxylate ion** (COO^-) (normally referred to the head of the soap)
  - It is polar, meaning there is an uneven distribution of charge in this region
  - Carboxylate ions are the conjugate base of carboxylic acids
- A metal ion (normally Na^+ or K^+)
- Even if a pure source of oil is used the fatty acids in the triglyceride can vary
  - For this reason chemists often represent the general equation for saponification with R', R'' and R'''



Soap Production:

- Different triglycerides are used
  - in Asia palm oil is used
  - In Europe olive oil is used
- It can be easily made
  - Heat a mixture of a suitable oil/fat
  - Mix it with concentrated sodium hydroxide solution
  - Then rinse it with water
    - This will remove any glycerol and any leftover NaOH
- While for industry
  - They heat it at very high temperatures
    - This ensures that all the oil is hydrolysed
  - And it is a continuous process
  - The soap is then precipitates through the addition of sodium chloride
  - Then removed through filtration

Limitations of Soap:

- In some parts of the world soaps have a limited affect
- This is due to the water supply containing high levels of metal ions such as Ca^{2+} and Mg^{2+}
  - This is described as hard water
- When a typical soap (e.g. sodium stearate) is added to hard water the **stearate ions mix with calcium and magnesium ions**
- While stearate is soluble calcium and magnesium are not
  - Therefore they precipitate from the wash as an unsightly scum

$$2CH_3(CH_2)_{16}COONa(aq) + Ca^{2+}(aq) \rightarrow (CH_3(CH_2)_{16}COO)_2Ca(s) + 2Na^+(aq)$$

The effect of hard water is:

- Poorly washed clothes
- Blocked drains from soap scum
- Grey scum in wash tubes
- Unsightly stains around basins and taps
- Bubbles will not be formed when u leather you hair with soap

Removal of Hard water:

- By adding a negative ions such as carbonate (CO_3^{2-})
  - This will precipitate the magnesium ions as magnesium carbonate

$$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

Detergents:

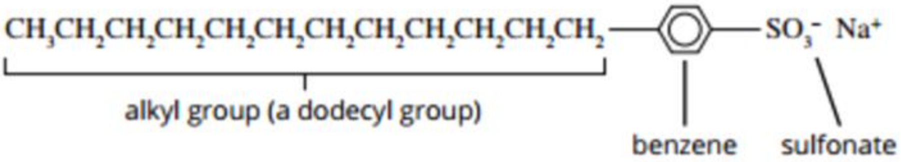
Are cleaning agents that do not suffer from some of the draw backs that soap do

- They have a very similar structure to soap
  - It also has a very long hydrocarbon chain
- However this hydrocarbon chain is sourced from petroleum products
- In contrast to soaps, they do not form insoluble salts with calcium ions or magnesium ions

Anionic Detergents:

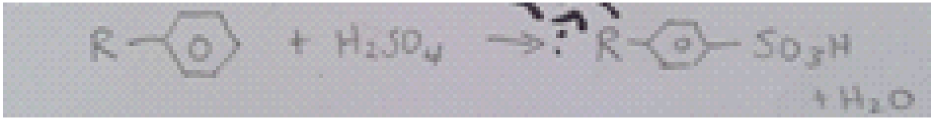
Anionic detergents are those whose active constituent is a negatively charged species

- This can be composed of a sulfonate group attached to a long carbon chain, often via a benzene ring

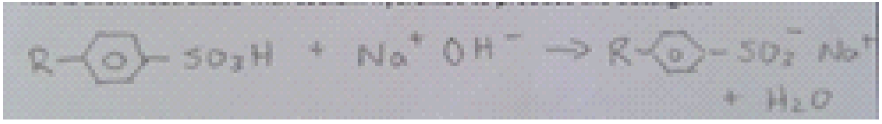


Making Detergents:

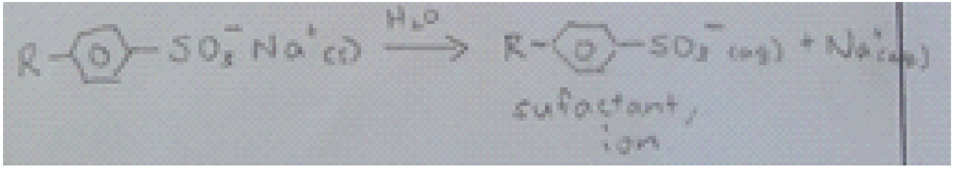
Detergents are produced when an alkylbenzene is reacted with concentration sulfuric acid



This is then neutralised with sodium hydroxide to produce the detergent



When placed in water, the akyl benzene sulfonate is able to form a surfactant ion, similar to soaps.



16.3 The Cleaning Actions of Soaps and Detergents

Sunday, 1 September 2019 2:24 PM

The cleaning action of soap and detergents molecules can be explained by looking at their structure
Due to soaps and detergents being so similar this process applies to both.

Soap in Water:

- In water the anion of the soap tend to come together and form clumps
- The **hydrophilic** ends are on the outer perimeter of these clumps where they are in contact with the water
    - Hydrophilic means " water loving"
        - Typically refers to molecules or ions that can form strong forces of attraction with water
- In case of soaps the forces between itself and the water is an ion-dipole **force**
    - These are formed between the ionic end of the soap and the highly polarised end O-H bond in the water
- The hydrophobic section of the soap are in the centre clumps
    - Hydrophobic means " water hating"
- The clumps are in a stable arrangement called a **micelle**

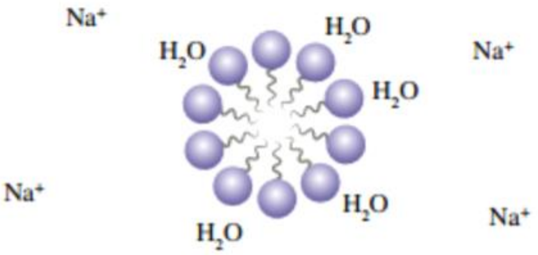


FIGURE 16.3.1 The arrangement of soap particles in a micelle. Micelles have a spherical shape.

Cleaning Action:

- during washing vigorous agitation is used to break up the micelles formed by soap
- The non-polar ends of the soap particle are then able to position themselves in drops of oil or grease
    - Leaving the hydrophilic ends exposed to the water
- As agitation continues the water molecule are attracted to the polar ends of the soap and the oil particle is lifted from the fabric
    - The non-polar end of the soap embed themselves around the oil
    - The charged end protrudes into the water
- The oil surrounded by soap molecules is in a stable arrangement that prevents stains from reattaching to the fabric
    - When the water is drained from the wash, the oil stains are drained away as well
- The non-polar chain and the charged ends of soap particles enable them to function as cleaning agents
    - With the addition of a soap, a polar solvent can successfully remove non-polar stains

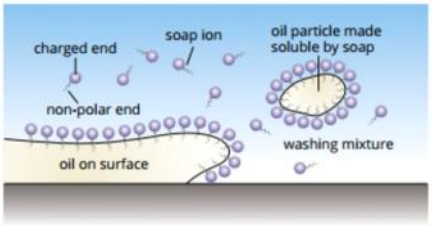


FIGURE 16.3.2 The cleaning action of soap. The non-polar chain of soap particles is embedded in an oil stain, while the charged part is in the water.

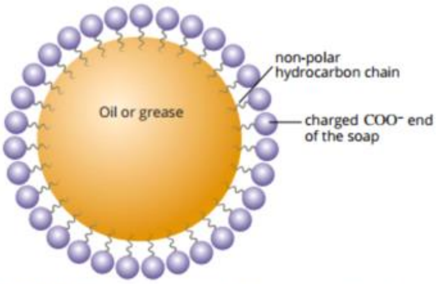


FIGURE 16.3.3 An oil or grease stain that has been lifted from the fabric

Surfactant:

Surfactants are compounds that lower the surface tension (or interfacial tension) between two liquids

- This is the general term for soaps and detergents

16.4 Production of Biodiesel

Sunday, 1 September 2019 2:46 PM

Biofuel:

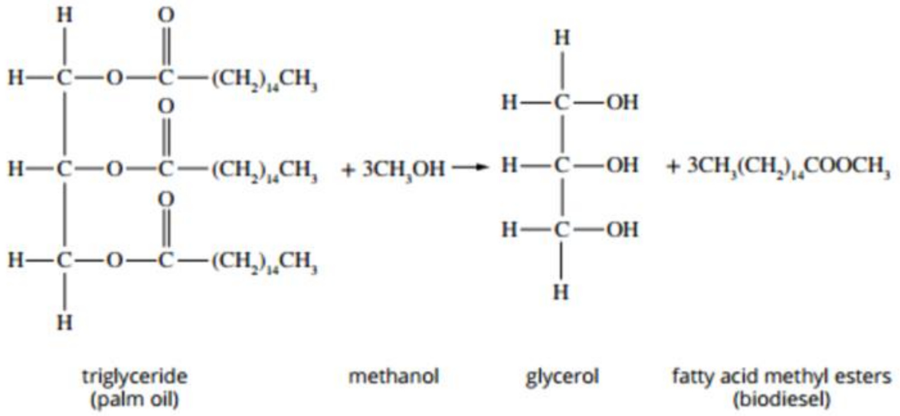
- A fuel produced from biomass (animal or plant material)
- Biodiesel is a type of biofuel

Need for Biodiesel:

- it is renewable
- Reduces the use of fossil fuels
- Reduce the production of greenhouse gases

Transesterification:

- The triglyceride is converted into biodiesel by warming it with an alcohol
  - Usually methanol
- This reaction needs a catalyst
  - Usually a base such as potassium hydroxide or an enzyme
- The triglyceride is converted into glycerol and three esters molecules with long carbon chains
  - These ester molecules are the biodiesel product



- Biodiesels are also referred to **fatty acid esters**
  - Because carboxylic acids with relatively long hydrocarbon chains are referred to as fatty acid
- Like pertodiesel, biodiesel is not a pure substance
  - The structure of the triglyceride varies depending on the particular plant or animal used
- Triglycerides produced by animals usually form saturated esters
- Triglycerides produced by plants usually form unsaturated esters

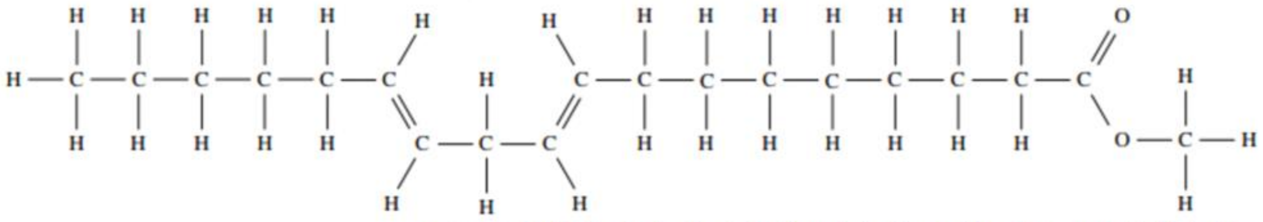
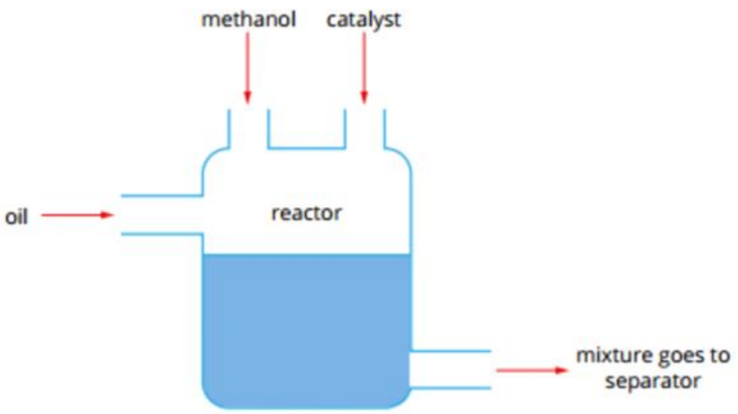


FIGURE 16.4.4 Biodiesel molecules derived from plants often contain carbon–carbon double bonds.

Manufacturing Biodiesel:

- Methanol, the triglyceride and a catalyst are added to a reactor in a batch process
- The initial mixture is heated gently and left for 30 mins



- The reaction mix is then pumped into a separator
- One of the products, glycerol is a small molecule with three hydroxyl functional groups
- The long hydrocarbon chain on the methyl ester makes the molecule non-polar
- This means that in the separator the two products do not dissolve in each other and separate into two distinct layers
- The biodiesel and glycerol extracted from the separator are then distilled to remove any unreacted methanol
    - Which is recycled back into the reactor
- The glycerol is only 80% pure

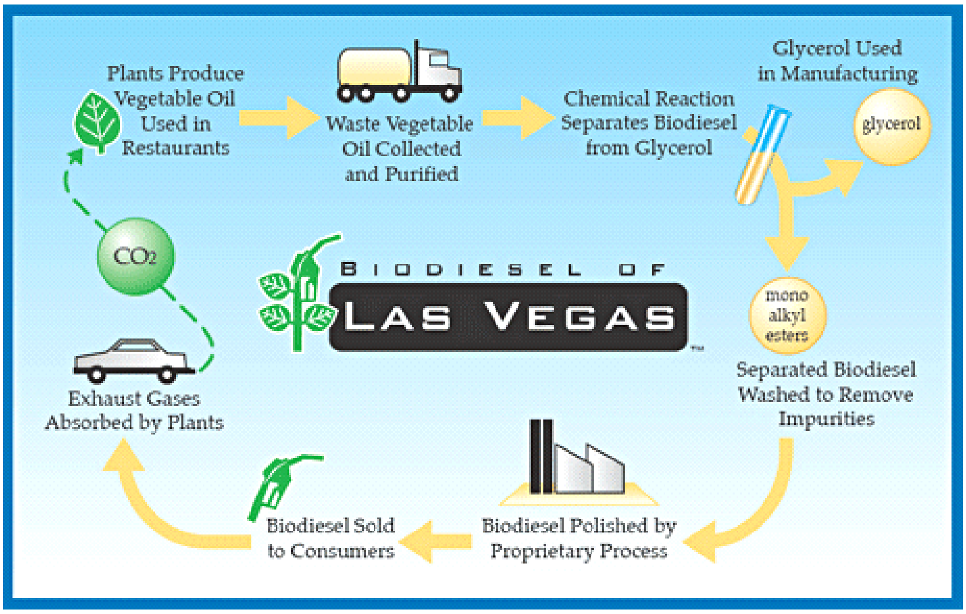
Choosing a Catalyst:

There are two catalysts used in the production of biodiesel:

- The lipase enzyme
    - A naturally occurring enzyme
- A base
    - Generally sodium hydroxide or potassium hydroxide
- The base-catalysed process is used for most times
    - It uses methanol, and operates at high temperature
    - Making the process quicker and more economical
- Using lipase would be more preferable
    - Because it can be used many times
    - It requires less energy
    - The transesterification process can be carried out at lower temperatures and pressures
    - Unfortunately the low reaction rate limits its use

Wilder Environmental Considerations:

- you can normally use used cooking oil to produce biodiesel
- This would reduce land clearance
- Requires less water and fertiliser


Plants Produce Vegetable Oil Used in Restaurants
Waste Vegetable Oil Collected and Purified
Chemical Reaction Separates Biodiesel from Glycerol
Glycerol Used in Manufacturing
glycerol
mono alkyl esters
Separated Biodiesel Washed to Remove Impurities
Biodiesel Polished by Proprietary Process
Biodiesel Sold to Consumers
Exhaust Gases Absorbed by Plants
CO2
BIODIESEL OF LAS VEGAS

17.1 Amino Acids

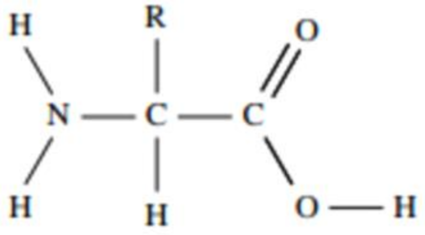
Tuesday, 17 September 2019 4:21 PM

Structure of Amino Acids:

- **Amino functional group** (-NH_2)
- **Carboxyl Group** (-COOH)
- A hydrogen atom attached to a central carbon atom
    - The carbon atom is called an alpha carbon

General Formula of Amino Acids:

- They have a general formula H_2N-CH(R)-COOH
- Alpha amino acids are when the amino group and carboxyl group are added to the same alpha carbon



Acid-Base Proprieties:

Amino Acids as Zwitterions:

A zwitterion is a molecule that contains positive charges but has no overall charge

- Amino acids can form hydrogen bonds with water molecules and are soluble in water
    - -NH_2 group can act as a base, accepting a proton to become a -NH_3^+ group
    - -COOH group can act as an acid, donating a proton to become -COO^- group
- ^+H_3N-CH(R)-COO^-
- The relatively high melting point of pure crystalline amino acids due to the zwitterion being present in the solid state

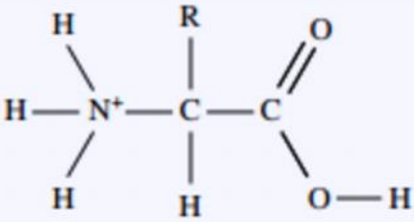
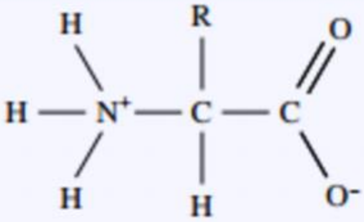
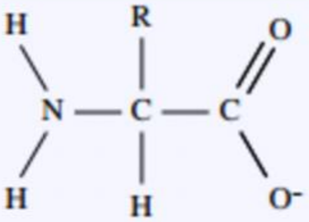
Acid-Base Properties of Amino Acids:

- At intermediate pH (typically pH 5-7), the zwitterion ^+H_3N-CH(R)-COO^- is most abundant
- At low pH, the cation ^+H_3N-CH(R)-COOH is most abundant
    - If the concentration of $H_3O^+_{(aq)}$ the position of the equilibrium lies well to the right

$$^+H_3N\text{–CH(R)–COO}^-(aq) + H_3O^+(aq) \rightleftharpoons {}^+H_3N\text{–CH(R)–COOH}(aq) + H_2O(l)$$

- At high pH the anion H_2N-CH(R)-$COO^{=}$ is most abundant
    - If the concentration of OH^- is very high, the position of this equilibrium lies well to the right

$$^+H_3N\text{–CH(R)–COO}^-(aq) + OH^-(aq) \rightleftharpoons H_2N\text{–CH(R)–COO}^-(aq) + H_2O(l)$$

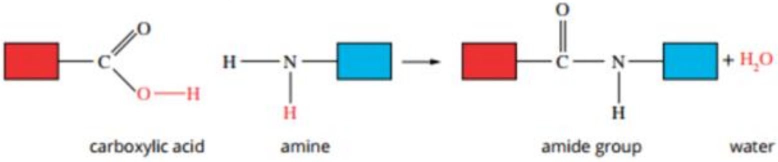
Low pH	Intermediate pH	High pH
 cation	 zwitterion (no overall charge)	 anion

17.2 The Formation of Proteins:

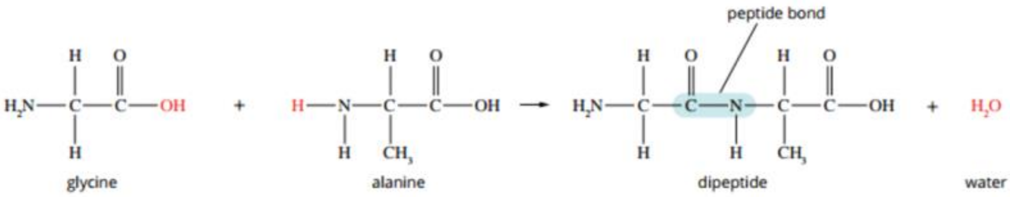
Tuesday, 17 September 2019 5:21 PM

Dipeptides:

- A condensation reaction occurs
- It is between a molecule carboxyl group (-COOH) and a molecule that contains an amino group ($-NH_2$)
- An amide functional group (-CONH-) is formed

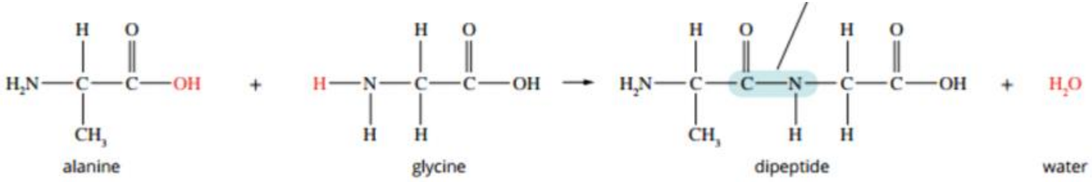


- Because alpha amino acids contain both an amino functional group and a carboxyl function group, they undergo condensation with each other
- When two amino acids react an amide group that links the molecules together
  - The amide link is called **a peptide link**
- The bond between the carbon and the nitrogen atoms in the amide group is called **a peptide bond**
- When two amino acid molecules react together the product is referred to a dipeptide
  - Molecules that are made from amino acids are often called peptides



Depending how the amino acids react, there are 2 different product molecules

e.g.



Polypeptides:

Are polymers formed by condensation polymerisation of amino acids

- During this amino acids can form long chains
- When three amino acids react, a **tripeptide** is formed
- When many amino acids react, a **polypeptide** is formed

Naming Polypeptides:

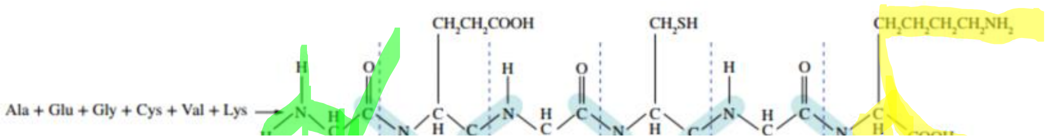
- A shorthand notation is often used to describe amino acid sequence in a polypeptide
- By convention the structure is drawn that:
  - The free amino group is on the left
  - The free carboxyl group is on the right
- When naming a polypeptide or protein, the order is in this direction

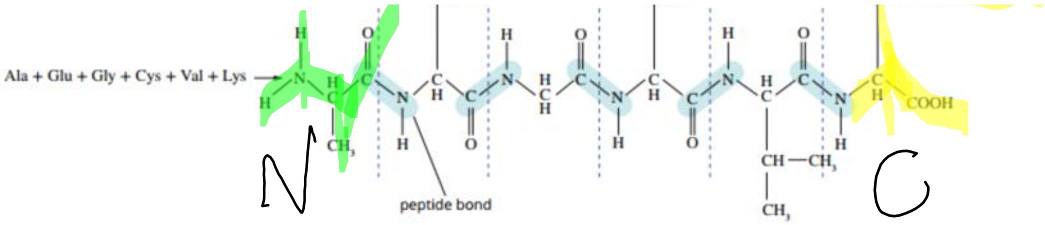
N-Terminal Amino Acid:

The amino acid that has a free amino group

C-Terminal Amino Acid:

The amino acid that has a free carboxyl group





Protein:

A poly peptide that has at least 50 amino acids

17.3 Primary and Secondary Structures of Proteins:

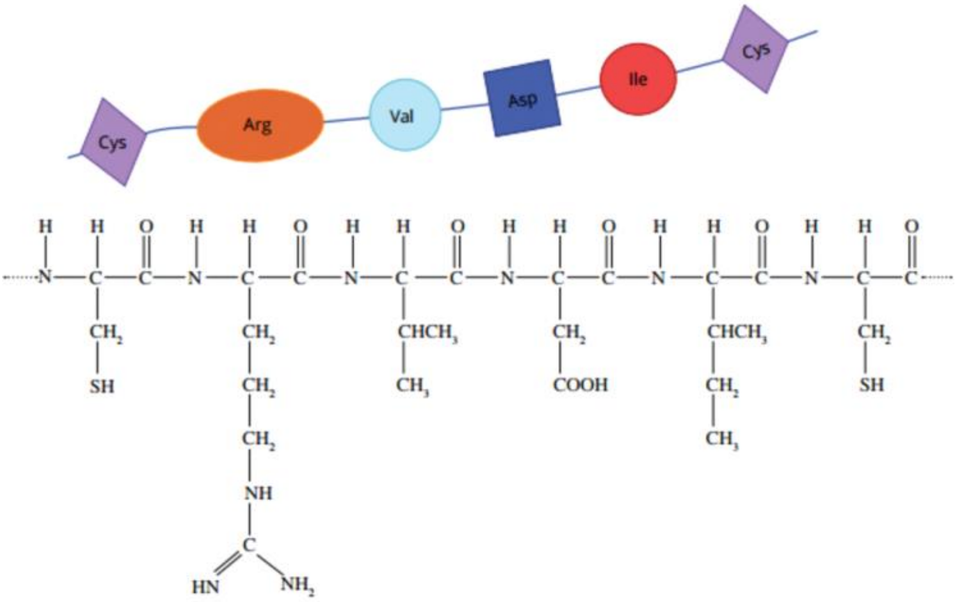
Tuesday, 17 September 2019 6:08 PM

Primary Structure of Proteins:

The number, type and sequence of the amino acids units in a protein

- The function of a protein is a consequence of its shape
    - Which is determined by the order in which amino acids are joined together
- The primary structure may be represented:
    - by three letter abbreviations for the amino acid
    - By structural formula of the protein
- It is written left to right (from N-terminal amino acid to C-terminal amino acid)

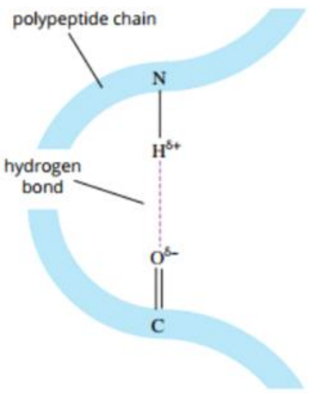
e.g.



- The three-dimensional shape of a protein is determined by the precise order which its amino acids are joined
    - Due to many interactions between nearby amino acids, leading to the folding of the protein chain

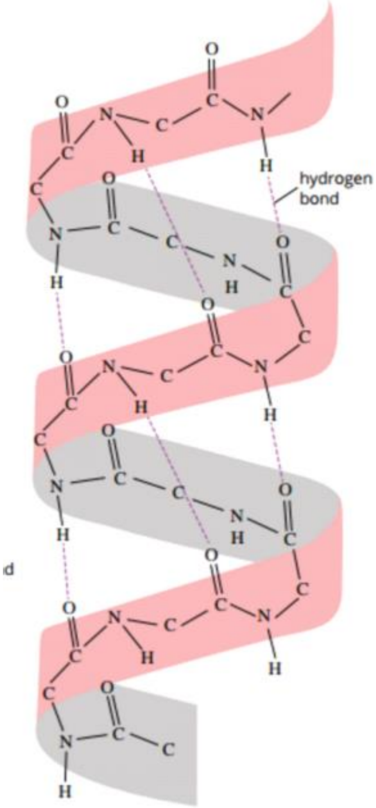
Secondary Structure of Proteins:

- Hydrogen bonds between the polar -NH group in one peptide link and the polar -C=O group in another peptide link can form at regular intervals
- This creates regions in which the molecule
    - coils into a spiral shape called an alpha helix
    - Or sections line parallel to each



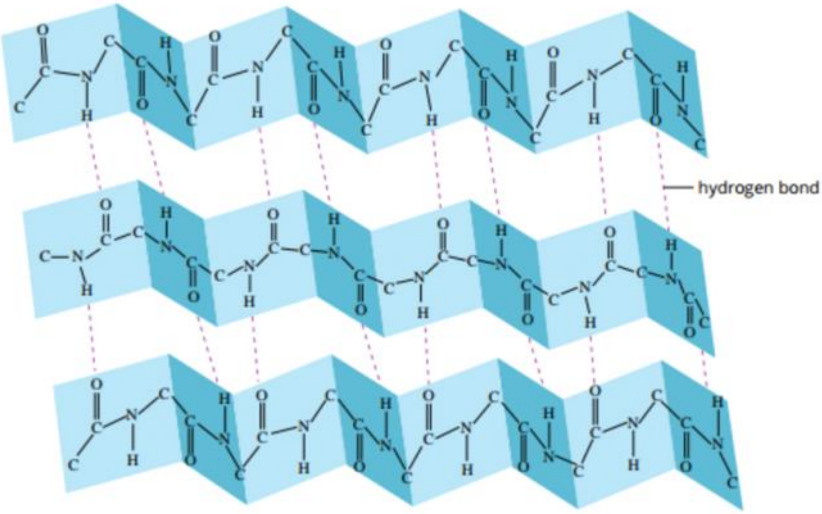
Alpha-Helices:

- Hydrogen bonding between the
    - ○ Partial positive end of a H from $-NH_2$
    - ○ Partial negative end of a O from -C=O
- The hydrogen bonds cause the molecule to join into the shape of an alpha helix



Beta Pleated Sheets:

- Hydrogen bonds can also form between peptide links to produce regions where two or more parts of the polypeptide chains line up parallel to each other
- The backbone of the protein chain (-N-C-C-N-C-C-N-C-C-) allows hydrogen bonds to form at regular intervals
- This stabilises the protein structure


hydrogen bond

17.4 Tertiary Structure of Proteins:

Wednesday, 18 September 2019 4:07 PM

Overall Shape of a Protein:

Tertiary Structure:

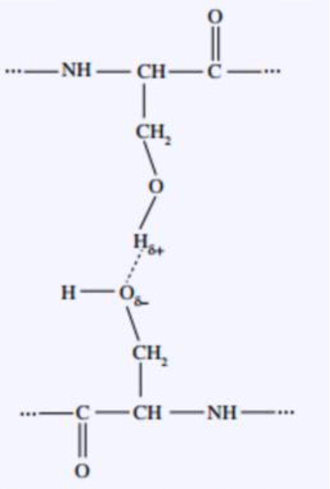
The overall three dimensional shape adapted by a protein molecule

- Produced by the three dimensional folding of its secondary structures
- The side chains of the amino acids units making up the polypeptide chain influence the overall three-dimensional shape of the molecule
- The side chains can interact with each other in a number of ways
    - Causing the protein to fold into its three-dimensional shape
- Amino acids tend to have **hydrophobic** chains
    - They tend to fold towards the interior of the protein molecule
    - Away from contact with water molecules

Bonding in the Tertiary Structure of Proteins:

Hydrogen bonds:

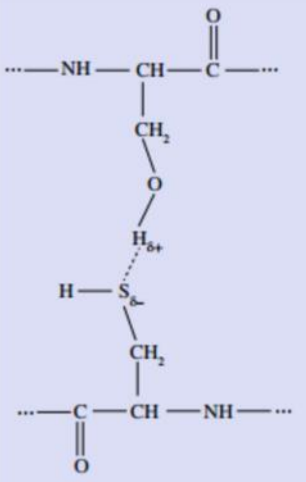
- Contains -O-H, -N-H or -C=O



A hydrogen bond linking two parts of a polypeptide chain

Dipole-Dipole Interactions:

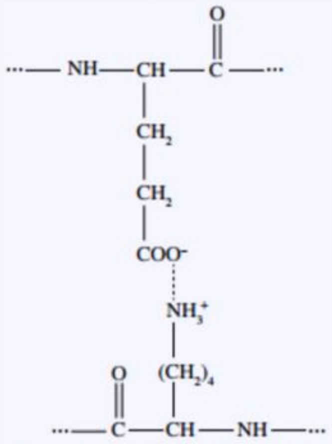
- Any polar group
- Such as those containing -S-H, -O-H or -N-H



A dipole–dipole interaction linking two parts of a polypeptide chain

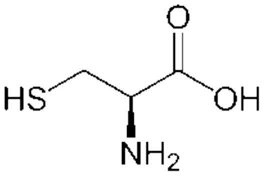
Ionic Interactions:

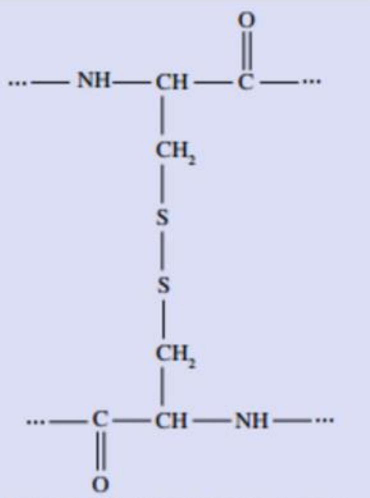
- Contains -NH_3^+ and another group that contains -COO^-



An ionic interaction linking two parts of a polypeptide chain

Covalent Cross-Links:

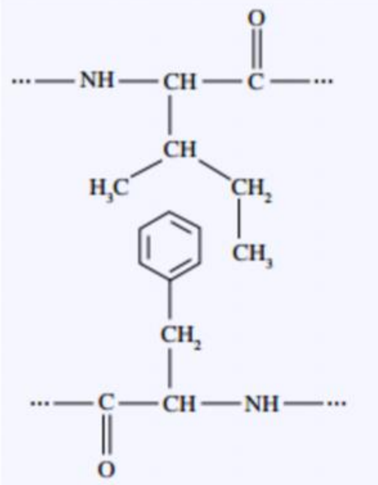
- Cysteine side groups react to form a disulfide bridge (-S-S-)
- 



A disulfide bridge linking two parts of a polypeptide chain

Dispersion Forces:

- Any non-polar group



Dispersion forces can link two parts of a polypeptide chain

18.1 Investigating Proteins:

Monday, 30 September 2019 10:07 AM

Role of Proteins In Biological Systems:

- The function of a protein depends on its three-dimensional shape
    - The specific sequence of amino acids in a protein results in a unique three dimensional shape
- Proteins can act as enzymes to catalyse biochemical reactions
- As a part of the immune system
- Assist with the transportation of substances across cell membranes

Protein Data Bank:

- Is a data bank that contains the amino acid sequence and three-dimensional shapes of large biological macromolecules
- It provides a mean for scientists to rapidly share their findings
- Its free
- Its on the internet
- It also includes a lot of additional information
    - The known function of the protein
    - Their location within the cell
- Understanding the structure of a large molecule helps us in understanding its function
    - Therefore helping us know its role in the human body

18.2 Enzymes

Monday, 30 September 2019 10:20 AM

Role of Enzymes:

- Enzymes are practically catalysts
    - They are able to increase the rate of reaction by providing an alternative reaction pathway with a lower activation energy , thereby increasing the proportion of reactant particles with sufficient energy to react

Similarities:

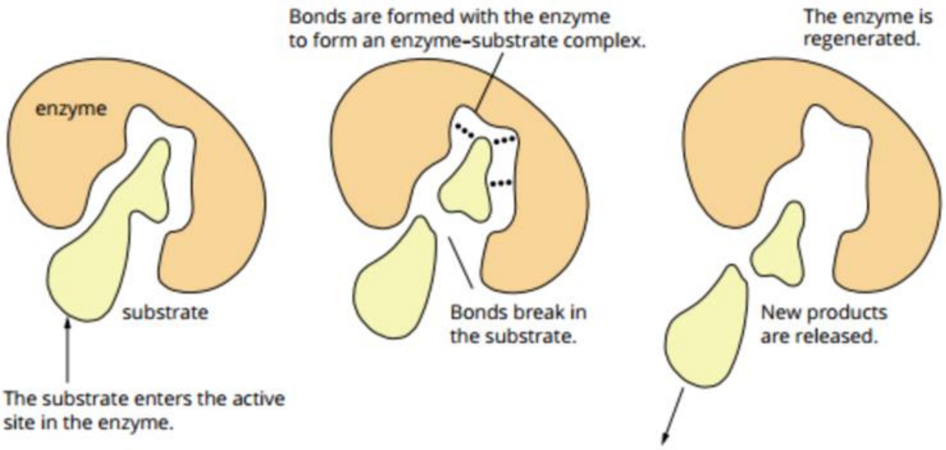
- Are only needed in relatively small amounts
- Are not used up or changed at the end of the reaction
- Do not alter a reactions equilibrium position

Differences:

- Inorganic catalysts can catalyse many different reaction
- **Specificity of Enzymes**
    - One the other hand enzymes can only catalyse one specific reaction or a reaction that involves a particular bond or functional group

Lock-and-Key Model of Enzyme Action:

- The catalytic activity of an enzyme is highly specific and depends on its overall three-dimensional structure
- Because they are a protein
    - Their three dimensional structure its dictated by their tertiary structure
- The specific part of the enzyme with which a reactant can interact is known as its **active site**
    - The site is usually a uniquely shaped flexible hollow cavity within the protein
- One of the earlier model of the catalytic action of an enzyme is the **Lock and Key Model**
    - It provides an explanation of the importance of the three dimensional shape of an enzyme
- In the lock and key model the substrate molecule fits into the enzyme like a key in a lock
    - It forms enzyme-substrate complex
    - Allowing the enzyme to break the bonds in the substrate



Induced Fit Model of Enzyme Action:

- Scientists have realised that enzymes have a flexible structure
- The shape of an enzyme's active site can be modified markedly by the binding of a substrate
- The induced fit model for enzymes can be applied to a larger number of chemical reactions

- The flexible active site can mould itself to achieve a better fit for substrate molecule
- After the reaction, the products are released from the active site and the active site returns to its initial shape
-

18.3 Enzyme: Dependence of pH and Temperature:

Monday, 30 September 2019 10:49 AM

Unlike inorganic catalysts, enzymes are very sensitive to their reaction condition

Dependence on pH:

- They are effective in a narrow pH range
- The pH at which the enzyme activity is the greatest is known as the optimum pH

Acid-Base Properties of Enzymes:

- Alpha amino acids can form zwitterions
- A zwitterions has a both positive and negative charge with in the molecule

Amino Acids have different charges depending on the pH of the surrounding environment

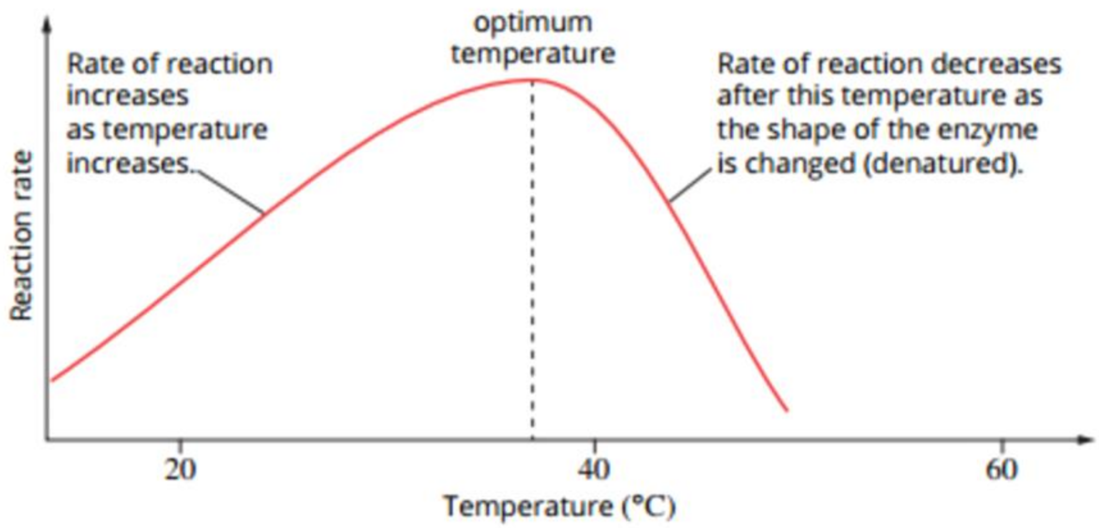
- At high pH, the $-NH_3^+$ group can act as an acid, donating a proton to become a $-NH_2^+$ group
- At a low pH, the $-COO^-$ group can act as a base, accepting a proton to become a $-COOH$ group

Low pH	Intermediate pH	High pH
$^+H_3N-CH(R)-COOH$	$^+H_3N-CH(R)-COO^-$	$H_2N-CH(R)-COO^-$
cation	Uncharged zwitterion	anion

- Intermolecular attractions between the side chains of a polypeptide maintain a protein's overall three-dimensional structure
- Some bonds that determine the tertiary structure of an enzyme may be disrupted as changes in pH alter the ionisation of some side chains
- Changes in pH have a large impact on the stability of enzyme structure
- As the tertiary structure of the enzyme is disrupted, the enzyme's active site changes shape and enzyme activity decreases
- At extreme cases of pH the enzyme will be denatured

Dependence on Temperature:

- Enzyme activity is also affected by temperature
- The temperature at which at which the enzyme activity is the greatest is known as the optimum temperature



High Temperature:

- The increased kinetic energy of the molecule disrupts the structure of the enzyme
- The increased movement throughout the enzyme breaks the intermolecular forces responsible for the tertiary structrue
- This change in the three-dimensional shape of the enzyme means the active site can no longer effectively catalyse the reaction
    - So the reaction rate decreases dramatically

Low Temperature:

- The enzyme and substrate molecules have lower kinetic energy
    - Resulting in less frequent and less energetic collisions between the molecules
- Also, according to the induced fit model, enzymes need a certain amount of flexibility so that the shape of the active site can change upon substrate binding

Denaturation

- Once the temperature becomes too high, the increased kinetic energy of the polypeptide chains of the enzyme break some of the bonds between the side chains of the amino acid units
- And new bonds are formed
- A change in the enzymes tertiary structure causes a change in the shape of the active site and the enzyme loses its catalytic activity

18.4 Enzymes in Industry

Monday, 30 September 2019 11:33 AM

Advantages:	Disadvantages:
• Enzymes are more specific, so that they can catalyse one particular reaction or type of reaction	• Enzymes are very sensitive to changes in temperature and pH. Reaction conditions must therefore be tightly controlled.
• In general, enzymes are effective at biological temperatures and pH levels. This saves energy and cost as high temperatures and pressure are not required	• Certain chemicals can also change the structure of enzymes and cause them to lose their function
• Enzymes are not consumes in the reaction, so they can be used for a long period of time	• Enzymes can be expensive to produce
• Enzymes are biodegradable and therefore cause less environmental pollution	• Enzyme-catalysed reactions generally take place in aqueous solutions. It can be difficult to separate the products from the reaction mixture

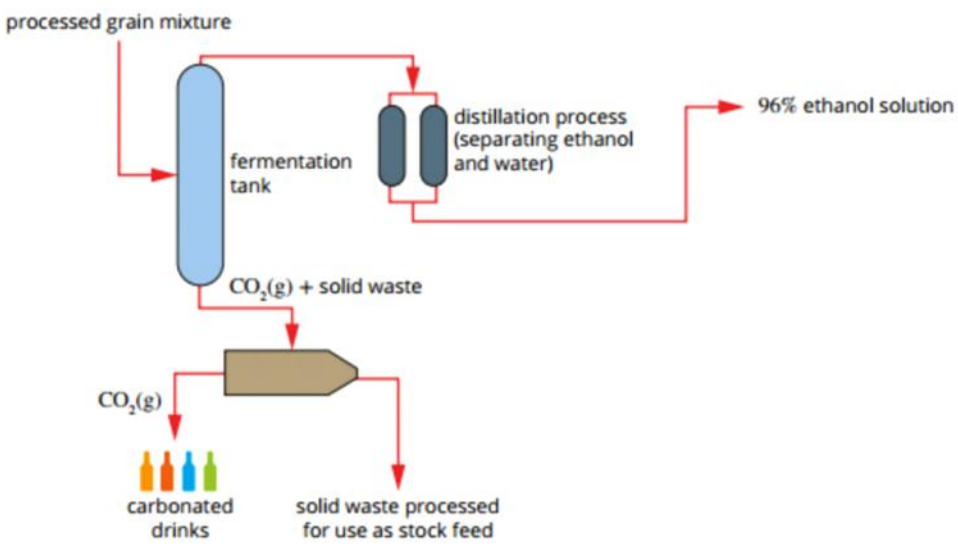
Production of Ethanol:

- It can be produced in two different processes:
  - Fermentation
    - An enzymatic process using corn, sugar cane or other grains as starting material
  - Hydrolysis of ethene
    - Which uses crude oil as a starting material

Fermentation:

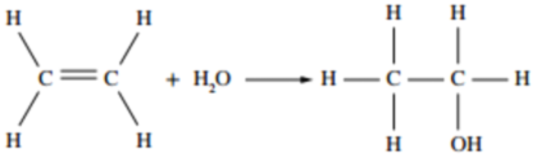
- Using enzymes to convert starches from grains and sugars to ethanol
- Enzymes are used to breakdown the polysaccharide starch to glucose
- Then the fermentation process uses other enzymes from yeast organisms to convert small sugar molecules, such as glucose and fructose, into ethanol and carbon dioxide

  $C_6H_{12}O_{6\,(aq)} \rightarrow 2CH_3CH_2OH_{(aq)} + 2CO_{2\,(g)}$
- Cellulose can also serve as a raw material for fermentation
- It reduces the need to dispose of waste materials in landfill or by burning
- The grains and other matter used for fermentation are prepared by:
  - Grinding and crushing
  - Adding water
  - Then heating to around 100*C in the presence of cellulase and amylase enzymes
  - This process breaks down the polysaccharides present in the raw material into simple sugars called monosaccharides that can undergo fermentation

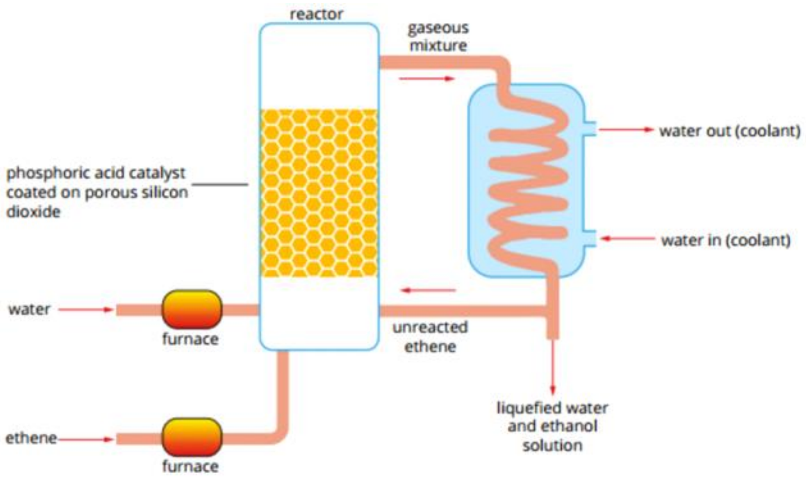


Industrial Production of Ethanol by Hydration of Ethene:

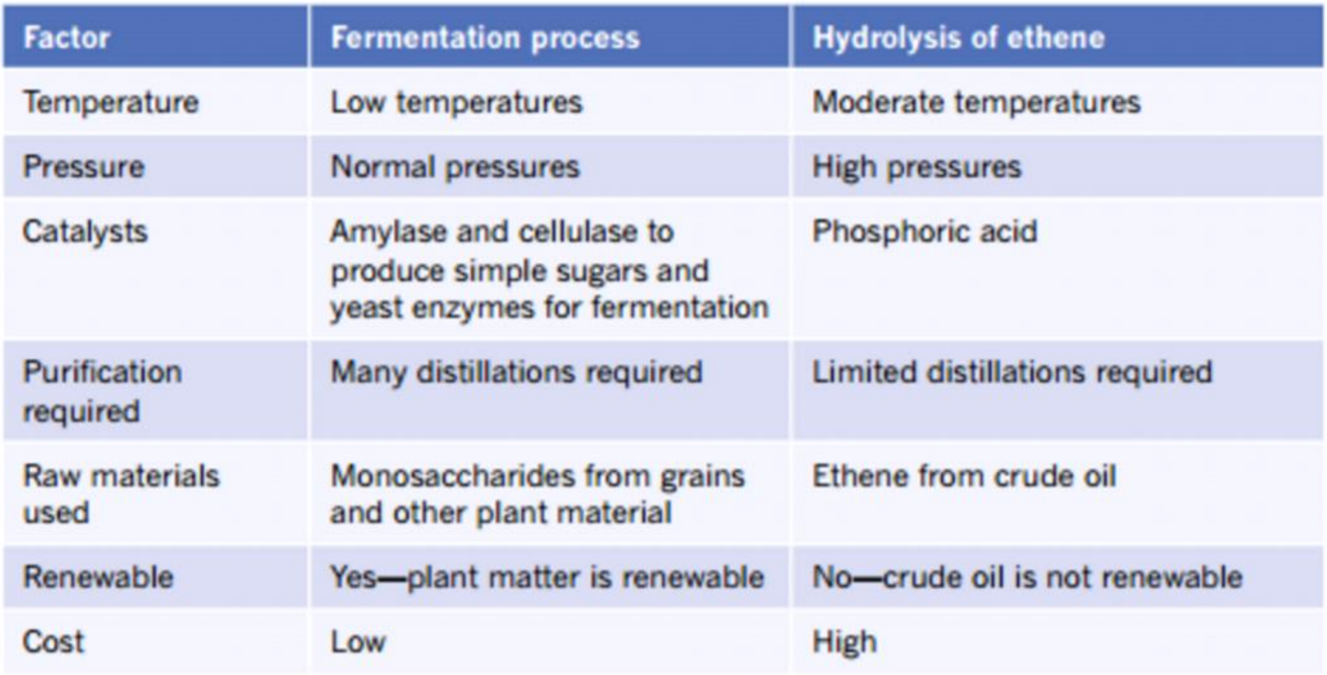
- Around about 10% of the words ethanol is produced this way
- Ethene is obtained from the catalytic cracking of larger hydrocarbon molecules in crude oil
- The ethene is then reacted with steam to produce ethanol



- The conditions for the reaction must be carefully selected to ensure that a compromise is reached between the reaction rate and yield
- The forward reaction is exothermic and there are more reactant gas particles than product gas particles
- A moderate temperature is used with a catalyst of phosphoric acid coated on a porous solid
- A relatively high pressure is used
  - As the cost associated with maintaining the reactants at high pressures is outweighed by the increase to reaction rate and yield.



Comparison of Industrial Methods for Ethanol Production:



Factor	Fermentation process	Hydrolysis of ethene
Temperature	Low temperatures	Moderate temperatures
Pressure	Normal pressures	High pressures
Catalysts	Amylase and cellulase to produce simple sugars and yeast enzymes for fermentation	Phosphoric acid
Purification required	Many distillations required	Limited distillations required
Raw materials used	Monosaccharides from grains and other plant material	Ethene from crude oil
Renewable	Yes—plant matter is renewable	No—crude oil is not renewable
Cost	Low	High

Saturday, 5 October 2019 12:51 PM

o

Liam

Jackson is a bad boy