

Industrial Chemistry

1. discuss the issues associated with shrinking world resources with regard to one identified natural product that is not a fossil fuel, identifying the replacement materials used and/or current research in place to find a replacement for the named material

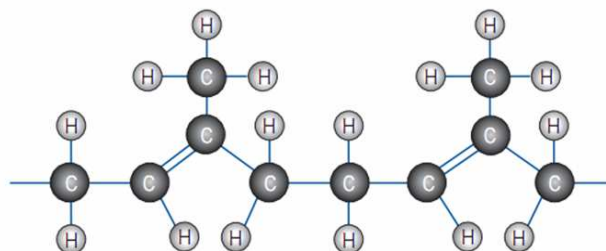
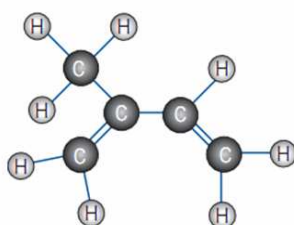
* identify data, gather and process information to identify and discuss the issues associated with the increased need for a natural resource that is not a fossil fuel and evaluate the progress currently being made to solve the problems identified

As the human population grows, there is increasing demand on world resources; yet the supply is finite and may not be renewable. Prolonged overuse of a natural resource leads to depletion or even permanent loss if it does not regenerate over time. Some resources cannot meet the demand, or cannot compete with cheaper synthetic alternatives or have largely been depleted, or cannot be used due to environmental or conservation considerations. As such, replacements need to be found.

The chemical industry is responsible for creation of these alternatives. They are used to replace substances no longer available or not economical, and generally have superior properties.

Named Product: Rubber (polymerised isoprene)

Natural rubber is an elastic hydrocarbon polymer that naturally occurs as a milky colloidal suspension, or latex, in the sap of some plants. The major source of natural rubber is/was from rubber trees. It is used extensively in many applications and products, such as car tyres, hoses, erasers, textiles, and gloves. It has many useful properties due to its unique nature. It is an elastomer and a thermoplastic and can be vulcanized.



Until the 1940s rubber had been obtained from plantations of rubber trees in tropical areas. In its pure form, it had limited usefulness. However, with sulfur cross-chain additives its hardness increased and made it less susceptible to chemical attack. Its demand in the automotive industry increased. Worldwide natural rubber supplies were limited and by mid-1942 most of the rubber-producing regions were under Japanese control. Military trucks needed rubber for tires, and rubber was used in almost every other war machine. The U.S. government launched a major (and largely secret) effort to develop and refine synthetic rubber.

Replacement Material: Synthetic Rubber (styrene-butadiene rubber)

As rubber is a hydrocarbon polymer, research centred around finding a substitute via petroleum refining. Styrene and butadiene are both by-products of petroleum refining and thus are readily obtained. Styrene-butadiene rubber is less likely to deteriorate and is also vulcanised. It remains the most important synthetic rubber and is used to manufacture car tires. There are a variety of monomers available, such as styrene-butadiene and chloroprene. These and other monomers can be mixed in various desirable proportions to be copolymerized for a wide range of physical, mechanical, and chemical properties. The monomers can be produced pure and addition of impurities or additives can be controlled by design to give optimal properties.

After the war, natural rubber plantations no longer had a stranglehold on rubber supplies, particularly after chemists learned to synthesize isoprene.

2. explain the effect of changing the following factors on identified equilibrium reactions
- pressure
 - volume
 - concentration
 - temperature

Recall from the module Acidic Environment the study of equilibrium reactions, and factor affecting the equilibrium position. These included pressure and volume, concentration, and temperature (depending on if the reaction is exothermic or endothermic). Some revision points on chemical equilibria:

- They are dynamic and involve reversible reactions, and can only be achieved in a closed system.
- Equilibrium is achieved when the rate of forward reaction equals the rate of the backward reaction.
- The position of the equilibrium describes the relative proportions of reactants and products at equilibrium. It depends on the pressure, volume, concentration of both products and reactants, and the temperature. When

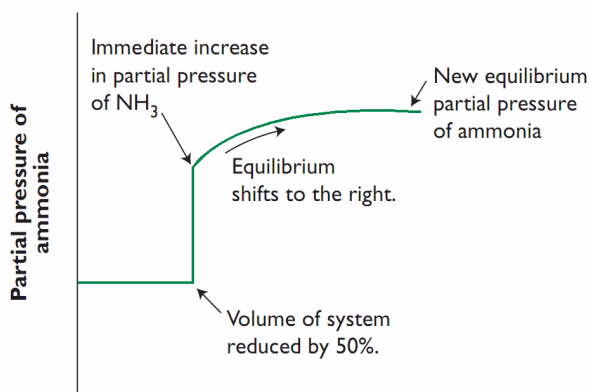
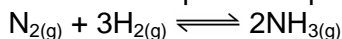
products dominate, equilibrium lies to the right; when reactants dominate, it lies to the right.

- Le Chatelier's Principle can be used to predict the response of an equilibrium system to a change in conditions.

Knowledge of the factors which affect equilibrium and how is important in industry, as industries must optimise yield to remain competitive.

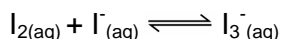
Pressure and Volume are related in considerations, as changing one while keeping the reactants the same will affect the other in the opposite manner (for example, decreasing pressure often means increasing volume and decreasing volume has the same effect as increasing pressure). Note that pressure changes only affect appreciably equilibria in the gaseous phase.

In some industries, chemical processes are carried out at high pressures to ensure high yield of product. An example is the previously studied Haber Process:



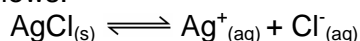
Changing the volume of a system, however, can affect not only gaseous systems but also ionic equilibria. The system acts in a similar way to the gaseous equilibrium; however, dissolved ions become analogous to moles of gas, while volume of water parallels the volume of the reaction chamber. If the equilibrium is disturbed, it shifts in such a way that the total

concentration of dissolved ions remains as close to before as possible. For example,



If we increase the volume of water, then the equilibrium shifts to the left in order to increase the concentration of dissolved ions. If we remove water (say, via evaporation) then the equilibrium shifts to the right to minimise the total amount of ions dissolved in the system.

The concentration of reactants and products in the system also affects the relative equilibrium position. An increase in reactant concentration shifts the equilibrium to the right; the same effect is achieved by removing products as the reaction progresses. An example is the continues liquefaction of ammonia in the Haber Process, and as follows:

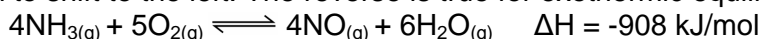


The removal of Ag^{+} by precipitation with S^{2-} will cause the $[\text{Ag}^{+}]$ to reduce, hence removing some products. As such, by Le Chatelier's Principle, more AgCl will dissolve due to the equilibrium shift to the product side.

Exothermic and endothermic chemical reactions are affected by changes in the temperature of the reaction vessel. Here we can treat latent heat as a reactant or product of reaction.

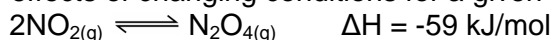
For example, $\text{CaCO}_{3(s)} \rightleftharpoons \text{CaO}_{(s)} + \text{CO}_{2(g)} \quad \Delta H = +178 \text{ kJ/mol}$
can be written as $\text{CaCO}_{3(s)} + \text{Heat} \rightleftharpoons \text{CaO}_{(s)} + \text{CO}_{2(g)}$

By Le Chatelier's Principle the increase in temperature will cause the equilibrium to shift in the right; a decrease in temperature will cause the equilibrium to shift to the left. The reverse is true for exothermic equilibria:



An increase in external temperature will shift the equilibrium position to the left to remove some of the heat produced; a decrease will shift it to the right.

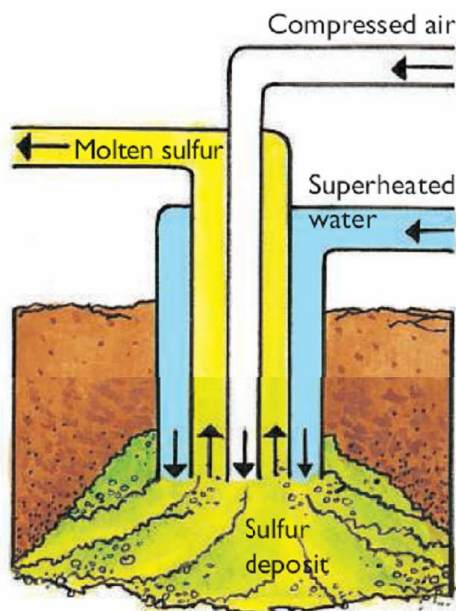
To summarise, the effects of changing conditions for a given equilibrium:



Change to condition	Effect on equilibrium position
Increase $[\text{NO}_2]$	Shift to right
Decrease $[\text{NO}_2]$	Shift to left
Increase $[\text{N}_2\text{O}_4]$	Shift to left
Decrease $[\text{N}_2\text{O}_4]$	Shift to right

	<div> <div>Increase Volume/Decrease Pressure</div> <div>Shift to left</div> </div> <div> <div>Decrease Volume/Increase Pressure</div> <div>Shift to right</div> </div> <div> <div>Increase Temperature</div> <div>Shift to left</div> </div> <div> <div>Decrease Temperature</div> <div>Shift to right</div> </div>	
* choose equipment and perform a first-hand investigation to gather information and qualitatively analyse an equilibrium reaction	<div> <div>• See Attachments</div> <div>• See Prac Book</div> </div>	
interpret the equilibrium constant expression (no units required) from the chemical equation of equilibrium reactions	<p>For a given chemical reaction</p> $aA + bB \rightleftharpoons cC + dD$ $K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$	
identify that temperature is the only factor that changes the value of the equilibrium constant (K) for a given equation	<p>Chemical systems reach equilibrium when the rate of forward reaction equals the rate of backward reaction. K is the equilibrium constant, and its value Temperature is the only factor which affects the equilibrium constant K. Regardless of any change in concentration, pressure, or volume, K remains the same as long as the temperature is constant. The species included in the reaction, however, are either all gaseous or all ionic. For example, for the equilibrium</p> $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$ $K = [Ag^+][Cl^-]$ <p>Similarly for</p> $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ $K = [CO_2]$ <p>For the Haber Process,</p> $K = \frac{[NH_3]^2}{[N_2][H_2]^3}$ <p>The units of the equilibrium constant vary with each equation and knowledge of them is not required by the syllabus.</p>	
* process and present information from secondary sources to calculate K from equilibrium conditions	<div> <div>• Skill</div> </div>	
* identify data, plan and perform a first-hand investigation to model an equilibrium reaction	<div> <div>• See Attachments</div> <div>• See Prac Book</div> </div>	
3. outline three uses of sulfuric acid in industry	<p>Sulfur can be used in industry for:</p> <ul style="list-style-type: none"> production of fertilisers such as superphosphate and ammonium sulfate pickling of steel to remove iron oxide coating prior to galvanising electrolyte in lead-acid automobile batteries 	
describe the processes used to extract sulfur from mineral deposits, identifying the properties of sulfur which allow its extraction and analysing potential environmental issues that may be associated with its extraction	<p>The Frasch Process is a method in which sulfur is extracted from naturally occurring elemental deposits. It has been used since the 1890s to extract vast deposits of sulfur, as it solved the problems of poisonous gas penetrating into mine shafts. Concentric pipes are bored down to an elemental deposit. Superheated water (170°C, 1.5MPa) is injected into the sulfur deposit through the outer pipe. Sulfur's melting point is low, so it is melted. Both liquids form an emulsion (foaming dispersion). Compressed air is injected down the central pipe, forcing the emulsion to the surface through the middle pipe. At the surface, this emulsion is collected in large vats and cooled. As this dispersion cools, it separates into water and solid sulfur (99.5% pure). It should be cooled quickly in order to avoid oxidation, which produces toxic SO₂.</p> <p>The properties of sulfur which allow for this extraction process:</p> <ul style="list-style-type: none"> Low melting point of 113°C due to weak dispersion forces (superheated water melts this easily) 	

- Insoluble in water and does not react with it chemically (allows it to be collected at surface)
- Low density (2.07g/cm^3) forms a sulfur-water emulsion that is light and can be readily transported to the surface with compressed air
- Inert, non-toxic and non-volatile, meaning no special precautions are required to protect health of miners



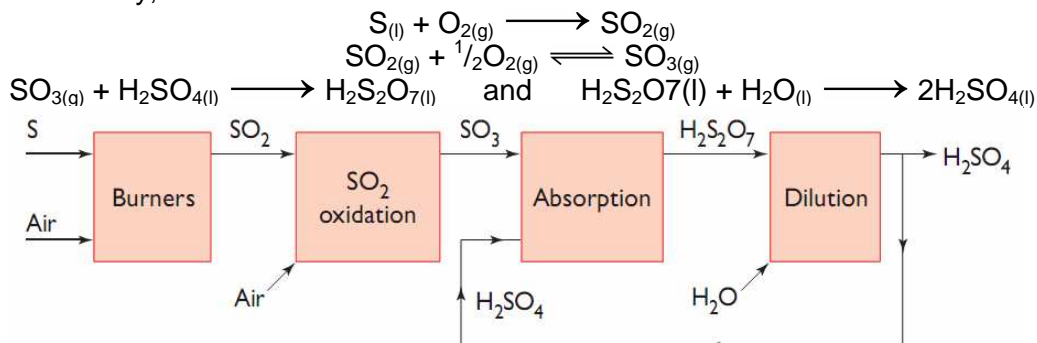
However, there are potential environmental issues. The recovered water contains some dissolved minerals. It also needs to be cooled to avoid thermal pollution, and should be recycled to avoid contamination of local ecosystems. Also, once the sulfur is extracted, the caverns remain and are prone to subsidence (collapse). They are difficult to backfill and can become filled with ground water over time.

outline the steps and conditions necessary for the industrial production of H_2SO_4 from its raw materials

describe the reaction conditions necessary for the production of SO_2 and SO_3

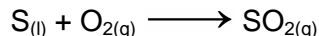
apply the relationship between rates of reaction and equilibrium conditions to the production of SO_2 and SO_3

The contact process is the main method used to produce sulfuric acid from elemental sulfur (or sulfur dioxide). There are four main steps. It is named after the contact which the sulfur dioxide and oxygen make with the catalyst. In summary, the reactions are:

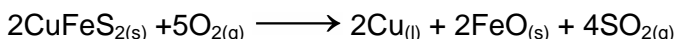


Step 1: Production of SO_2

If the process is started with elemental sulfur, it is first melted then sprayed into an excess of dry air at atmospheric pressure. The air is dried by passage through sulfuric acid, a dehydrating agent. This is done to avoid acid mist and corrosion in downstream pipes.

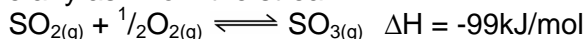


An excess of air (oxygen) ensures the sulfur reacts completely. The combustion of sulfur generates a lot of heat. It is necessary to cool the gas stream from 1000°C to around 400°C , the optimum temperature for the next step. Heat exchangers are used to remove and recycle this heat so it can be used to remelt more sulfur or power turbines for electrical energy. Alternatively, SO_2 can be obtained from the smelting of metal oxide ores. For example:



Step 2: Catalytic oxidation of SO_2 to SO_3

Clean, dry sulfur dioxide is the feedstock for this stage. Electrostatic precipitators are used to remove any ash from the stream.

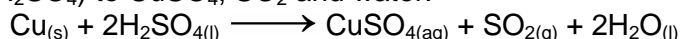


The sulfur dioxide is mixed with air at pressures slightly higher than atmospheric, and is passed through a catalyst tower, called a converter. The tower contains 3 or 4 layers of vanadium oxide catalyst. Unreacted gases are recycled back into the gas stream.

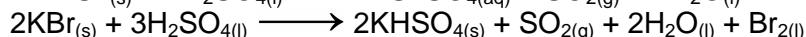
* gather, process and present information from secondary sources to describe the steps and chemistry involved in the industrial production of H_2SO_4 and use available evidence to analyse the process to predict ways in which the output of sulfuric acid can be maximised

	<u>Equilibrium Considerations</u>
	To maximise the yield (force equilibrium to the right) we would have : <ul style="list-style-type: none"> • excess oxygen • high pressure (due to 1.5:1 ratio) • low temperature (as reaction is exothermic)
	<u>Kinetic Considerations</u>
	To maximise the rate of reaction, we would have: <ul style="list-style-type: none"> • a catalyst • high temperature • high pressure (increasing frequency of collisions as concentration increases)
	<u>Energy Considerations</u>
	To minimise energy use (thus cost), we would have: <ul style="list-style-type: none"> • atmospheric pressure (as high-pressure containers are expensive) • no catalysts, as cost of researching, producing and using are them high • heating from exothermic reactions (combustion of sulfur)
	<u>Compromise Conditions</u>
	A gas pressure between 100 and 200 kPa increases the collision frequency between the reacting gases. They increase the yield by driving the reaction to the right (1.5 to 1 mole of gas). These pressures are also sufficiently low to avoid expensive apparatuses.
	An excess of oxygen will drive the reaction to the product side, increasing the yield. Thus, a 5:1 air:SO ₂ ratio is used (essentially 1:1 O ₂ :SO ₂) creating an excess of oxygen.
	If the temperature is too low then the reaction is slow. If the temperature is too high, then the yield will be too low, due to equilibrium considerations. Thus, compromise temperatures of 550°C (high rate, first bed), then 400°C (high conversion, later beds) are used.
	A catalyst is used to increase the rate of reaction, compensating for the lower temperature. Its identity is V ₂ O ₅ supported on a silica bed.
	Sulfur trioxide is removed from the reaction mix, just before the last bed, by passing it through an interpass absorption tower (producing oleum). It helps shift the reaction to the right and increase yield. As such, the gases removed to the atmosphere contain no more than 0.3% SO ₂ .
	In summary, the conditions for the conversion of SO ₂ to SO ₃ are: <ul style="list-style-type: none"> • Pressure slightly higher than atmospheric • Excess of oxygen (1:1 ratio)
	<u>Step 3: Absorption of SO₃</u>
	The cooled sulfur trioxide from the final catalyst bed is dissolved in 98% sulfuric acid in an absorption tower. The acid is sprayed over the SO ₃ and produces an oily liquid called oleum.
	$\text{SO}_{3(g)} + \text{H}_2\text{SO}_{4(l)} \longrightarrow \text{H}_2\text{S}_2\text{O}_7(l)$
	This is preferable to directly dissolving sulfur trioxide in water, as this forms sulfuric acid mists, due to the large heat of dissolution (130kJ/mol), which are very hard to control and difficult to coalesce. Also, it is difficult to separate the sulfuric acid gas from other gases, such as nitrogen.
	<u>Step 4: Conversion of oleum to H₂SO₄</u>
	In the diluter, water is mixed with oleum to produce 98% sulfuric acid (18M).
	$\text{H}_2\text{S}_2\text{O}_7(l) + \text{H}_2\text{O}(l) \longrightarrow 2\text{H}_2\text{SO}_{4(l)}$
	It is sold either as concentrated (98%) or diluted acid.
describe, using examples, the reactions of sulfuric acid acting as:	In dilute solutions of H ₂ SO ₄ hydronium ions act as oxidants, and reactive metals are oxidised by sulfuric acid releasing hydrogen gas. It reacts with elements higher on the activity series than hydrogen.
<ul style="list-style-type: none"> • an oxidising agent • a dehydrating agent 	$\text{Zn}_{(s)} + 2\text{H}_3\text{O}^+_{(aq)} \longrightarrow \text{Zn}^{2+}_{(aq)} + \text{H}_{2(g)} + 2\text{H}_2\text{O}_{(l)}$ <p>However, some reactive metals such as Al, Ni and Cr are not as readily attacked by sulfuric acid due to the formation of an inert passivating oxide layer on their surface.</p> <p>In concentrated sulfuric acid the sulfate ions are the oxidant, and it can only oxidise metals above lead in the activity series (and in some cases, the oxidation will cease rapidly as an insoluble product coats the material surface).</p>

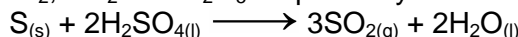
Hot, concentrated sulfuric acid oxidises metal copper (which does not react with dilute HCl or H₂SO₄) to CuSO₄, SO₂ and water.



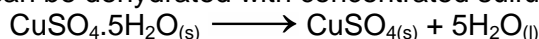
The sulfate ion is usually reduced to sulfur dioxide (but hydrogen sulfide or sulfur may be produced in certain cases). Concentrated sulfuric acid also oxidises bromide and iodide ions.



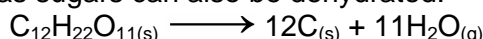
Hot concentrated sulfuric acid also oxidises non-metals such as carbon, sulfur and phosphorus to CO₂, SO₂ and P₂O₅ respectively.



Concentrated sulfuric acid readily absorbs water from the air (desiccating or dehydrating agent). It is thus used to dry the air used in the contact process. Hydrated crystals can be dehydrated with concentrated sulfuric acid.



Carbohydrates such as sugars can also be dehydrated.



The mixture caramelises, turning brown then black (black porous solid is mainly carbon). The heat from the reaction turns water to steam, causing the mass to expand. Carbon reacts with sulfuric acid in a second step to produce sulfur dioxide, carbon dioxide and water.

Concentrated sulfuric acid is also used to dehydrate ethanol to produce ethene, and is also a common catalyst to manufacture esters.

* perform first-hand investigations to observe the reactions of sulfuric acid acting as:

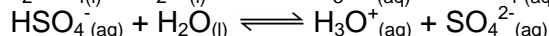
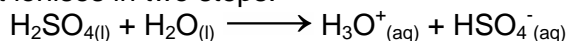
- an oxidising agent
- a dehydrating agent

- See Attachments
- See Prac Book

describe and explain the exothermic nature of sulfuric acid ionisation

identify and describe safety precautions that must be taken when using and diluting concentrated sulfuric acid

The dilution and ionisation of sulfuric acid in water generates considerable amounts of heat. It ionises in two steps:



Each step is an exothermic process, and the resulting solution can become very hot and boil if the volume of water is small ($\Delta H = -90\text{kJ/mol}$). This is due to the almost completely unionized form of 98% sulfuric acid, with water tied up in hydrates. In contrast, concentrated solutions of other acids already contain enough water so that they are all ionized, meaning less heat is released.

Sulfuric acid is also:

- A strong acid which can corrode metals and other materials and damage both structure and function of living organisms
- It acts as a strong oxidising agent, which allows it to attack materials which are normally resistant to attack just from hydrogen ions of simpler acids. It is also a strong dehydrating agent, easily destroying a wide range of organic materials (e.g. living tissue).

As such these procedures and precautions must be followed:

- Always wear protective goggles, gloves and a lab coat, as concentrated H₂SO₄ causes serious damage to skin and clothing, charring it (see dehydration of sucrose).
- When dilution H₂SO₄, add small volumes of concentrated acid to large volumes of water, stirring to disperse the heat. Also, when pouring, pour down the side of a glass rod to prevent splashing.
- Work near a running supply of water. If the acid contacts the skin, it must be washed off rapidly with copious amounts of tap water (however with large spills onto skin, wipe off excess first).
- Have a supply of neutraliser (sodium carbonate or bicarbonate) in case it is spilt. It should be first isolated to prevent it spreading and the area evacuated in case of fumes. Sand and a bucket can be used to clear acid for neutralisation.

- Store acid in smaller, easier to handle bottles (<1L). Avoid dribbling acid down the sides of containers, and wipe off any as soon as possible if present. Always place the bottle in a drip tray to ensure that drips do not contact the bench or shelf.

* use available evidence to relate the properties of sulfuric acid to safety precautions necessary for its transport and storage

98% sulfuric acid is almost completely molecular and has not ionised, meaning that it does not attack either iron or steel, as a passivating layer forms. It can be thus safely stored in steel or iron containers or transported in tankers. Steel is stronger than glass or plastic, and is less likely to rupture if there is an accident. It is preferable to transport concentrated rather than dilute acid as it is cheaper per mole of H_2SO_4 and allows transport in steel containers rather than more fragile glass or plastic.

Diluted sulfuric acid contains hydronium ions and vigorously attacks metals, meaning dilute acid must be stored in glass or plastic containers. This also means, when storing or transporting 98% sulfuric acid, care must be taken to avoid contamination with water. This means the containers must be well sealed. It should be stored well away from metals (especially metal powders), bases and water, as exothermic reactions will occur. It should be stored away from wooden shelves or metal trays.

4. explain the difference between galvanic cells and electrolytic cells in terms of energy requirements

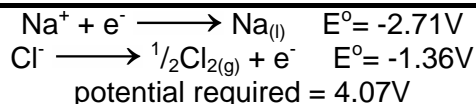
	<p>Galvanic cells convert stored chemical potential energy into electrical energy. In order to do so, they use spontaneous redox reactions to create an electron flow between species. Their compartments need to be separated so that electron flow can be collected in an external circuit.</p> <p>For example, the pictured cell will produce 1.10V at standard conditions, from the spontaneous reaction:</p> $\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \longrightarrow \text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)}$ <p>Copper will be deposited on the cathode while the zinc anode will oxidise.</p>
	<p>Electrolytic cells convert external DC electrical energy into chemical energy in order to drive a non-spontaneous reaction. The polarities of the anode and cathode in this cell, however, are reversed.</p> <p>For example, the cell pictured required 1.10V at standard conditions in order to drive the non-spontaneous reaction:</p> $\text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)} \longrightarrow \text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)}$ <p>Zinc will be deposited on the cathode while the copper anode will oxidise.</p>

Cell Feature	Galvanic Cell	Electrolytic Cell
Oxidation at	anode (-)	anode (+)
Reduction at	cathode (+)	cathode (-)
Electron flow in external circuit	from anode to cathode	from negative battery terminal to cathode and from anode to positive battery terminal
Net Cell Reaction	spontaneous	non-spontaneous
Electrical Energy	produced	required

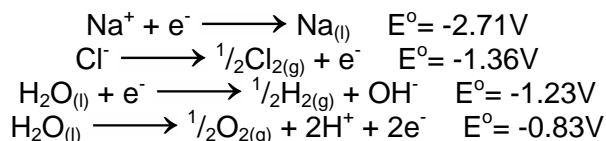
* analyse information from secondary sources to predict and explain the different products of the

In molten sodium chloride, there are only two species present, chloride and sodium ions. The obvious products thus are pure sodium and gaseous chlorine, as only two reactions can happen (note, however, that the reduction of sodium and oxidation of chlorine will be extremely difficult and will not occur).

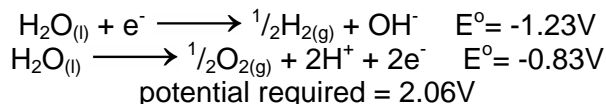
electrolysis of aqueous and molten sodium chloride



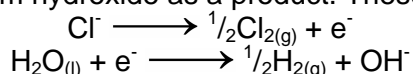
Aqueous sodium chloride, however, has three species (since water is now present). Thus, these reactions are possible (with potentials at standard conditions).



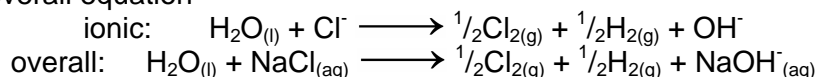
However, the reactions preferred are those with the lowest energy requirements.



We wish to obtain sodium hydroxide as a product. These reactions must occur:



For an overall equation



To achieve this reaction, we need to diverge from standard conditions. This can be done by using a concentrated solution of NaCl (brine). The higher concentration of chloride allows its reduction to be done more readily, more so than the reduction of water.

* identify data, plan and perform a first-hand investigation to identify the products of the electrolysis of sodium chloride

- See Attachments
- See Prac Book

outline the steps in the industrial production of sodium hydroxide from sodium chloride solution and describe the reaction in terms of net ionic and full formulae equations

distinguish between the three electrolysis methods used to extract sodium hydroxide:

- mercury process
 - diaphragm process
 - membrane process
- by describing each process and analysing the technical and environmental difficulties involved in each process

Sodium hydroxide is an important chemical in industry. It is generally made from the electrolysis of brine. As chlorine is a significant by-product, its production is called the chlor-alkali process.

Two initial methods of producing sodium hydroxide from electrolysis of brine are the mercury and asbestos processes. They start from the process of brine purification, which removes calcium and magnesium impurities.

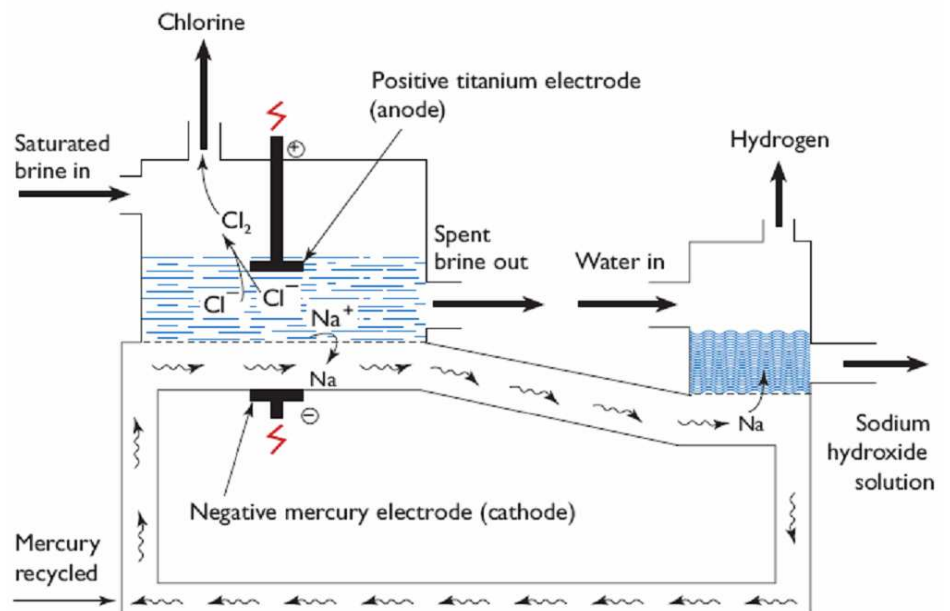
Impurity	Reactant	Equation
Ca^{2+}	CO_3^{2-}	$\text{Ca}^{2+} + \text{CO}_3^{2-} \longrightarrow \text{CaCO}_{3(\text{s})}$
Mg^{2+}	OH^-	$\text{Mg}^{2+} + \text{OH}^- \longrightarrow \text{Mg}(\text{OH})_{2(\text{s})}$
Fe^{3+}	OH^-	$\text{Fe}^{3+} + \text{OH}^- \longrightarrow \text{Fe}(\text{OH})_{3(\text{s})}$
Ca^{2+}	SO_4^{2-}	$\text{Ca}^{2+} + \text{SO}_4^{2-} \longrightarrow \text{CaSO}_{4(\text{s})}$
SO_4^{2-}	CaCl_2 or BaCl_2	$\text{Ca}^{2+} + \text{SO}_4^{2-} \longrightarrow \text{CaSO}_{4(\text{s})}$

Subsequently the purified brine can be processed in three different ways:

Mercury Process

This cell is designed to ensure that the products are kept separate (hydrogen and chloride together are explosive).

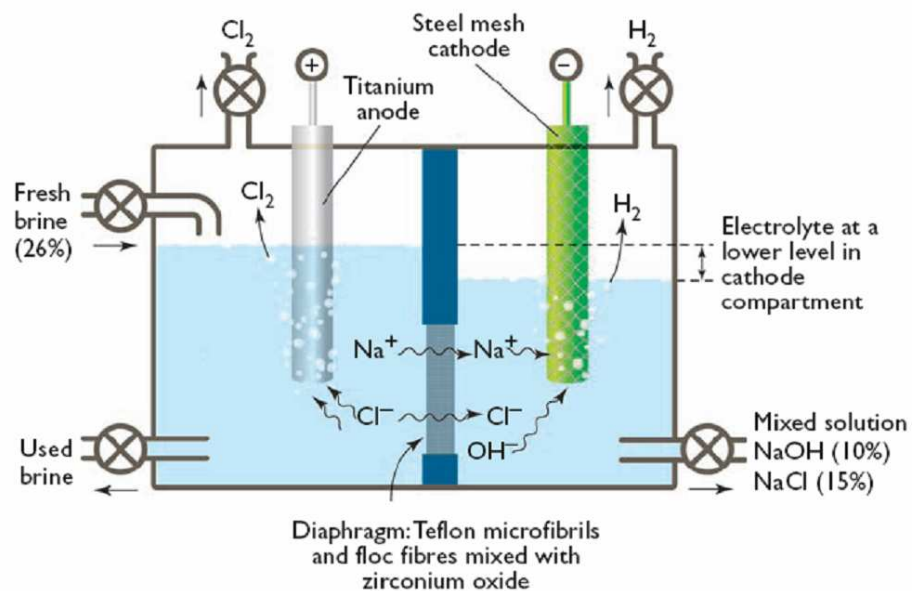
- The water is saturated with purified salt (26% v/v) to form concentrated brine. Titanium plates are used as the anode.
- Chloride ions are oxidised at the anodes to form chlorine gas, which is removed from the cell. It is washed and dried before compression into cylinders.
- Mercury forms a flowing liquid cathode at which sodium ions are preferentially reduced to sodium metal, rather than water being reduced to hydrogen gas and hydroxide ions. The sodium metal rapidly dissolves in mercury to form an amalgam (alloy of sodium and mercury).
- This amalgam flows into another chamber, which contains pure water. The sodium reacts with water and the amalgam decomposes. Hydrogen gas and sodium hydroxide solution are formed. The mercury is recycled.



Diaphragm Process

The diaphragm cell consists of two compartments separated by a porous diaphragm (traditionally asbestos). As in the mercury cell, the anode is made from titanium and the cathode from steel mesh.

Chlorine is oxidised at the anode to produce chlorine gas, which is constantly pumped out. At the cathode, water is reduced to form hydrogen gas and hydroxide ions. The electrolyte in both compartments is concentrated brine, but the level in the cathode compartment is lower, to reduce mixing (contamination). The resultant solution contains 10% NaOH and 15% NaCl . To remove the unwanted NaCl , the solution is fractionally crystallised by cooling, and NaCl is less soluble than NaOH and so precipitates out, leaving a solution of 50% NaOH and 1-2% NaCl .

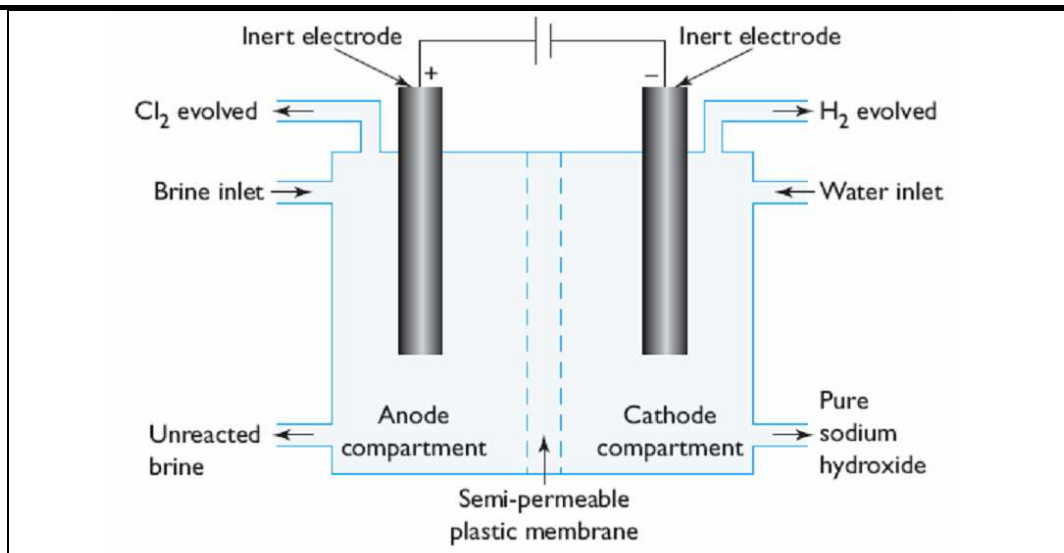


Membrane Process

The membrane cell can produce NaOH with a salt impurity of about 0.02% only and thus is very pure. It operates in a similar fashion to the diaphragm cell.

The anode is made of titanium metal and the cathode of stainless steel mesh. Ion-selective membranes were developed that prevent the movement of chloride ions and hydroxide movement across the membrane while still allowing the movement of ions. The resultant NaOH solution is concentrated to around 50% using heat from steam.

Also, pure water or dilute NaOH is used for the cathode compartment rather than NaCl .



- See Cell Comparisons Attachment

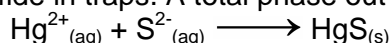
Pollution and Health Issues

Mercury:

Although the mercury in the mercury cell is recycled there is inevitably loss into the environment. Waste water usually contains dissolved mercury (traditionally 200g per tonne). This waste water causes the mercury to enter the food chain via seafood.

Mercury is a toxic heavy metal and poisons the nervous system, leading to mental degeneration and loss of motor control.

The plants which still use mercury are required to remove it. This can be done by precipitation with sulfide in traps. A total phase out is expected soon.



Asbestos:

Asbestos is a carcinogenic substance and can lead to lung diseases. Its use was eventually banned and led to the development of polymer diaphragms instead.

Other:

The disposal of chlorinated water into the environment is detrimental. Thus environmentalists pressure the plants to reduce such waste water.

The high energy requirements of the chlor-alkali industry are an environmental concern as such energy required combustion of fossil fuels. This release carbon dioxide into the atmosphere and enhances the greenhouse effect.

Product Purity and Quality Control

Industrial chemists working in this industry monitor the purity of their products and feedstocks to maximise profit. They use the techniques:

- acid-base titration of NaOH
- AAS to determine level of Ca, Mg impurities in brine
- gravimetric analysis to determine moisture content of Cl_2 produced
- ion-selective electrode to monitor concentration of ions such as chloride

Site Location

When choosing a location for a chlor-alkali plant the following factors should be considered:

• Location of Markets:

The new plant should be close to other industries which use its products (e.g. petrochemical plants which use chlorine to make PVC). They are usually located near major cities.

• Energy:

This industry requires a large amount of energy and thus vast amounts of electricity should be available.

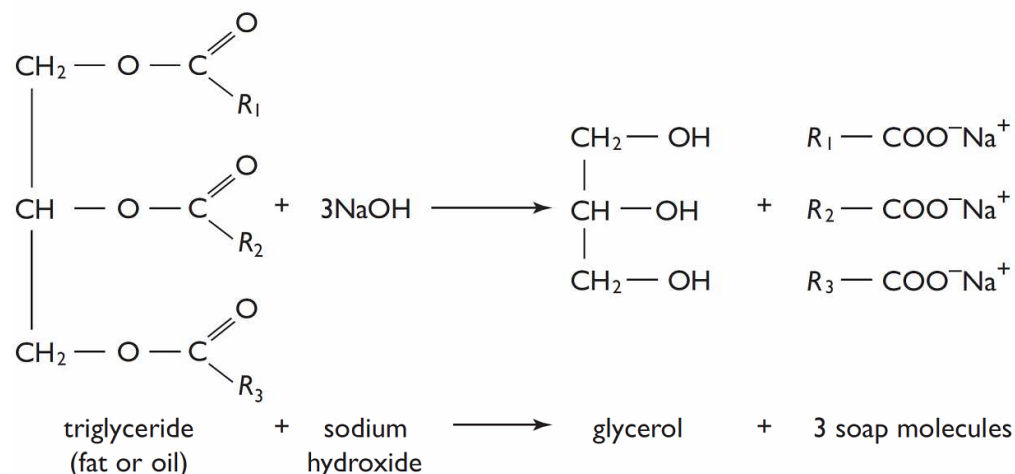
• Raw Material and Feedstocks:

Brine or salt should be readily available, meaning many plants are located near the coast. The waste brine should also be able to be discharged into the environment safely and cause minimal pollution.

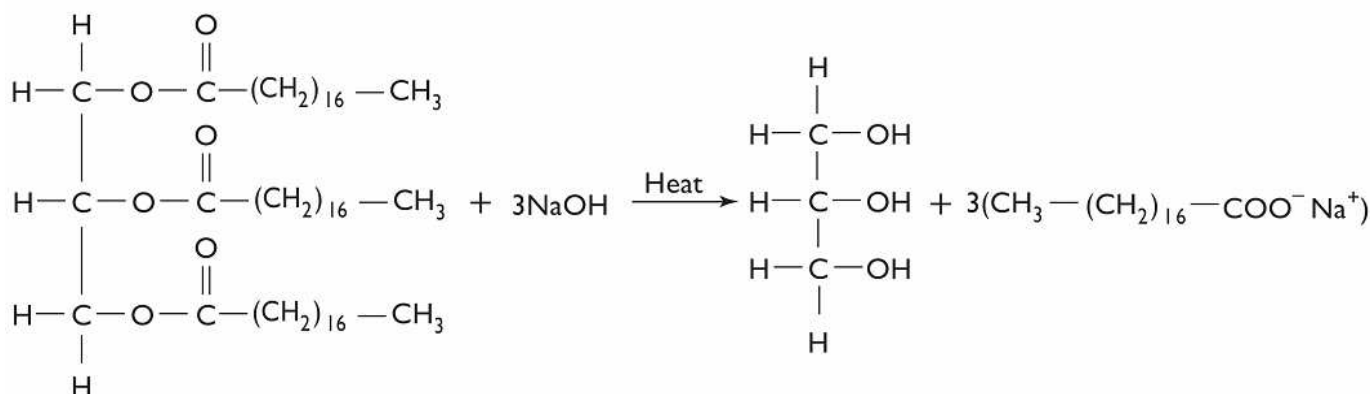
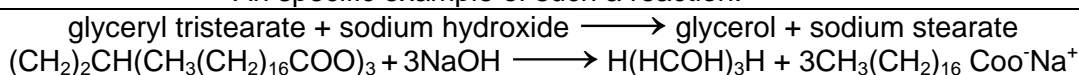
- **Transport Networks:**
Site should be close to transportation such as road, rail or shipping. In some industries products should be transported efficiently. The products should not need to be transported too far before overseas shipping.
- **Scientists, technicians and site workers:**
A large workforce is required and many chemical jobs required tertiary education. Close placement to a large population centre is good.

5. describe saponification as the conversion in basic solution of fats and oils to glycerol and salts of fatty acids

Saponification is the process of making soap, from the chemical reaction in which fatty esters (fats and oils) are hydrolysed in basic conditions. This process converts fats and oils, via a basic reaction medium, to salts of these fatty acids.



An specific example of such a reaction:



describe the conditions under which saponification can be performed in the school laboratory and compare these with industrial preparation of soap

- See Attachments
- See Prac Book

The laboratory preparation of soap (known as the cold process) involves the following steps:

1. Cofa (solid coconut oil) is melted in a saucepan (over a hot plate). Some castor oil is added.
2. Concentrated sodium hydroxide is heated to about 37°C
3. The sodium hydroxide is then stirred into the coconut oil.
4. This mixture is heated and stirred for up to 40 minutes. This can be stopped when the mixture is successfully traced (indicating it has reached a suitable thickness).

5. It is then poured into a mould and allowed to solidify over time.

It is possible to add saturated salt water solution to the mixture in order to force the soap to precipitate out (this process is called 'salting out').

The industrial preparation of soap is much different. We will discuss two of the three main processes:

- Kettle boiled batch process:

This process is carried out in large, heated, pressurized steel containers called kettles. The fats and oils are first mixed with concentrated sodium hydroxide in the kettles. The mixture is boiled using high-pressure and high-temperature steam (from injectors in the kettle). Additional hot brine and steam are added at

the end of saponification to salt out the soap and wash it free of glycerol. The mixture settles for several days and the soap curd eventually collects at the surface. The brine, glycerol and soap curds are separated from one another and individually collected.

The soap is washed with water and then spray and vacuum dried. It is converted into small pellets with fragrances and colours before reblending and reprocessing into the desired form (liquid, powder or bars).

• Fatty acid neutralization process:

This process occurs in two steps. In the first step, high pressures (5MPa) and temperatures (250°C) are used to break down fatty esters, with steam, into fatty acids and glycerol. The reaction is carried out in long steel tubes (20m long x 1m diameter) in the presence of a zinc oxide catalyst. These are fractionally distilled and various mixtures of these are used in the second step.

In the second step, the fractions are stoichiometrically neutralised with hydroxides to produce soap. The soap is recovered by salting out as usual, and processed.

Similarities	<ul style="list-style-type: none"> Fats and oils are mixed with concentrated alkali and heated. The crude soap is washed.
Differences	<ul style="list-style-type: none"> A blend of fats and oils is used in industry rather than one fat or oil used in the laboratory. Concentrated brine is used to separate the soap from the aqueous phase in industry. High-pressure steam is used to heat and stir the mixture in industry; a glass rod and a hotplate are used in the laboratory. The glycerol is removed and purified in industry; in the laboratory, some glycerol remains in the soap. In industry, settling of the soap occurs over several days; in the laboratory the soap is relatively crude. No fragrances or colours were added to the soap produced in the laboratory.

* gather, process and present information from secondary sources to identify a range of fats and oils used for soap-making

<u>Fat or Oil</u>	<u>Property</u>
Tallow	<ul style="list-style-type: none"> common animal fat from beef/sheep processing makes a hard, greasy soap
Lard	<ul style="list-style-type: none"> derived from pigs produces hard soap, lathers quickly but does not dissolve readily
Coconut Oil	<ul style="list-style-type: none"> derived from pressed, dried fruit of coconut palm produces soap which lathers in salty or hard water
Palm Oil	<ul style="list-style-type: none"> derived from flesh of palm fruit long hydrocarbon chains give it properties more like tallow than other vegetable oils

* perform a first-hand investigation to carry out saponification and test the product

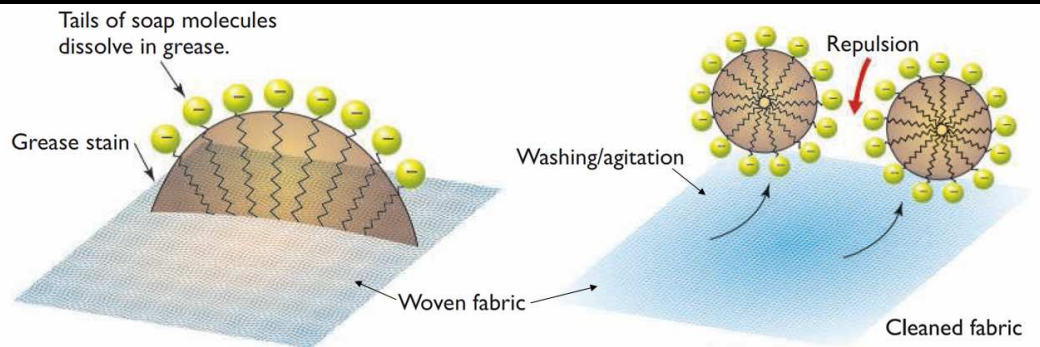
- See Attachments
- See Prac Book

explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier

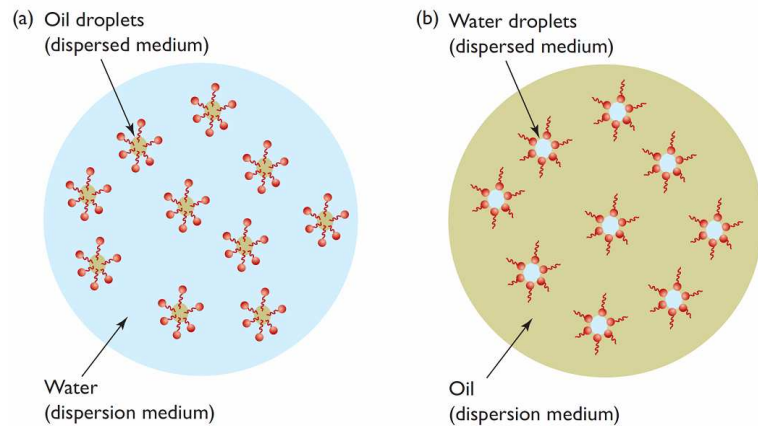
An emulsion is a type of dispersion in which two normally immiscible substances are stabilised by another substance, called an emulsifier. For example, olive oil and water will not dissolve in one another, as their intermolecular forces differ (like dissolves like). While we can agitate to form a suspension, it is temporary only and the oil and water will eventually separate into distinct layers.

Soap (once dissociated in water) consists of a non-polar hydrocarbon tail which forms dispersion forces, and a polar head, which forms dipole-dipole and hydrogen bonds with water.

The presence of soap in a mixture of oil/grease and water will create an emulsion upon agitation. The hydrocarbon tails of soap dissolves in the oil and promotes droplet formation. These droplets repel each other, as they have the same net negative charge. These individual droplets can be dissolved in water as they form ion-dipole interactions.



There can be oil-in-water or water-in-oil emulsions, where soap is the emulsifier.

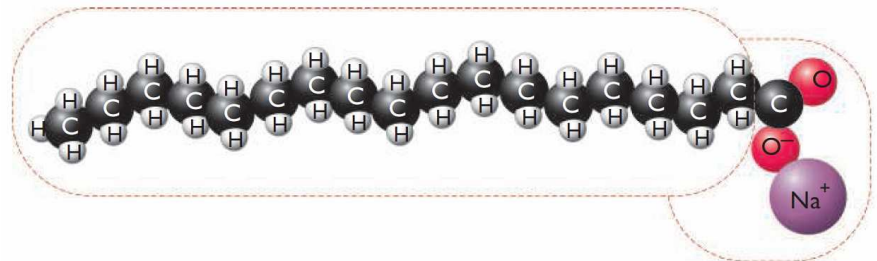


account for the cleaning action of soap by describing its structure

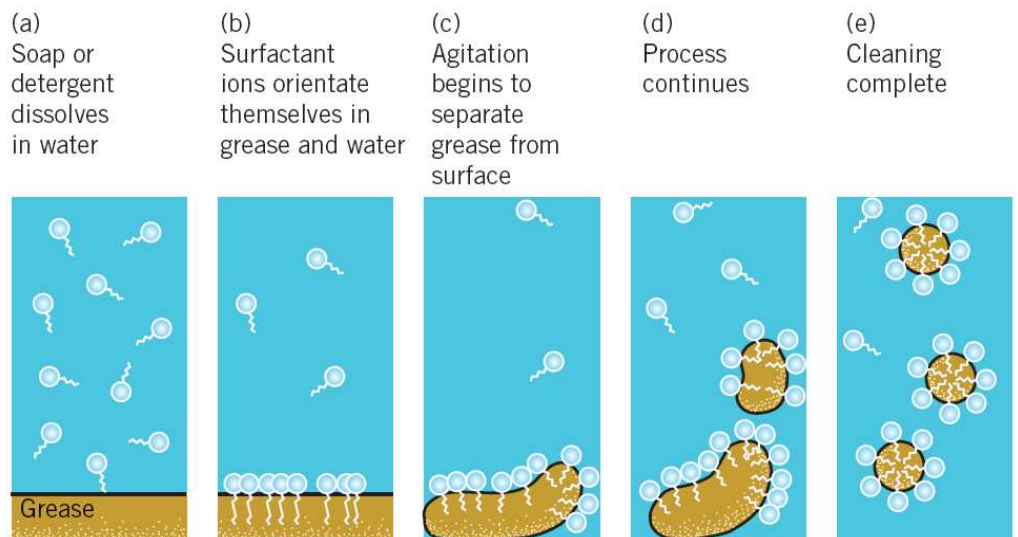
Soaps are a non-petrochemical, non-synthetic cleaning agent and can be used to clean skin or wash clothes. The greasy stains can be removed by soap's surfactant properties.

Soaps (once dissociated in water) consist of:

- a hydrophobic (water-repelling), non-polar alkyl (hydrocarbon) tail that can form dispersion forced with oils
- a polar, negatively charged, hydrophilic (water-loving) carboxylate head that can form ion-dipole and dipole-dipole interactions with water, as well as hydrogen bonds



When a greasy stain is added to a soap-water mixture, the long hydrocarbon tails of the soap start to dissolve in the stain. The charged heads remain at the surface of the grease, interacting with the water molecules. These interactions are due to the fact that 'like dissolves like.'



The non-polar carbon chain forms dispersion forces with the grease while the charged polar head forms dipole-dipole and hydrogen bonds with the water, allowing interaction. Thus, the long hydrocarbon tail sticks in the oil and grease and the polar anionic end sticks out into the water.

Agitation then allows the soap-grease to be lifted clear of the surface. These stabilise to form an emulsion, as the negatively charged heads repel each other and prevent the micelles from grouping again. Excess soap also forms a lather of soap, water and air, and helps to suspend the grease. This allows for soaps to remove the fats or oils (greasy substances) from a surface, as excess water and agitation flushes the grease or dirt away.

- * perform a first-hand investigation to gather information and describe the properties of a named emulsion and relate these properties to its uses

- See Attachments
- See Prac Book

- * perform a first-hand investigation to demonstrate the effect of soap as an emulsifier

- See Attachments
- See Prac Book

distinguish between soaps and synthetic detergents in terms of:

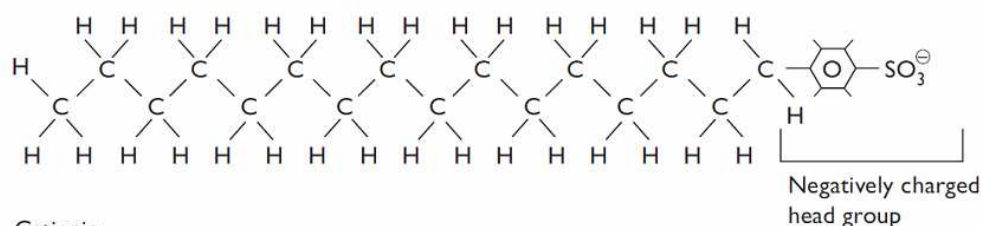
- the structure of the molecule
- chemical composition
- effect in hard water

Synthetic detergents were developed in order to replace soaps for cleaning, to overcome some of soap's shortcomings. This included soap's inability to lather in hard or acidic water and its possible shortages, as it is reliant on fats and oils. Synthetic detergents are derived from the petrochemical industry. There are three main classes of detergents: anionic, cationic, and non-ionic.

Examples of detergent:

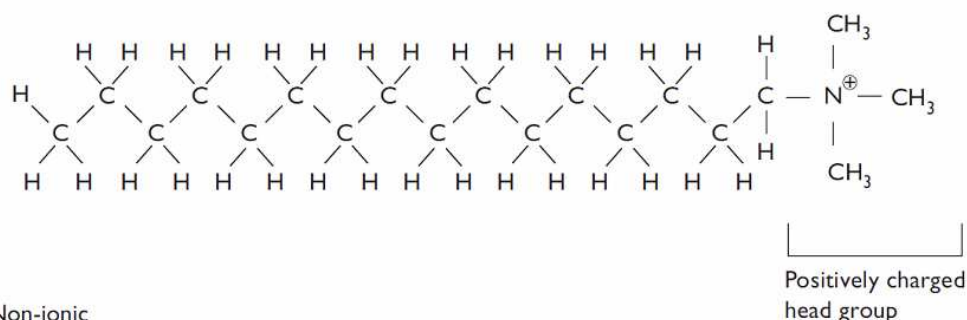
Anionic

e.g. Alkyl benzenesulfonate detergent



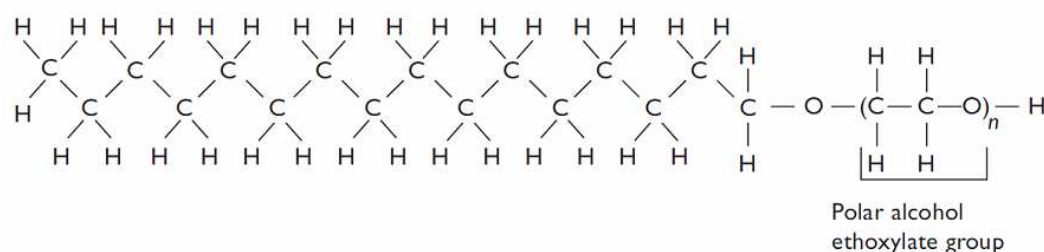
Cationic

e.g. Quaternary ammonium detergent



Non-ionic

e.g. Alcohol ethoxylate detergent



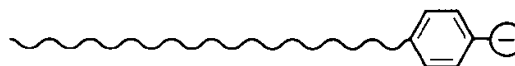
Surfactant	Structure and Chemical Composition
Soap	Soaps consist of a long hydrocarbon tail with a short negatively charged carboxylate head. Their chemical composition is usually $\text{CH}_3(\text{CH}_2)_n\text{COO}^- \text{Na}^+$.

Anionic synthetic detergent	Anionic detergents consist of a long hydrocarbon tail and a negatively charged head group. However they differ from soaps in that the head is a different ion to carboxylate. Common anionic detergents include alkyl benzenesulfonates and alkyl phosphates, where the heads are benzenesulfonate or phosphate ions respectively. A possible (typical) chemical composition is $\text{CH}_3(\text{CH}_2)_n(\text{C}_6\text{H}_5)\text{O}(\text{SO}_2)\text{O}^- \text{Na}^+$.
Cationic synthetic detergent	These detergents consist of a long hydrocarbon tail with a positively charged head, which is usually a quaternary ammonium group (alkyl ammonium group). There can be one or two long alkyl chains connected to the nitrogen, with two or three methyl groups. The negative ion is often a halide (e.g. Br^- or Cl^-). Sometimes the positive head is a pyridium group. A possible (typical) chemical composition is $\text{CH}_3(\text{CH}_2)_n\text{N}^+(\text{CH}_3)_3 \text{Cl}^-$.
Non-ionic synthetic detergent	These are characterized by the presence of hydrophilic groups rather than charged heads. They consist of a long hydrocarbon tail, and a polar alcohol ethoxylate (polyoxyethylene ethers) group. They are molecules, not ions. A typical chemical composition would be $\text{CH}_3(\text{CH}_2)_n\text{O}(\text{CH}_2\text{CH}_2\text{O})_n(\text{CH}_2)_2\text{OH}$. The 2 nd n varies from 5 to 50.

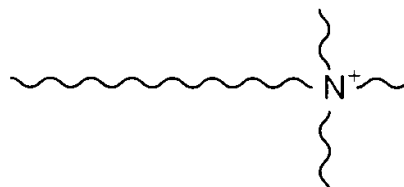
soap



anionic



cationic



non-ionic



<u>Surfactant</u>	<u>Effect in Hard Water</u>
Soap	Soap anions precipitate with calcium and magnesium ions, forming a grey scum which persists on clothing. This reduces the number of available soap molecules, reducing its cleaning ability.
Anionic synthetic detergent	These lather in hard water well except alkyl sulfates and alkyl phosphates. However, they do not form scums in low pH water. Instead, they form soluble complexes, so their efficiency is slightly reduced as some of the surfactant is 'tied up'.
Cationic and non-ionic synthetic detergent	These detergents are not affected by hard water and do not form complexes or precipitates with Ca^{2+} or Mg^{2+} .

<u>Surfactant</u>	<u>Uses and Relation to Properties</u>
Soap	These are mainly used in personal hygiene.
Anionic synthetic detergent	These are used for general cleaning, particularly in laundry and dishwashing detergents. They are effective in removing grease and stains from natural fibres, and excellent for cleaning glass. They are not used in personal hygiene as they are too powerful and remove much oil from skin and hair.

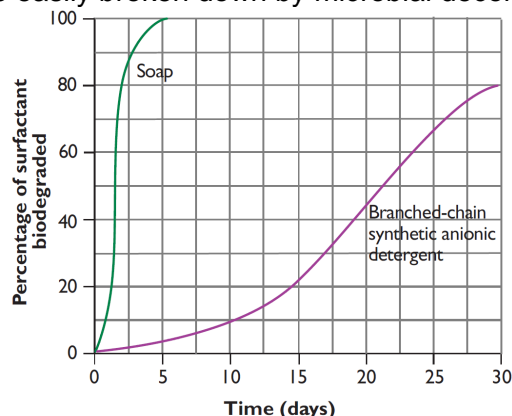
		Sodium dodecylbenzene sulfonate is the most commonly used anionic detergent. It is cheap, lathers well and can be dried to powder form.
	Cationic synthetic detergent	These detergents bond very strongly to negatively charged surfaces unless the pH is above 10. Thus, they find use in fabric softeners and hair conditioners, as they reduce static friction and tangling as they persist (hair becomes negatively charged when washed). They can also be used to create antistatic surfaces on glass, but aren't used in dishwashers due to the greasy feeling they give glass (adsorbed detergent). They can also be used to clean plastic effectively (better than anionic detergents) and as flocculating agents. Monoalkyl cationic detergents are biocides, and their antiseptic properties are useful in household disinfectors and sanitizers (e.g. mouthwashes, antiseptic soaps).
	Non-ionic synthetic detergent	They produce less foam than other detergents. As such, they find use in applications where low foam is desired, such as dishwashing liquids. They can be added to other detergents to provide greater stability. They are used in applications such as paints, adhesives, pesticides and cosmetics, as improved contact between polar and non-polar substances is required.

* solve problems and use available evidence to discuss, using examples, the environmental impacts of the use of soaps and detergents

These products are designed to be used once and then flushed down the drain. As such, they can have a varying range of impacts (possibly significant) upon the environment:

- Biodegradability:

The earliest developed synthetic detergents were non-biodegradable due to their branched hydrocarbon chains. It was discovered that they did not decompose within a few days and thus persisted in the environment. These caused waterways in the 1960s and 70s to build up with foam. Industrial chemists eventually rectified this problem by synthesising detergents with non-branching tails. These are more easily broken down by microbial decomposers.



On the other hand, soaps are biodegradable as they are single-chain hydrocarbons (derived from fatty acids). These are easily broken down within 5 days.

- Phosphate Builders:

Synthetic detergents were developed in part to combat the failure of soap to work in hard water. The soap anion molecules form a grey scum precipitate with Ca^{2+} and Mg^{2+} , which persists on clothing. While detergents don't form this precipitate, the presence of these ions causes their effectiveness to be reduced. As such, many detergents have added phosphate builders such as $\text{Na}_5\text{P}_3\text{O}_{10}$ to reduce water hardness and increase cleaning power. These builders form complexes with the metal ions and 'remove' them from the water. However these builders, with the detergent, can enter domestic sewage and end up in waterways. Recall that phosphate is a nutrient for many organisms and

increased concentrations of it lead to eutrophication, algal blooms and stagnation.

Thus, in many countries there are restrictions on the amount of phosphates allowed in washing powders and liquids. Also, zeolites are now being used to replace phosphate builders since they do not cause eutrophication. Phosphate builders are not added to soap as they do not have an effect on body cleaning.

- **Biocidal Properties:**

Cationic detergents have mild biocidal properties, as they disrupt the cellular processes in bacterial cells. Thus, their presence in wastewater and sewerage can cause the bacteria which breaks down waste to be killed. This occurs at higher concentrations only; lower concentrations of cationic detergents don't harm the bacteria which break them down.

6. describe the uses of sodium carbonate

Sodium carbonate is used in a number of industries:

- **Glass manufacture**

The main use of Na_2CO_3 is in the production of glass for windows and bottles. When heated at very high temperatures, combined with sand (SiO_2) and calcium carbonate (CaCO_3), and cooled very rapidly, glass is produced. Sodium carbonate acts as a flux in glass production as it lowers the melting point of the mixture of silicon dioxide and calcium carbonate.

- **Soap and detergent production**

Sodium carbonate can be used as a base in soap and detergent manufacture, in place of alkalis such as sodium hydroxide. It is also used to make sodium phosphate and sodium silicates which act as builders.

- **Softening agent**

Some laundry powders contain sodium carbonate to lower hardness. Sodium carbonate can be used to soften hard water as the carbonate ions precipitate calcium and magnesium ions.

- **Primary Standard**

Sodium carbonate is a moderately weak base. It has a decently high molecular mass and remains sufficiently pure. It is solid and also air-stable, allowing it to be weighed and thus used accurately.

- **Electrolyte**

Electrolytes are usually salt-based, and sodium carbonate acts as a very good conductor in the process of electrolysis. Unlike chloride ion which form chlorine gas, carbonate ions are not corrosive to the anodes.

- **Baking Soda production**

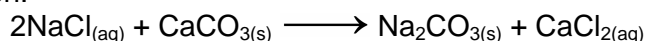
NaHCO_3 is produced as part of the Solvay process (process for manufacture of Sodium Carbonate). It is commonly called baking soda and is used in cooking to produce carbon dioxide as a raising agent. It is also used in CO_2 fire extinguishers.

- **Borax manufacture**

Borax is used in the manufacture of glazes and glass, as well as a cleaning agent in laundry products. Borax is the salt formed when boric acid neutralises sodium carbonate solution.

identify the raw materials used in the Solvay process and name the products

The raw materials required in the Solvay process are salt and limestone. Overall equation:

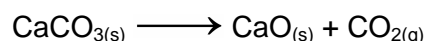


identify, given a flow chart, the sequence of steps used in the Solvay process and describe the chemistry involved in:

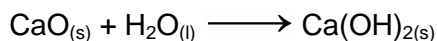
- brine purification
- hydrogen carbonate formation
- formation of sodium carbonate
- ammonia recovery

Brine Purification (feedstock production)

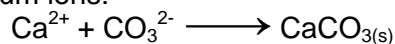
Crushed limestone is decomposed in a kiln to produce CaO and CO_2 gas. This process is called calcination, and the CO_2 released is compressed and cooled.



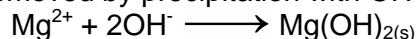
The CaO is then used to produce a $\text{Ca}(\text{OH})_2$ suspension, with addition to water:



A concentration brine solution is prepared from salt (which comes from underground rock deposits or evaporation of salt water). This needs to be purified to remove calcium ions:



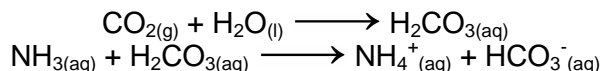
Magnesium ions are removed by precipitation with OH^- :



The purified brine is concentrated at ~30%(w/w). This is then saturated with ammonia, derived from the Haber process. This occurs in the ammonia tower. This is then called the ammoniated or ammoniacled brine.

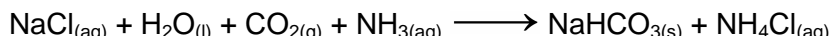
Hydrogen Carbonate Formation (carbonation of ammoniated brine)

The acid-base reaction between carbon dioxide and ammonia creates hydrogencarbonate ions:



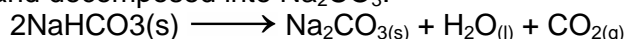
Sodium hydrogencarbonate then precipitate out of reaction. This is due to its low solubility in low-temperature water (reaction done at <15°C). A solution of ammonium chloride is left behind.

Overall:



Formation of Sodium Carbonate (decomposition of NaHCO₃)

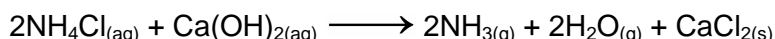
Filters are used to separate the solid sodium hydrogencarbonate from the solution. The filtrate is run to the ammonia recovery plant, while NaHCO₃ is dried, heated and decomposed into Na₂CO₃.



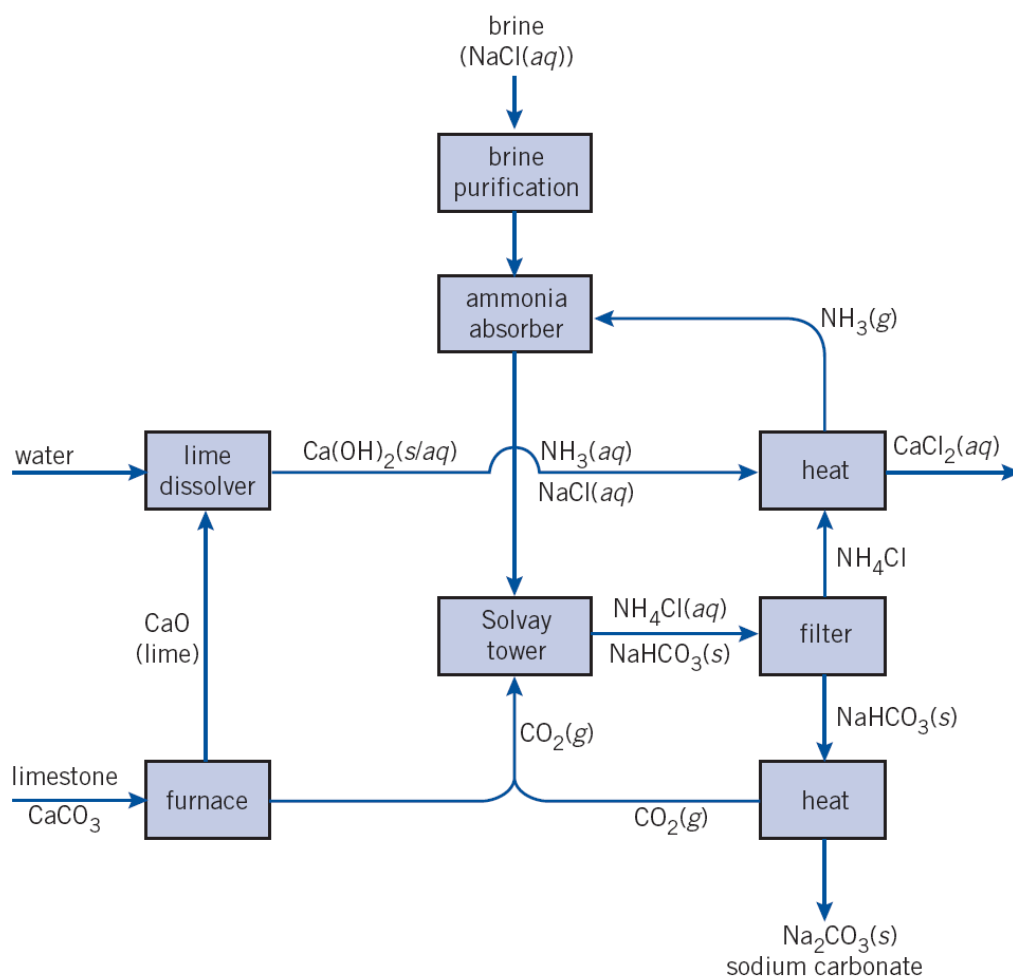
Ammonia Recovery

The filtrate recovered contains ammonium chloride together with other chemicals. These are removed by distillation, removing salt, dissolved ammonia and carbon dioxide.

Calcium hydroxide suspension is then added, which reacts with ammonium and releases ammonia. This is distilled off, and the waste product is calcium chloride.



A flowchart can be used to represent the sequence of steps in the Solvay Process:



* process information to solve problems and quantitatively analyse the relative

• Skill

This dot point analyses the amounts of reactants and products at each step via molar calculations. For example, given a mass of calcium carbonate, we may need to calculate the yield at each step.

quantities of reactants and products in each step of the process	
* perform a first-hand investigation to assess risk factors and then carry out a chemical step involved in the Solvay process, identifying any difficulties associated with the laboratory modelling of the step	<ul style="list-style-type: none"> • See Attachments • See Prac Book
discuss environmental issues associated with the Solvay process and explain how these issues are addressed	<p>The Solvay process has a range of environmental impacts:</p> <ul style="list-style-type: none"> • Calcium Chloride The Solvay process produces CaCl_2 as a waste (not wanted) product, as a ~15% solution containing various other chemicals. Some of the CaCl_2 is recovered and purified for sale, but the market for this is not large. Thus, there needs to be an efficient method of discharge Australia's only Solvay plant is located near Adelaide, close to a large, saline water body. The ions cause no damage as they are already present in high levels in the ocean, and the pH is not damaging (solution is slightly basic). Note however, that the ion concentration is unsuitable for discharge into freshwater bodies as it can raise salinity and cause aquatic organism stress. If no ocean is available, CaCl_2 can be buried in large underground stores. However, ground water can become gradually contaminated as calcium chloride is highly soluble in water. This can cause problems as significant increases in Ca^{2+}, Cl^- and SO_4^{2-} have been detected where such disposal methods occur. • Thermal Pollution Thermal pollution is another potential problem as CaCl_2 waste is produced at high (95 to 100°C) temperatures. Cooling towers and heat exchangers can capture most of this energy, for recycling. Solvay plants are also located near large water bodies, so cooling towers can access water supplies. The final discharged waste solution is slightly warm but do not cause damage to organisms in the food chain (e.g. DO does not decrease significantly). • Ammonia The ammonia used in the Solvay process could potentially contaminate the environment, as it is a greenhouse gas and a weak base (allowing it to disrupt normal body functioning). However, industrial techniques are now sophisticated enough that virtually no ammonia is lost in recycling. This also saves resources for the Solvay plant. • Mining The limestone required for the Solvay process is mined, often in open-cut mines. The normal issues associated with mining and environmental damage should be addressed, in addition to cultural issues and use of land. The establishment of salt farms to evaporate sea water also needs to be regulated, such that any damage to the environment is minimised. • Emissions Particulate emissions from kilns and dryers are controlled by scrubbers and electrostatic precipitators. Such processes are also used when handling crushed limestone.
* use available evidence to determine the criteria used to locate a chemical industry using the Solvay process as an example	<p>There are several factors to be aware of in locating an efficient Solvay Plant.</p> <ul style="list-style-type: none"> • Proximity to resources and raw materials (or easy access to them, via transport) The resources must be readily available either locally or via transport. This lowers their cost, which is favourable. Energy should be available as electricity and heat for the plant. Rail transport of coal and coke should be established. Raw materials need to be transported to the factory and products readily transported to markets. For example, salt should be obtained by solar evaporation near the location of the plant, meaning the area is hot with low rainfall. Brine can then be pumped to the Solvay plant. Limestone can be mined locally and on its dedicated rail line.

Also, water pipelines link a fresh water reservoir to the Solvay plant. Ammonia is transported from (rail) tankers from Haber plants.

Coke is used to decompose limestone and for heating, and coal is used to generate electricity and as a fuel for steam (can be transported via rail links). The Solvay process is not as energy hungry as some, so strategic placement to raw materials is more important than energy.

- Proximity to markets (close to industries which use Na_2CO_3)

The products of the chemical industry should be readily marketable locally, domestically or internationally.

Soda ash is a major component of glass manufacture so nearby (domestic or local) glass industries ensure profitability. Markets for baking soda are also important. Products can be exported through coastal ports and transported interstate by road.

- Proximity to waste disposal facilities

Waste disposal strategies need to be established to prevent environment pollution.

Heat exchangers should be used to recycle excess heat such that thermal pollution to waterways is minimised. CaCl_2 waste (in the form of a slurry) can be diluted and discharged into oceans with minimal effect (but not into freshwater).

- Proximity to workforce and facilities

Chemical factories should be located near towns or cities to obtain the necessary skilled workforce, including technicians and chemists. These towns also provide housing and schools for families.

Consider Australia's only Solvay plant, located in Osborne near Adelaide. The diagram below shows the Penrice Solvay plant, in relation to the limestone mine, salt-extraction fields and transportation.

The plant receives raw materials by rail. Salt is produced in the coastal salt fields, quite close to the plant. Sea water is evaporated in warm weather and salt crystals harvested, and a brine solution is piped to plant from the fields. The limestone mine has a dedicated rail line to transport the limestone to the plant. Liquid ammonia is transported to Osborne from Newcastle in rail tankers. Two nearby glass manufacture plants make use of the sodium carbonate, allowing efficient use of materials (markets are close). NaHCO_3 produced in the plant are also sold overseas.

The CaCl_2 from the plant can also be easily discharged into the ocean.

