

Chemical Monitoring and Management

1.1.1 Various, e.g.:

Occupation	Work
Pharmacist	dispenses and advises on medicines in a chemist shop, hospital
Analytical chemist	measures concentrations of chemicals in industry, our water supply, air and foods
Environmental chemist	monitors pollution in air, water etc and considers its impact
Biochemist	studies chemicals and the chemical reactions in organisms
Chemistry teacher	chemical education at secondary and tertiary level.

1.1.2 Various, e.g.:

	Information gathered
Name of occupation	Chemical engineer
Industry in which this chemist is likely to be employed	Manufacture of ammonia for fertilisers and explosives
Role of this chemist	Develop and monitor the production plant
Examples of work this chemist would undertake	Control the temperature, pressure, reaction rate and input/output of the plant to maximise production and ensure safety

- 1.1.3 (a) Various. For Internet sites, give complete URL, for books give title, author, publisher and date of publication, for personal contacts, give name of person, title and occupation.
- (b) Various. Comment on the agreement you found between information provided in different sources (this is one reason for using a range of resources).

Comment on the likely reliability of the sites you chose to access. Reliable websites would be those of industry associations such as RACI (Royal Australian Chemical Institute), universities, government bodies, research institutes and recognised experts in the field.

1.1.4 1d, 2f, 3a, 4b, 5c, 6e

1.2.1 Various. Information can be gained on staff of universities, the CSIRO, other research institutes and companies such as Shell, Caltex, Orica. Information is available on the Internet, in scientific journals (available in public libraries) and by contacting companies.

- 1.2.2 (a) Various, e.g. an electrochemist may use electrode potentials and oxidation numbers, an industrial chemist may use Le Châtelier's principle, an analytical chemist may use principles of volumetric or gravimetric techniques.
- (b) Various. You will need to outline the principle and describe how this principle is related to the work of the chemist.
- For example, for an electrochemist, using electrode potentials to determine the electrical output from a particular battery he/she may have designed.

Electrode potentials are voltages obtained from connecting a half-cell with a standard hydrogen cell. These can be used to predict the electrical output from other combinations of half-cells such as in a new battery.

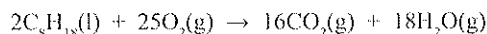
1.3.1 Each chemist has a particular expertise and hence a particular part in the overall process. However, for the plant to run efficiently and safely, each chemist must share their ideas and data so that efforts can be coordinated, e.g.

Industrial chemists would monitor the conditions of operation of the process in order to maximize the yield and ensure the safety of the plant.

Analytical chemists would test the purity of the raw materials and the quality of the products and consult with the industrial chemist to determine ways of maintaining and improving standards.

Environmental chemists would monitor and advise on any pollution and the disposal of waste products. The disposal of wastes must be economical and safe for workers and the environment. The industrial chemist would work with the environmental chemist to implement the required procedures. The analytical chemist would advise the industrial and environmental chemists of suitable techniques to analyse and dispose of any wastes and give reports on the monitoring of wastes.

1.4.1 Complete combustion:

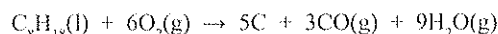


Incomplete combustion:

Various, e.g.



Carbon may also be a product for incomplete combustion, e.g.



1.4.2

	Complete combustion	Incomplete combustion
Products formed	CO_2 and H_2O	H_2O and any combination of CO , C , CO_2 and unburned hydrocarbons
Relative ratio of oxygen to fuel	Unlimited (excess) oxygen available (high air-to-fuel ratio)	Insufficient O_2 for the amount of fuel (low air-to-fuel ratio)
Relative amount of energy released	Maximum energy	Much less energy obtained from fuel
Environmental effects	Greenhouse gas CO_2 produced	Much more polluting as CO is very toxic, C particles form in air and greenhouse gases produced

1.4.3 Various. In your answer you should refer to the need to monitor combustion to ensure safety, economy, the conservation of non-renewable substances and minimal pollution, e.g.

Combustion – For economy, the maximum energy output is required from the minimum amount of fuel burnt. Pollution is minimised and energy output is maximised when oxygen is in excess, so the chemist should monitor the process to ensure that the air-to-fuel ratio is sufficient for complete combustion.

Pollution – Possible pollutants are carbon dioxide, carbon monoxide, sulfur dioxide, oxides of nitrogen and particles. (You should include equations.) Pollution should be minimised to reduce damage to people and the environment. (Describe effects of some of the pollutants you have identified.) Temperature of operation and the ratio of fuel to oxygen present can affect the products formed so these must be monitored to reduce the formation of pollutants. Also constant monitoring of the products and the plant are essential to detect pollutants formed.

- 2.1.1 (a) In fertilisers, as a raw material in the manufacture of chemicals, e.g. nitric acid and explosives, as a cleaning agent and as a weak base to neutralise acids.
- (b) Fertiliser – In agriculture and horticulture ammonia is applied to crops as either a solid or liquid. It is used as ammonia solution, as ammonium nitrate, sulfate of ammonia or ammonium phosphate. The nitrogen in the ammonia is an essential plant nutrient.

Production of chemicals – Ammonia is used as a raw material in the production of nitric acid (a strong oxidising agent) which in turn is used to manufacture synthetic fibres such as nylon and explosives such as TNT.

Cleaning agent – Ammonia solution (ammonium hydroxide) destroys bacteria so it is a component of many household cleaners such as floor and bathroom cleaners. It is a component in medicinal products such as mouthwashes and antiseptic soaps and washing products such as nappy washes and fabric softeners.

Weak base – Ammonia is used to safely neutralise acidic by-products in petroleum refining and in acid spills. Being a weak base, it generates heat slowly during neutralisation (an exothermic process) so does not cause further burning.

- 2.2.1 (a) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
- (b) nitrogen and hydrogen

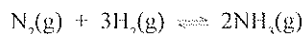
2.2.2 Nitrogen is obtained by fractional distillation of liquefied air.

Hydrogen is obtained by the reaction of steam with methane obtained from natural gas.



- 2.3.1 (a) Reversible reaction – a reaction which can proceed in both directions.
- (b) Equilibrium – a reversible reaction proceeding in a closed system and with the rate of the forward reaction equal to the rate of the reverse reaction.

- 2.3.2 Hydrogen and nitrogen react very slowly to form ammonia and, at the same time, the ammonia decomposes into nitrogen and hydrogen. This means the reaction is **reversible** and can be written as:



In a closed system, **equilibrium** will be reached when the rate of the forward reaction is the same as the rate of the reverse reaction. However, for this reaction the equilibrium is slow to be reached and lies to the left.

- 2.3.3 To form ammonia, nitrogen atoms and hydrogen atoms must combine. However, nitrogen and hydrogen do not exist as single atoms, they both exist as diatomic molecules held together by strong covalent bonds. Nitrogen molecules are held together by very strong triple covalent bonds and the single covalent bond between hydrogen atoms is also quite strong. A lot of energy is needed to break these bonds and form atoms that can rearrange to form ammonia. This energy is called the activation energy, the energy needed to start the chemical reaction. Therefore the activation energy is high.

- 2.4.1 Correct words are: released, less, less, weaker

- 2.4.2 (a) ΔH means the change in enthalpy. ΔH is negative, indicating that the reaction as written is exothermic and heat energy is released by the reaction. 92 kJ of energy is released for every mole of ammonia formed.

- (b) Energy profile for formation of ammonia:

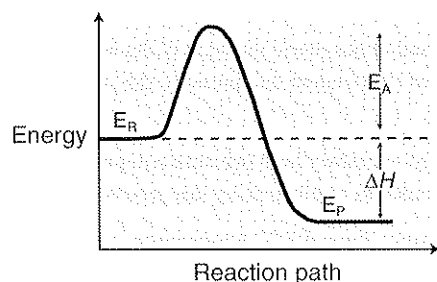
In this profile, the following symbols are used:

E_R = energy of reactants

E_P = energy of products

E_A = activation energy (the energy needed to start the reaction)

ΔH = change in enthalpy.



Reaction path of exothermic reaction

- (c) The diagram shows lower energy in the bonds of the product than in the bonds of the reactants. Therefore, during the reaction, there was a net decrease in energy stored in the system and energy was released to the environment.

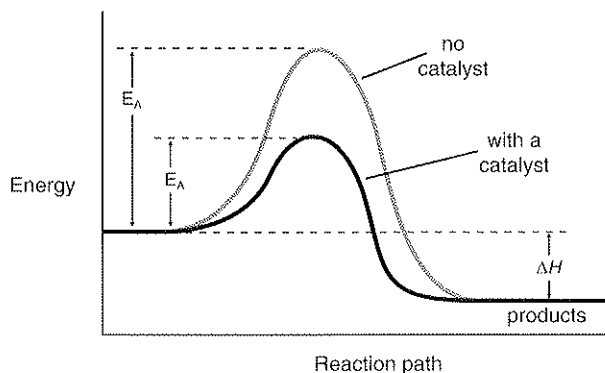
- 2.4.3 endothermic

- 2.5.1 (a) An increase in temperature makes molecules move faster, they have greater kinetic energy. This results in more energetic and more frequent collisions.
- (b) More frequent collisions leads to faster reactions because molecules react when they collide with sufficient energy.
- (c) Both the forward and reverse reactions will increase in rate as temperature increases.
- 2.6.1 If a system in equilibrium is changed, the system will adjust to minimise the change.
- 2.6.2 (a) The equilibrium will shift to the left (reverse reaction favoured).
- (b) As temperature increases, the equilibrium moves left to absorb this added heat (Le Châtelier's principle). The increase in temperature is minimised by the system absorbing the added heat. Since the reaction is exothermic and the reverse reaction is endothermic, the rate of the reverse reaction will increase to absorb the heat. Thus the equilibrium shifts to the left.

- 2.7.1** In your answer you should include:
- A statement describing the Haber process. Include an equation.
 - State the effect of increased pressure: Equilibrium shifts to the right, favours production of ammonia.
 - Analyse the effect mentioning Le Châtelier's principle: By Le Châtelier's principle, when there is an increase in pressure, the system moves to lower the pressure. The equilibrium shifts to the right, as there are four gas molecules on the left and only two gas molecules on the right. (Fewer gas particles in the same volume means lower pressure.)
The shift in the equilibrium position to the right to counter the pressure change, favours the formation of ammonia, hence an increase in pressure will increase the yield of ammonia.
- 2.8.1** (a) Low temperature shifts equilibrium to the right (Le Châtelier's principle, exothermic reaction) and favours ammonia formation, increasing the yield of ammonia.
- (b) The rate of reaction slows down (fewer collisions at lower temperatures), hence formation of ammonia is slower.
- 2.8.2** A relatively high temperature is required in order to provide enough kinetic energy for the particles to ensure a reaction occurs at a satisfactory reaction rate.
- However, at a high temperature, the yield would be very low due to the equilibrium lying too far to the left (Le Châtelier's principle, exothermic reaction). This is overcome by the use of other means (pressure) to force the reaction to the right. The temperature of 450°C is high enough to allow a good reaction rate and low enough to obtain ammonia.
- 2.8.3** The high temperature causes the system to move left (Le Châtelier's principle and exothermic reaction) to use up the added heat. High pressure shifts the equilibrium in the forward direction, overcoming the effect of temperature on the equilibrium position.
- 2.8.4** Cool to liquefy the ammonia.
- 2.9.1** Haber succeeded in making small amounts of ammonia from hydrogen and atmospheric nitrogen in the laboratory. He discovered a catalyst for the reaction and worked out the conditions of temperature and pressure that allowed a reasonable yield.
- Bosch developed the process to an industrial scale including inventing the necessary high pressure equipment that would enable the process to be carried out on a large scale. Germany had succeeded in implementing this process by 1913.
- 2.9.2** Nitrogen and hydrogen used in a ratio of 1:3; 250-350 atmospheres pressure; about 450°C temperature; catalyst of finely divided iron or iron oxide; ammonia liquefied and removed as it is formed.
- 2.9.3** In your answer you should include the following:
- How ammonia was obtained before the Haber-Bosch process was used, e.g.
Nitrates were obtained from deposits of sodium nitrate in Chile and transported to Europe by ship.
 - Identify uses of ammonia – manufacture of fertilisers and explosives.
 - Discuss the effect of World War I, e.g.
The British navy prevented the transport of nitrate by ship from Chile to Germany and so cut off the supply.
 - Explain the need for large quantities of ammonia at that time in history, e.g.
Population increases since the industrial revolution required more and more food to be supplied and in turn this required more fertilisers for crops. Also, there was an increased demand for explosives (WWI). Ammonia is used in fertiliser and is converted to nitrates for the manufacture of explosives.
 - Make an evaluation, e.g.
The ability to manufacture ammonia using atmospheric nitrogen (the Haber-Bosch process) and hence to manufacture explosives gave Germany a distinct advantage during the First World War and enabled Germany to continue the war for much longer than otherwise would have been possible. Historians believe that Germany would have run out of nitrates by 1916 if it had not developed the Haber process. On the other hand, the Allies had to rely on Chilean nitrates which became more expensive as the war progressed. Hence the synthesis of ammonia from hydrogen and nitrogen by the Haber-Bosch process had a significant impact on the course of history during the early 20th century.
Also, increased fertiliser production, using the Haber-Bosch process to manufacture ammonia, has enabled increased food production and thus continued the increase in the world population.

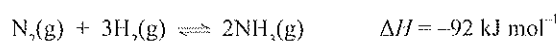
- 2.10.1**
- (a) Catalyst – a substance that changes the rate of a chemical reaction without being used up in the reaction.
 - (b) The catalyst lowers the activation energy and hence allows the reaction to proceed more quickly and at lower temperatures.
 - (c) Catalyst increases the rate of the forward and the reverse reactions. Thus equilibrium is reached faster. It has no effect on the equilibrium position.

2.10.2



2.10.3 Finely divided iron or iron oxide.

2.10.4 The Haber process involves a reversible, equilibrium reaction.



The forward reaction is exothermic, so the high temperature needed to produce a fast reaction rate would push the equilibrium to the left and result in a low yield.

The reaction rate for both forward and reverse reaction is increased by using a catalyst. A lower temperature can be used with the catalyst to achieve a faster reaction rate. This helps in the delicate balance between the effect of temperature on rate and the effect on equilibrium position.

2.11.1 nitrogen, hydrogen, reversible, reactants, increase, forward, ammonia, maximum, ammonia.

2.11.2 The team running the plant must continually monitor the ratio of gases fed in, their purity, the temperature and pressure in the reaction vessel and the performance of the catalyst. The unused gases are returned to the reaction vessel and the ammonia removed. Checks must be made that no gases being used or produced are allowed to escape into the environment. Also disposal of any wastes and the safety of the plant must continually be checked.

3.1.1

Compound	Solubility	Compound	Solubility
Sodium chloride	soluble	Magnesium phosphate	insoluble
Calcium hydroxide	insoluble	Calcium sulfate	slightly soluble
Magnesium sulfate	soluble	Zinc carbonate	insoluble
Barium sulfate	insoluble	Iron hydroxide	insoluble
Silver chloride	insoluble	Silver phosphate	insoluble

- 3.1.2 (a) Anions are negatively charged ions such as phosphate, chloride and sulfate ions. Cations are positively charged ions such as calcium and sodium ions.

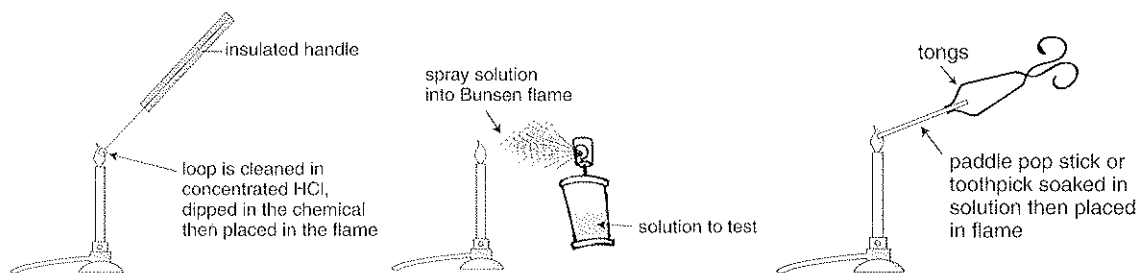
(b)

Anion	Test used	Positive result and equation
Phosphate (PO_4^{3-})	(i) Add silver nitrate (ii) Acidify, add ammonium molybdate $((\text{NH}_4)_2\text{MoO}_4)$ and warm	(i) yellow cloudiness $\text{PO}_4^{3-}(\text{aq}) + 3\text{Ag}^+(\text{aq}) \rightarrow \text{Ag}_3\text{PO}_4(\text{s})$ (ii) blue solution
Sulfate (SO_4^{2-})	Add barium ions, e.g. barium nitrate	White precipitate of barium sulfate that is insoluble in dilute hydrochloric acid $\text{SO}_4^{2-}(\text{aq}) + \text{Ba}^{2+}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$ (Note: Barium carbonate is also white and insoluble)
Carbonate (CO_3^{2-})	Add dilute hydrochloric acid	Carbon dioxide gas is produced $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ This turns limewater ($\text{Ca}(\text{OH})_2$) milky $\text{CO}_2(\text{g}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$
Chloride (Cl^-)	Add silver nitrate solution	White precipitate of silver chloride $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$

(c)

Cation	Test used	Positive result and equation
Barium (Ba^{2+})	Flame test Add sulfate ions	Apple-green flame White precipitate of barium sulfate $\text{SO}_4^{2-}(\text{aq}) + \text{Ba}^{2+}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$
Calcium (Ca^{2+})	Flame test Add carbonate ions	Orange/red flame White precipitate of calcium carbonate $\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CaCO}_3(\text{s})$
Lead (Pb^{2+})	Add iodide ions	Yellow precipitate of lead iodide $\text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(\text{s})$
Copper (Cu^+ or Cu^{2+})	Flame test Add hydroxide ions	Blue-green flame Deep blue precipitate which dissolves in excess hydroxide
Iron (Fe^{2+}) (oxidises to Fe^{3+} on standing)	Add hydroxide ions	White precipitate of iron(II) hydroxide which oxidises in air to red-brown iron(III) hydroxide
Iron (Fe^{3+})	Add hydroxide	Red-brown gelatinous precipitate of iron(III) hydroxide

- 3.1.3 (a) Various. Flame tests can be carried out using a platinum or nichrome wire loop and placing a loop of the ion solution into a Bunsen flame. The wire loop should be cleaned in concentrated hydrochloric acid. Alternately, the solution can be sprayed into the flame from a pump bottle. A third method is to use tongs to hold a toothpick or paddle pop stick soaked in the solution in the flame.



Risk assessment depends on method used. You should identify the danger, explain the danger and describe the precaution taken, e.g. Corrosive or toxic chemicals can be splashed into the eye and burn the eye. So always wear goggles when using chemicals to prevent the chemicals reaching the eye. Name the corrosive or toxic chemicals used.

- (b) This test uses emission of light by atoms after they have been sufficiently heated to cause their electrons to move to higher energy orbits. The energy absorbed by the atoms is released as light when the electrons return to their lower energy level. The process is called emission spectroscopy.
- (c) The colour emitted depends on the energy difference between the excited state of the electrons and their ground states. Different metals have different electron configurations. Thus the pattern of electron movement varies and so does the colour emitted.
- (d) Lead vapour would be formed. Lead is very toxic.

3.1.4

- (a) Coloured compound developed with a specific reagent, precipitation reactions and production of a gas when reacted with acid.
- (b) Various, e.g. chloride and phosphate ions can be distinguished by precipitation with silver nitrate as the reagent. This test can be used because the silver compounds produced are easily distinguished by their colours.

Silver chloride is a white precipitate. $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$

Silver phosphate is a yellow precipitate. $\text{PO}_4^{3-}(\text{aq}) + 3\text{Ag}^+(\text{aq}) \rightarrow \text{Ag}_3\text{PO}_4(\text{s})$

3.1.5

Foods need to be monitored to ensure that they do not contain any toxic materials, that they meet the required standard and also to ascertain their nutritional value. Labelling laws require the ingredients to be listed on the tins/packets along with nutritional information for the consumer. The ingredients should be fully described to prevent dangerous allergic reactions in some consumers.

With medicines, it is crucial that the correct quantity of active ingredient is always present in each dose and the product must be pure. This requires constant monitoring. Similarly water quality is constantly monitored and appropriate treatment applied to ensure safety and taste and to detect any pollution.

3.2.1

Various, e.g. mercury:

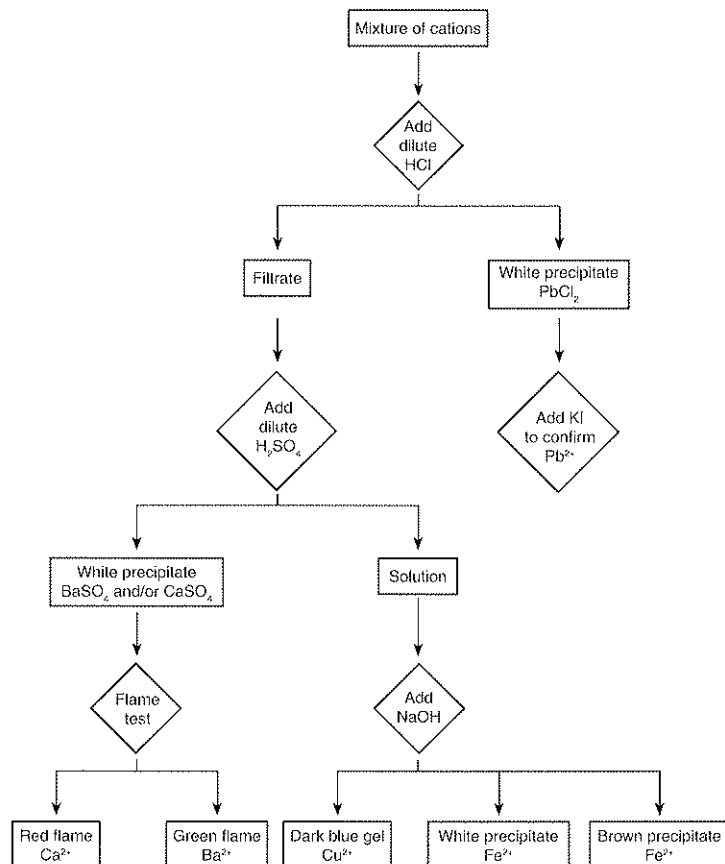
	Summary of Information gathered
Identify the ion chosen	Mercury
Why the ion needs to be monitored	Mercury is a toxic heavy metal. It occurs as the element, as inorganic salts and as organomercury compounds. The latter are particularly dangerous as they can enter the brain and cause neurological damage and can cross the placenta. Mercury has been linked to damage to the nervous system, kidneys, endocrine system and miscarriages as well as developmental defects and learning disorders in children. Mercury can enter the body by inhalation or ingestion. It is difficult to excrete and accumulates in tissues, called bioaccumulation.
How the ion is monitored	Mercury is readily detected and measured by AAS which measures quantities as low as ppb.
Substances monitored for this ion	Blood, hair and other tissues, soil, water, food and the atmosphere. Persists in the environment.
Sources of the ion in these substances	Fossil fuels contain mercury which is airborne when these fuels burn. Mining and refining of mercury metal produces mercury vapour. Disposal of products containing mercury, e.g. mercury-based batteries are no longer manufactured because of disposal difficulties. Mercury compounds are used as fungicides, and in eyedrops and antiseptic ointments. Wastes from industries using mercury. Mercury was used as an electrode in the electrolysis of sodium chloride solution to make sodium, chlorine and sodium hydroxide. Contaminated food, e.g. fish. The FDA in USA warns that some fish, e.g. shark, swordfish and tuna have dangerous mercury levels and suggests limiting fish consumption especially for pregnant women.
Incidents involving this metal	Minamatta Bay (Japan): 81 tonnes of metallic mercury was dumped in the bay. Sea floor bacteria converted this to organic compounds which entered the food chain and caused birth defects, severe abdominal pain and deaths of more than 140 people. In Iraq, 6500 people were ill and 450 died when seed wheat treated with mercury was accidentally used to make bread.

- 3.2.2 (a) mg/L is milligrams per litre,
 µg/L is micrograms per litre, (a microgram is 10^{-6} gram)
 ppm is parts per million, 1 ppm can be, for example 1 g in 1 000 000 g or 1 mL in 1 000 000 mL.
 ppb is parts per billion, for example 1 ppb can be 1 g in 10^9 g.
- (b) $200 \text{ µg/L} = 200/1000 \text{ mg/L} = 0.2 \text{ mg/L}$
 $200 \text{ µg/L} = 0.2 \text{ mg}/1000 \text{ mL} = 0.2 \times 1000 \text{ mg}/10^6 \text{ mL} = 0.2 \text{ g}/10^6 \text{ g}$ or ppm (1 mL water = 1 g water)
 $200 \text{ µg/L} = 0.2 \text{ g}/10^6 \text{ g} = 200 \text{ g}/10^9 \text{ g}$ or ppb.

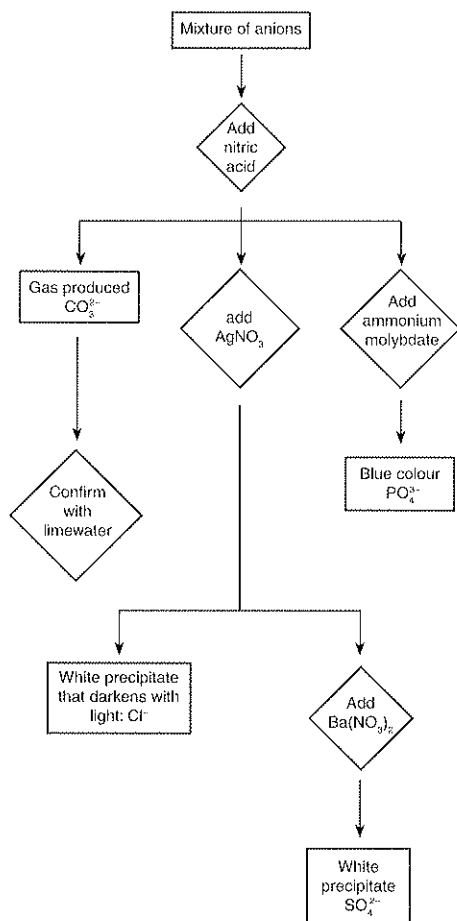
3.3.1

Test	Result	Ions present
Add KI	Yellow precipitate	lead
Add OH^- ions dropwise	Deep blue precipitate that dissolves in excess hydroxide	copper
Spray into flame	Apple-green colour	barium
Add AgNO_3	White precipitate that darkens on exposure to light	chloride
Add dilute HCl	Gas produced that turns limewater milky	Carbonate/hydrogen carbonate

3.3.2



3.3.3



3.3.4 Various, e.g. Add silver nitrate to a sample of each solution. A white precipitate will identify the two chloride solutions. The carbonate can be confirmed by addition of acid and passing the gas produced through limewater. The two chloride solutions can be distinguished by flame tests. Calcium produces a brick-red flame colour whereas sodium produces an orange/yellow flame. You should include equations – see Question 3.1.2.

3.4.1 (a) Both determine the contents of a mixture such as the ingredients in a food. However, in qualitative analysis the quantities of the components of the mixture are not measured, just the composition (chemicals present) is determined, whereas in quantitative analysis, the percentage of each component is also determined by volumetric, gravimetric or colorimetric methods.

(b) Various, e.g. The analysis of sulfate in lawn fertiliser carried out in this subsection is an example of quantitative analysis. Quantities are measured and the percentage of sulfate is determined. If sulfate had been detected by the formation of a precipitate with barium ions, but no measurements taken, the analysis would have been qualitative.

3.4.2 (a) Various. The method probably involved weighing a sample of the fertiliser, dissolving it in strong acid using heat and stirring to ensure all the sulfate was dissolved. Any undissolved material would have been removed by filtration. The sulfate would then be precipitated by the addition of barium ions and the precipitate collected by filtration. The residue would be washed with deionised water and dried to constant weight. Steps in the method should be listed. Include a labelled diagram of the filtration steps.

(b) The acid aids dissolution by the reaction $\text{SO}_4^{2-} + \text{H}^+ \rightleftharpoons \text{HSO}_4^-$.

This is an equilibrium reaction that shifts to the right with the addition of acid.

The sulfate is precipitated by addition of barium ions as barium sulfate is very insoluble.

$\text{SO}_4^{2-}(\text{aq}) + \text{Ba}^{2+}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$. This separates out the sulfate which can then be collected.

- 3.4.3 (a) Mass of dry $\text{BaSO}_4 = 1.25 \text{ g}$
 moles of $\text{BaSO}_4 = m/M = 1.25/233.37 = 5.36 \times 10^{-3}$
 moles of $\text{SO}_4^{2-} = 5.36 \times 10^{-3}$
 mass of sulfate $= nM = 5.36 \times 10^{-3} \times 96.07 = 0.515 \text{ g}$
 % sulfate in fertiliser $= 0.515/1.05 \times 100 = 49\%$

(b) The sulfate content of the commercial lawn fertiliser tested was found experimentally to be 49%.

3.5.1 (a) Various – state the results for your class.

(b) Various. It is likely the results from the class varied widely between groups. Compare them and also compare the results with any information provided on the fertiliser container produced by the manufacturer.

Any differences could be due to experimental error which varies with the expertise of the various groups. However, problems with the method could also have contributed to the variation. For example, it is possible that not all the sulfate was dissolved in the initial step, depending on the cations present. Also the barium sulfate precipitate is very fine and cannot be collected with the Whatman no. 1 filter paper normally available in schools.

(c) Various, e.g. The results are not very reliable as can be seen by the degree of variation in the class results. Greater expertise, more suitable equipment or a modified method would need to be used in order to improve the reliability.

3.5.2

Step in the procedure	Problems encountered, if any	Possible solutions	Validity of the step
Grind fertiliser to fine powder and accurately weigh sample.	Can be accurately carried out with care.	Take care grinding and transferring chemical.	Valid procedure, if carried out carefully.
Dissolve fertiliser in acid.	Not all fertiliser dissolved, and since some sulfates are insoluble it was difficult to decide when all sulfates had dissolved.	Add more acid, heat and allow time for dissolution. ($\text{SO}_4^{2-} + \text{H}^+ \rightarrow \text{HSO}_4^-$)	Valid step if carried out with extreme care. However, this is a possible source of error.
Filter and collect filtrate containing dissolved sulfates.	Filtrate was cloudy and needed more than one filtration to remove solids.	Repeat filtration until filtrate is clear. Wash filter paper to ensure minimal loss of solution.	Valid step if carried out with extreme care. However, is possible source of error.
Add barium nitrate to precipitate out sulfates.	Unsure of quantity to add in order to ensure excess Ba^{2+} ions.	Add barium nitrate until no further precipitate forms. Allow time for precipitate to settle.	Possible source of error as solution is cloudy and it is difficult to see when no further precipitate is formed.
Filter to collect precipitate of barium sulfate.	Despite repeated filtrations, the filtrate remained cloudy.	Need vacuum filtration and a very fine filter such as a Millipore filter or sintered glass filter.	Not valid with normal school equipment. Needs special filter to collect the fine precipitate.
Wash, then dry to constant mass.	Slow and time consuming. Needs to be continued over a long period.	Take care and exercise patience to carry out properly. Use same balance for each weighing. Make sure no precipitate is lost.	Valid step if carried out with extreme care. However, is possible source of error.

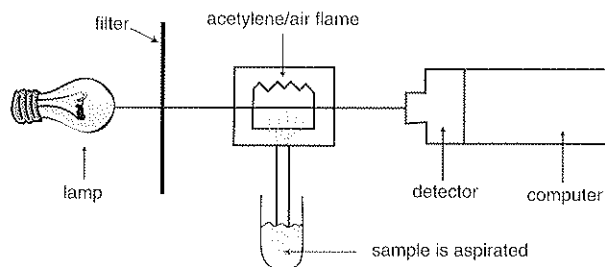
3.6.1 Similarity – Both methods are analytical tools for determining the composition of a mixture and detecting small amounts of substances present in a mixture. Both rely on the movement of electrons between energy levels in atoms.

Difference – Emission spectroscopy uses the energy released when electrons move to an orbit of lower energy whereas absorption spectroscopy measures the energy absorbed when electrons move to an orbit of higher energy.

3.6.2 (a) Sir Alan Walsh

(b) Atoms absorb light as their electrons jump to higher energy levels. Atoms of different elements absorb different wavelengths of light. This is due to their different electron configurations. This enables just one element to be detected in a complex mixture by choosing a lamp with the appropriate wavelength. AAS measures the light absorbed.

(c) In AAS a lamp emits the same pattern of wavelengths that is absorbed by the element to be measured in the sample. The sample is atomised into a chamber and the light of specific wavelengths is passed through the sample. Depending on the concentration of the element in the sample, some of the light will be absorbed, the more of the element being tested for in the sample, the more light absorbed. A detector determines the proportion of light absorbed and a calibration curve is used to convert the absorption reading into concentration units. The diagram shows how AAS works.



3.6.3 Various – you should include three examples:

Medicine – the levels of metals in tissues can be measured such as iron levels in blood. Also lead or heavy metal content in people can be diagnosed.

Pharmaceutical and food industries – traces of elements such as arsenic, fluoride can be detected in the final product.

Agriculture – levels of trace elements in soil can be measured.

Industry – the quality of raw materials and final product can be determined. For example the level of a metal such as gold in an ore can be accurately measured or the composition of an alloy determined .

Environmental analysis – monitoring of air, water and soil by AAS detects low levels of pollutants such as mercury, cadmium etc. This can indicate pollution at a stage before it becomes too dangerous.

- 3.6.4**
- (a) Elements required by living things in only very small amounts for the efficient action of enzymes, e.g. copper, zinc, boron, cobalt, molybdenum, iron.
 - (b) Trace elements such as copper, zinc, boron, cobalt, molybdenum, iron and magnesium are required by plants and animals for the action of enzymes. The processes of photosynthesis and respiration require trace elements. Crop yields will be low and plants unhealthy if soils are deficient in trace elements. Animals need these elements as cofactors for enzymes in respiration and other reactions. Animals derive these minerals ultimately from plants through the food chain.
 - (c) Until AAS was invented, trace elements could not be detected in sufficiently low levels, so their importance in crop growth and health of livestock was not understood. Using AAS, experiments can be carried out to compare growth conditions to yield which allows the efficient supplementation of a trace elements to soils. The detection of trace elements in the tissues has led to an understanding of the chemistry of these elements in organisms.

3.6.5 AAS is a relatively simple, fast, accurate and inexpensive technique that can be used to monitor levels of trace elements such as copper, zinc, boron, cobalt, molybdenum, iron and magnesium.

Until AAS was invented, trace elements could not be measured accurately, so their importance in crop growth and health of livestock and humans was not understood. No other method is sensitive enough to detect the low levels of these minerals.

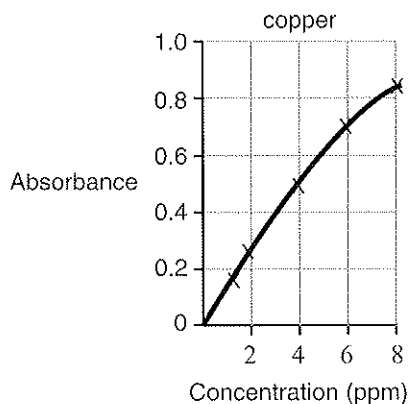
Using AAS, experiments can be carried out to compare growth conditions to yield which allows the efficient supplementation of trace elements to soils. The detection of trace elements in the tissues has led to an understanding of the chemistry of these elements in organisms.

AAS has also improved the health of humans through increased understanding of the role of trace elements in our bodies and the detection of heavy metal contamination. It has been a very important technical advance.

AAS has had a profound effect on agricultural productivity, improving crop yields, health of crops and livestock.

- 3.7.1**
- (a) Standard solution – A solution of accurate, known concentration of a particular ion. Absorbance – The fraction of the incident light of a certain wavelength absorbed by a substance. As the concentration of the substance increases, the amount of light absorbed will increase.
 - (b) In AAS standard solutions are made up and placed, one by one, into the atomic absorption spectrometer. The readings obtained are the absorbance of each solution. The concentration of each solution is graphed against its measured absorbance.
- 3.7.2**
- (a) A series of standard solutions is made up and tested using AAS to measure the absorbance of each solution. The concentration of each solution is plotted on the horizontal axis and the absorbance reading for each standard, obtained by AAS, is plotted on the vertical axis.
- This gives a graph which is used to convert AAS readings to concentration units. When unknown solutions are tested using AAS, their absorbance levels obtained allow us to read off their concentration of the substance being tested from the curve.
- (b) Measurements are made and quantitative techniques involve measurement.

3.7.3 (a)

(b) (i) 2.2 ppm, 2.2×10^{-3} g/L(ii) 0.8 ppm, 0.8×10^{-3} g/L(iii) 4.1 ppm, 4.1×10^{-3} g/L

(c) Various, e.g. The higher levels of copper were due to proximity to a copper mine or smelter.

3.7.4 (a) Mining and refining of ores, factories and industries using metal compounds, power stations burning fossil fuels, chemical manufacturers, sewage effluent, agricultural run-off.

(b) Government organisations such as Environmental Protection Agency (EPA), Health departments, local councils. Individual companies are responsible for their own pollution monitoring and control.

3.7.5 AAS is a very valuable tool in pollution control.

It can be used to measure low concentrations of many different pollutants in many environments, e.g. in atmosphere, soil, water, food and in living organisms.

A disadvantage is that it is only possible to test for one ion at a time. For each ion tested, it is essential to use a lamp of the correct wavelength and the relevant standard solutions.

Also the equipment is expensive to purchase. However, once the machine has been purchased and set up, it can be used to carry out assays quickly, accurately and cheaply so it can be used to monitor pollution.

Authorities can get results quickly so action can be taken to control pollution and detect the source of the pollution. People are also protected when harmful pollutants are detected in consumer products.

4.1.1

Name of layer	Minimum and maximum distance from the surface of the Earth (km)	Composition	Temperature
Troposphere	0 – approximately 15	78% N ₂ , 21% O ₂ , 0.9% Ar, small amounts of other gases such as CO ₂ , Ne, He and pollutants such as methane and oxides of sulfur and nitrogen.	Variable. This is the layer where weather is determined.
Stratosphere	15 – 50	Ozone (O ₃) and other gases as in the troposphere	–50°C to 30°C at top
Ionosphere (made up of two layers called mesosphere and thermosphere)	50 – 150 (atmosphere gradually fades away – there is no sharp upper boundary)	Ions and atomic particles	About –50°C

4.1.2 Atmospheric gases are not spread evenly. About 90% of atmospheric gases occur in the troposphere, 9% in the stratosphere and 1% in the ionosphere.

4.2.1 Sulfur dioxide – acid rain, common allergen.

Carbon monoxide – toxic – combines with haemoglobin better than oxygen, causing asphyxiation.

Nitrogen dioxide – acid rain.

Carbon dioxide – greenhouse gas, contributes to global warming.

4.2.2

Pollution	Sources – artificial	Sources – natural
Nitrogen oxides (NO_x , e.g. NO , NO_2)	Motor vehicles, electricity production, jet engines	Biomass burning, lightning, soil bacteria
Volatile organic compounds	Unburnt fuel, solvents and paints	Emitted by vegetation, e.g. eucalypts
Carbon monoxide (CO)	Motor vehicles, incomplete combustion of fuels	Biomass burning, volcanoes, decomposition of plants and animals
Carbon dioxide (CO_2)	Combustion of fuels in motor vehicles and electricity production	Biomass burning, volcanoes, decomposition of plants and animals
Sulfur dioxide (SO_2)	Electricity production, smelting metal sulfide ores, combustion of fossil fuels, industries, e.g. paper and food processing	Bacteria, volcanoes
Particles	Combustion of fossil fuels, mining, construction, incinerators	Biomass burning, soil (wind erosion), pollen, spores
Lead	Smelting metal ores, incinerators, paint, manufacturing, e.g. batteries	Erosion of lead ores

4.3.1

- (a) Ozone forms in the stratosphere when an oxygen molecule is decomposed, by high energy radiation, to form two oxygen atoms (reactive free radicals). $\text{O}_2(\text{g}) \rightleftharpoons 2\text{O}\cdot(\text{g})$. Each oxygen atom then combines with another oxygen molecule to form ozone. $\text{O}_2(\text{g}) + \text{O}\cdot(\text{g}) \rightleftharpoons \text{O}_3(\text{g})$.

In the troposphere, oxygen free radicals and ozone are formed when electrical discharge from storms and machines such as photocopiers and laser printers decomposes oxygen and also when the sunlight breaks down nitrogen oxides in petrochemical smog.

- (b) Most, about 90%, occurs in the stratosphere and 10% in the troposphere.
- (c) In the lower atmosphere ozone is a pollutant. It is a toxic, pungent gas that causes irritation of the eyes and airways, coughing and increased incidence of respiratory conditions such as asthma. It also causes lowering of resistance to infection. Being a strong oxidising agent, it disrupts biochemical reactions.

4.3.2

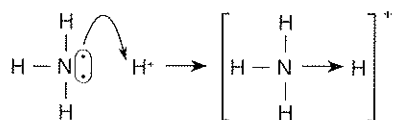
- (a) UV is damaging to humans. It burns the skin, damages biological molecules such as RNA, DNA and proteins thus leading to cancer and suppression of the immune system. It damages the eyes forming cataracts (cloudiness) of the lens and can damage the retina. By contributing to the formation of photochemical smog, it also causes respiratory problems.
- (b) Australia has the highest incidence of skin cancer in the world and UV radiation causes skin cancer.
- (c) UV radiation from the Sun is largely absorbed by the ozone layer, particularly the more dangerous UV-B part of the spectrum which is the higher energy, smaller wavelength UV. It is very important that a large percentage of the UV rays reaching the Earth be absorbed by the atmospheric ozone in order to maintain life on Earth. UV decreases plant growth, affects aquatic organisms and causes increased cancer rates in humans as well as other health effects (see part (a)).

4.4.1

- (a) An attractive force between two atoms that are sharing two electrons.
- (b) The coordinate bond is formed when one atom donates both the electrons in the shared pair. A lone pair from one atom forms the bond.
- (c) In normal covalent bonds, one electron comes from each atom to form the shared pair, however, in coordinate bonds both electrons come from the same atom. Once the bond is formed, the properties are the same and the bonds cannot be distinguished.

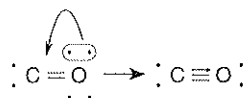
4.4.2

Ammonia has a central nitrogen atom covalently bonded to three hydrogen atoms. The N atom has a lone pair of electrons in its valence shell. This lone pair can be donated to an H^+ ion, forming an ammonium ion. The four bonds to the hydrogens are all equal once they are formed.

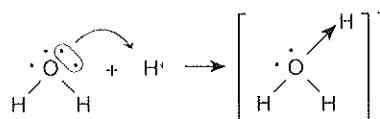


4.5.1

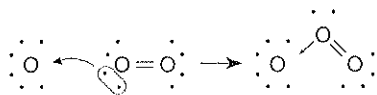
(a) Carbon monoxide



(b) hydronium ion



(c) ozone



4.6.1 Different forms of an element in which the identical atoms are arranged differently so the forms have different properties. Carbon has allotropes – graphite, diamond, fullerenes.

4.6.2 Both substances are composed of oxygen atoms, but they are arranged differently. Oxygen is a diatomic molecule with the two atoms joined by double covalent bonds. Ozone molecules have three oxygen atoms, two of them joined by double covalent bonds and one joined to the central atom by a single coordinate bond. Include a diagram.

4.6.3

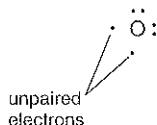
Property	O ₂ (oxygen gas)	O ₃ (ozone)
State and colour	Colourless gas	Pale blue gas.
Odour	Odourless	Sharp, pungent odour.
Reactivity	Moderately reactive. Decomposed by high energy UV light.	Highly reactive. Decomposed by medium energy UV light.
Effect on humans	Essential for life	Causes coughing, chest pain and rapid heart beat. Irritates eyes and airways. At concentration > 1 ppm it is toxic.
Melting point and boiling point	M.P. -218.75°C B.P. -182.96°C	M.P. -192.5°C B.P. -110.5°C
Structure and bonding	Diatomic molecule – two oxygen atoms held together with a covalent double bond.	Three oxygen atoms held together with 1 double covalent bond and 1 single coordinate covalent bond.
Shape	Molecule is linear shape	Molecular shape is bent

4.6.4 Ozone and oxygen molecules both have dispersion forces between their molecules, but ozone is also polar and thus has stronger intermolecular forces. The donation of the electron pair from the central oxygen atom leaves a small positive charge on the central O atom. Therefore the ozone molecule becomes a dipole whereas diatomic oxygen is non-polar. The higher melting and boiling points of ozone are due to stronger intermolecular forces in ozone than in oxygen.

O₂ has a strong double bond which has more stability than the single coordinate bond in ozone, thus more energy is needed to break the O₂ bonding than the ozone bonding so the ozone molecule is more reactive than diatomic oxygen and is a stronger oxidising agent.

4.7.1 (a) A reactive particle that contains one or more unpaired electrons in its outer shell. An oxygen atom is a free radical containing two unpaired electrons in its valence shell.

(b)



4.7.2 Very reactive, a molecule with one atom that reacts immediately with its surroundings. Very reactive because it exists in a high energy state and it has two unpaired electrons in the valence shell.

Toxic because it reacts with organic molecules in living cells causing toxic damage.

4.7.3 O_2 , O_3 and the oxygen free radical ($O\cdot$) are all forms of the element oxygen, but the free radical is much more reactive and the most toxic. O_2 and O_3 are relatively stable in the atmosphere unless acted on by UV, but the free radical only exists briefly, once formed it immediately reacts.

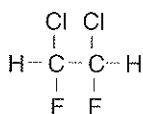
- 4.8.1**
- (a) methane, ethane, propane, butane, pentane, hexane, heptane, octane
 - (b) fluorine, chlorine, bromine, iodine, astatine
 - (c) Alkane with one or more halogen atoms substituted into the molecule in place of hydrogen atom(s).
 - (d) fluoro-, chloro-, bromo-, iodo-

- 4.8.2**
- Use prefixes for the halogen groups.
 - If more than one type of halogen atom is present, list them in alphabetical order.
 - Use di, tri, tetra when there is more than one atom of any halogen.
 - Number the carbon chain, giving the lowest set of numbers to the halogen present.
 - If the numbers are the same from both ends of the chain, then give the first named halogen the lowest number.

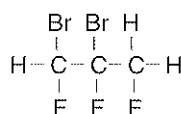
- 4.8.3**
- (a)
 - (i) 1,1-dichloroethane
 - (ii) 2-bromo-3-chlorobutane
 - (iii) 1,2-dichloroethane
 - (iv) 4-bromo-2-chloro-3,3-difluorohexane
 - (v) 2,2-difluoro-3-methylbutane
 - (vi) 2-chloro-4-ethylheptane

(b)

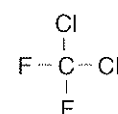
(i)



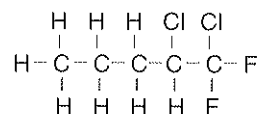
(ii)



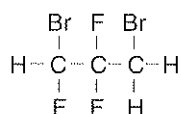
(iii)



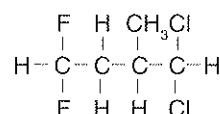
(iv)



(v)



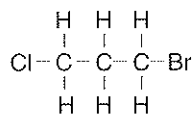
(vi)



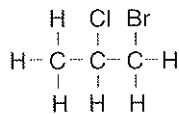
4.8.4 There are three pairs of isomers – Part (a)(i) and (iii); Part (b) (ii) and (v); Part (b) (iv) and (vi). In each case they have the same molecular formula, but different structural formulas.

4.9.1 Various, e.g. with molecular model kits (describe what you used as atoms and to represent bonds) you may have constructed, drawn and named a number of haloalkanes. By placing the halogens on different carbons you would have made isomers. Isomers have the same molecular formula, hence same number of each type of atom, but the atoms are arranged differently. Use diagrams to illustrate some isomers you made.

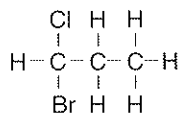
4.9.2



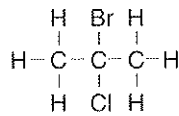
1-bromo-3-chloropropane



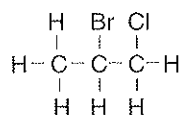
1-bromo-2-chloropropane



1-bromo-1-chloropropane



2-bromo-2-chloropropane



2-bromo-1-chloropropane

4.10.1

- (a) CFCs are halogenated alkanes with all hydrogens substituted with chlorine and fluorine atoms, e.g. dichlorodifluoromethane and 1,1, 2,2-tetrachloro-1,2-difluoroethane.
- (b) Halons are halogenated alkanes with hydrogens substituted with bromine and fluorine atoms, e.g. bromotrifluoromethane, bromochlorodifluoromethane.

4.10.2

Although a small amount of chloromethane is produced naturally by micro-organisms, most CFCs and halons are entirely synthetic. Haloalkanes have been manufactured by industries since the 1930s when they began to replace ammonia as a refrigerant. As demand for refrigeration and air conditioners grew, they were produced in increasing quantities and more uses were found.

4.10.3

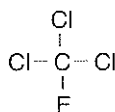
CFCs were used as refrigerants in air conditioners and refrigerators; as solvents in dry-cleaning and as propellants in aerosol spray cans. They were used for these purposes because they are non toxic, inert and are easily liquefied and then returned to the gas phase.

Halons were used in fire extinguishers as they do not support combustion.

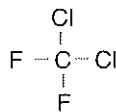
4.10.4

(a)

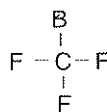
(i) trichlorofluoromethane



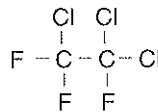
(ii) dichlorodifluoromethane



(iii) bromotrifluoromethane



(iv) 1,1,2-trichloro-1,2,2-trifluoroethane

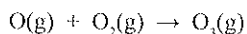


- (b) (i) 1,1,1,2-tetrachloro-2,2-difluoroethane
- (ii) chlorotrifluoromethane
- (iii) tribromofluoromethane
- (iv) 1,1,1-tribromo-2,2,2-trifluoroethane

- 4.11.1 Ozone levels vary with seasons (lower in winter) and with latitude (more dense layer at the equator than at the poles).

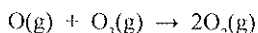
Ozone is formed when high energy UV radiation splits oxygen molecules into oxygen atoms (free radicals). $\text{O}_2(\text{g}) \rightarrow 2\text{O}(\text{g})$

These reactive oxygen free radicals combine with other oxygen molecules to form ozone.



Medium energy UV can break down ozone again. The UV radiation is absorbed by the ozone before it reaches the Earth's surface. $\text{O}_3(\text{g}) \rightarrow \text{O}(\text{g}) + \text{O}_2(\text{g})$

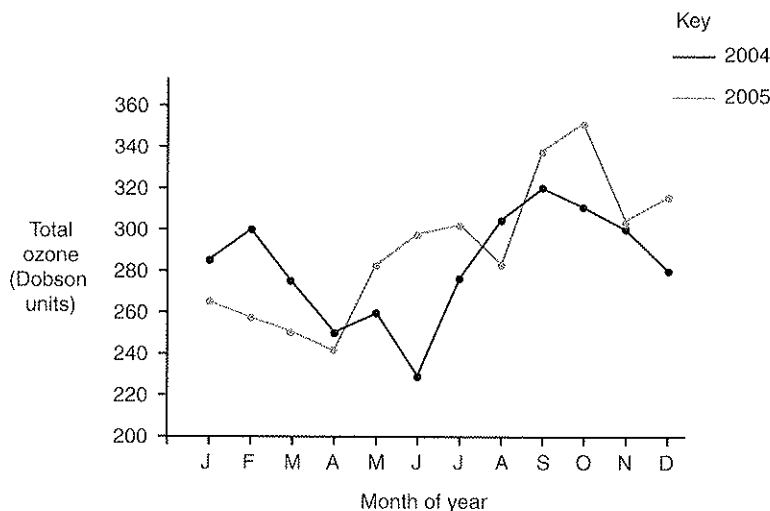
Oxygen free radicals also react with ozone to decompose it, forming oxygen gas.



- 4.11.2 Meteorological stations use balloons, aircraft and ground-based spectrometers to monitor stratospheric ozone. (There are five ground-based stations around Australia – Perth, Darwin, Melbourne, Brisbane and Macquarie Island.) Satellites are also used, e.g. NASA has a satellite spectrometer called Ozone Monitoring Instrument (OMI) – which replaced the Total Ozone Mapping Spectrometer (TOMS) on January 1, 2006. This satellite covers the whole area of the Earth every day and accurately maps ozone levels at all altitudes.

- 4.11.3 (a) Initially because of curiosity about atmospheric circulation in the upper regions of the atmosphere and to help with weather forecasting. We now monitor to try and achieve a comprehensive global picture of ozone levels so we can understand normal fluctuations and the effects of human activities in the hope that we can minimise any damage.
- (b) Ozone levels have decreased in the stratosphere especially over Antarctica. In 1985 it was revealed that the ozone concentration over Antarctica had decreased by 50% from 1975 to 1985. This was measured from both satellites and ground-based stations in Antarctica. This hole continues to grow and now covers about 24 million km². There was also a 40% thinning in the Arctic ozone layer by the late 1990s. Total ozone at mid and high latitudes has decreased by about 8% in the last 40 years. Many areas now report thinning which is worse in summer due to the stronger UV radiation in summer.
- (c) Early ground-based measurements of ozone levels provided limited information about ozone levels in the atmosphere above limited locations. The introduction by NASA of TOMS, and now OMI, mapping of ozone has led to much more accurate measurement of ozone levels over a much wider area and for all elevations. There seems no doubt that the ozone levels have decreased over recent years, however, as we have only been making these observations for a relatively short period of time, we do not really know whether this is part of a regular cyclic pattern.

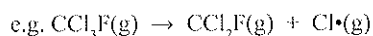
- 4.11.4 (a)



- (b) Various, e.g.
 Both graphs show considerable fluctuation.
 Both decline in the early months of the year and then increase.
 Both had their highest values in spring (Sept to Nov).
- (c) Various, e.g.
 Ozone levels above Sydney Harbour Bridge fluctuated throughout 2004 and 2005, reaching their highest levels in spring of each year.

4.12.1 Various, e.g. The Australian Bureau of Meteorology, The Australian Institute of Geoscientists, NASA.

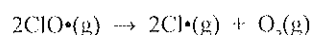
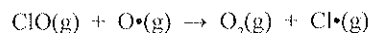
4.12.2 (a) Since CFCs are inert, they are able to reach the stratosphere without being changed. There, the UV radiation releases a chlorine atom (free radical) from the CFC molecule.



(b) The chlorine atom (a free radical) is highly reactive and immediately attacks an ozone molecule:



(c) The $\text{ClO}\cdot$ (chlorine oxide radical) then either reacts with a free oxygen radical or decomposes to form another chlorine atom and O_2 .



Chlorine free radicals are again released to continue reacting with ozone.

4.12.3 The loss of molecules of ozone, formation of O_2 molecules and the regeneration of chlorine atoms (free radicals).

4.12.4 Each chlorine atom introduced into the stratosphere can destroy thousands of ozone molecules before it forms a stable compound and is removed. As shown by the equations in answer to Question 4.12.2, each chlorine atom (free radical) released breaks down an ozone molecule and then further reactions release it to break down yet another ozone molecule. This process can be repeated thousands of times until the chlorine manages to react with something else and form a stable compound.

4.13.1 CFCs are stable, so they last a long time. They make their way up to the stratosphere and dissociate there forming chlorine free radicals which attack ozone.

Include equations as in 4.12.2.

The removal of ozone has allowed more UV light to reach the Earth's surface. This has led to a greater risk of skin cancer, cataracts and other health problems in humans. Plant growth has decreased including the growth of plankton. Plankton are an important source of atmospheric oxygen and the decrease in producers in the ocean can also affect the marine food chain and lead to a decrease in marine organisms.

4.13.2 (a) In 1985 a number of governments adopted the Vienna Convention on Protection of Ozone Layer. The Montreal Protocol of 1987 was a UN initiated international agreement to phase out the manufacture of substances that deplete the ozone layer. There have been a number of amendments to the Protocol. By 1996, 155 countries had ratified the Montreal Protocol and its amendments. The Protocol sets out a time schedule for freeze and reduction of ozone depleting substances such as CFCs and halons. A broad range of industrial chemicals used as refrigerants, aerosol propellants, fire retardants, solvents and fumigants are involved. Developed nations acted quickly to comply with the Montreal Protocol and developing nations must comply by 2010. Aerosol cans are, where possible, replaced by pump sprays. Gases in old equipment are collected and disposed of, not released into the atmosphere. Hydrohalogenated compounds have been developed to replace CFCs as refrigerants.

(b) All countries did not agree to all aspects of the Montreal Protocol. This has to some extent decreased its effect. Also China and other developing nations do not have to comply with the Montreal Protocol until 2010.

However, the changes made worldwide have still brought about a large reduction in the release of CFCs into the atmosphere. They have also increased peoples' awareness of problems associated with the destruction of ozone and CFC levels are now monitored along with ozone. Unfortunately CFCs already in the atmosphere are stable compounds. They will persist and continue to destroy the ozone for some time.

The replacement gases introduced have a CH bond that is less stable, so they tend to be attacked while still in the lower atmosphere. Thus they do not reach the stratosphere to attack the ozone. However, these replacements are generally more expensive and in some cases less effective. Also they are mostly greenhouse gases, contributing to global warming and some of them are toxic.

Although the steps taken have effectively reduced the volume of ozone depleting gases entering the atmosphere, the problem is by no means solved. More needs to be done to ensure the survival of ozone as it is vital in protecting us from the Sun's harmful UV rays.

- 4.14.1** Haloalkanes with some hydrogen atoms are now used. They are called HCFCs (hydrochlorofluorocarbons) and HFCs (hydrofluorocarbons, e.g. CF_3CHCl_2 , CF_3CFH_2 , $\text{CClF}_2\text{CHF}_2$).
- 4.14.2** They have been very effective as replacement chemicals but they are not a perfect solution. These compounds are less stable than CFCs due to their CH bond and so are broken down in the troposphere. They don't reach the stratosphere and so don't deplete ozone. However, as refrigerants and propellants, they are not always as effective as CFCs and tend to be more expensive. They also contribute to the greenhouse effect. They should be collected and disposed of carefully rather than being released into the atmosphere.
- 4.14.3** Various. In your answer you should include the following:
- Identify some uses of CFCs.
 - Name and state formulas for some CFCs.
 - Give reasons for their uses (mention properties).
 - Describe problems with their use – destruction of ozone and its effects.
 - Include equations. Explain the importance of the chlorine free radical. (*Note:* This is NOT a chloride ion)
 - Describe steps taken to alleviate problems – Montreal Protocol, education of the public and replacement of CFCs.
 - Discuss advantages of, and problems with, these steps.
 - Make an assessment of the effectiveness of these steps, based on evidence you have presented. Your assessment should make a judgement – do the steps effectively solve the problems?
- 5.1.1** Sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate. However, the concentration of the ions varies and the ocean concentration is much higher.
- 5.1.2** (a) Your answer should include most of the following:
- The minerals present in rocks and soils over which the water flows.
 - The rate of the flow of water affects the concentrations of the ions dissolved.
 - Gases from the atmosphere dissolve in water, the colder the temperature, the more soluble the gas, e.g. CO_2 dissolves readily in water to form CO_3^{2-} .
 - The acidity of water affects the ions dissolved, e.g. aluminium salts are more soluble in acidic conditions.
 - Pollution changes the types of ions present.
- (b) The composition of the oceans varies very little as ions that wash into the ocean from rivers are removed by marine organisms and deposition on the sea floor. Slight variations occur with temperature. Pollution may cause localised changes.
- 5.1.3** (a) Water which will not lather easily and forms a scum with soap.
- (b) calcium, magnesium, carbonate and sulfate ions
- (c) Hard water does not lather well, it forms a scum and discolours washing. It has a metallic taste. Hard water may leave a deposit in water heaters and it may be unsuitable for drinking.
- 5.1.4** Various, e.g.
- Atmospheric CO_2 dissolves in water to form carbonic acid, the cooler the water, the more CO_2 dissolved and the lower the pH.
 - Also gases such as sulfur dioxide and nitrogen oxides form acids when they dissolve in water and acids lower the pH. These are pollutants formed mainly by combustion of fossil fuels.
 - The composition of the soil and rock also affects the pH.
 - Discharge of effluents into the water can cause high or low pH.

- 5.1.5 (a) Cloudiness of the water, its clarity.
- (b)
- Erosion causes silt and clays to be suspended in water.
 - If pH or temperature changes, solubility of compounds in water varies and particles may come out of solution, increasing turbidity.
 - Growth of micro-organisms creates turbidity.
 - Eutrophication increases turbidity. This occurs with discharge of fertiliser, detergent or sewage into waterways and the resultant algal bloom.
- 5.2.1 (a) DO – The amount of O₂ (mg) dissolved in 1 L of water. Oxygen enters water from the atmosphere and is also produced by marine plants. Animals need oxygen for respiration and will die or move away if there is insufficient O₂. Animals need at least 5 mg/L (5 ppm) O₂ for survival.
- (b) BOD – The amount of oxygen used by 1 L of water kept in the dark for five days at 20°C. It is equal to the initial DO minus the DO at five days. Decomposers use O₂ to break down the organic material in the water. The greater the quantity of organic matter, the greater the demand for oxygen by the decomposers. If the BOD exceeds 5 ppm, there will not be sufficient O₂ for the aquatic organisms. It is a measure of the amount of organic matter in the sample.
- 5.2.2 (a) Nitrates, nitrites and phosphates. These ions are present in animal waste and fertilisers.
- (b) Nitrogen and phosphorus are required by plants for growth, so as the levels increase in water, algal growth occurs. If the N:P ratio is about 10:1 with N greater than 1 ppm and P > 0.1 ppm, then eutrophication tends to occur. The ratio is used as an indicator of pollution with sewage, fertiliser or detergents, all of which contain high levels of N and P.
- 5.2.3 They dissolve in rain and form acid rain, e.g.
- $$\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_3(\text{aq})$$
- $$2\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_3(\text{aq}) + \text{HNO}_2(\text{aq})$$
- This increases the concentration in the water of hydrogen ions, sulfate and nitrate ions.
- Increase in hydrogen ion concentration can increase the solubility of some salts and release more ions, e.g. aluminium ions into the water.
- 5.2.4 Irrigation and land clearing cause the water table to rise, bringing with it salt from underground. The salt washes into waterways, increasing the content of sodium ions (Na⁺) and chloride ions (Cl⁻) in the water.
- 5.2.5

Test for	Effect on water quality
Concentration of common ions	High concentration of Na ⁺ and Cl ⁻ ions indicates salt water or salinity of fresh water. Nitrates and phosphates can indicate sewage or agricultural run-off. Ca ²⁺ and Mg ²⁺ ions indicate hard water. H ⁺ ion concentration can be a sign of acid rain contamination.
Total dissolved solids (TDS)	Can indicate brackish or bore water which may require treatment to reduce ions. Can also indicate salinity.
Hardness	Hardness test indicates high Ca ²⁺ , Mg ²⁺ , CO ₃ ²⁻ ion concentrations and although this is normal for ground water, it may require treatment before use especially for drinking.
Turbidity	May indicate erosion and run-off from land, or may be due to high numbers of micro-organisms. Can indicate pollution.
pH	Extremes of pH will kill aquatic life. Change in pH affects content of other ions, e.g. Al ³⁺ ions, because solubility of ionic compounds varies with pH. Can indicate acid or alkali contamination from pollution. pH is normally 8.8 for sea water and 5.0 to 8.5 for fresh water.
DO and BOD	High DO indicates well aerated water with sufficient oxygen to maintain life. Needs to be considered alongside oxygen demand as this indicates organic material. High BOD can be due to sewage or industrial effluents.

5.3.1 Various results, depending on your samples and equipment available, e.g.

Test for	Method used	Qualitative or quantitative test?
Common ions	AAS for cations	Quantitative
	Flame tests	Qualitative
	Precipitation	Qualitative (or quantitative if you weighed amounts)
Insoluble solids	Filter measured sample, dry and weigh residue.	Quantitative
TDS	Filter sample, evaporate a measured amount, dry and weigh residue.	Quantitative
	Measure electrical conductivity with data logger and conductivity probe.	Quantitative
Hardness	Precipitation tests to determine calcium.	Quantitative
	Ability to lather with soap.	Qualitative
Turbidity	% light transmitted through standard depth or depth at which lines in turbidity tube can just be seen.	Quantitative
Acidity	Indicators	Qualitative
	Data logger with pH probe	Quantitative
DO	Data logger with O ₂ probe	Quantitative
BOD	Difference between DO after five days in dark under standard conditions and initial DO.	Quantitative
Phosphate	Colorimetric – add ammonium molybdate, measure depth of colour when blue compound formed	Quantitative

5.3.2 Various depending on the origins of the samples you tested, e.g. pond water may have high phosphate, high BOD and high turbidity. This would indicate organic matter and algal growth.

- 5.3.3**
- (a) 3.36 g/L
- (b) This indicates that all the water has been evaporated and only the solids remain. Increases accuracy of results, otherwise you do not know if it is thoroughly dry.

5.3.4 24.4 g L⁻¹

- 5.4.1**
- (a) Various, e.g. lead, mercury, cadmium, silver (any metal with a density over 5 g/cm³).
- (b) Various, e.g. mercury – organomercury compounds can enter the brain and cause neurological damage. Symptoms of mercury poisoning include loss of hair, insomnia, heart disease, birth defects and thyroid problems. It can also cause death.
- (c) Bioaccumulation – building up to high levels in the tissues of organisms.
Biomagnification – concentration increases as it moves along the food chain.
- 5.4.2**
- (a) An increase in the nutrient content of water leading to excessive algal growth (an algal bloom) which is followed by decay of the organisms and depletion of oxygen in the water.
- (b)
- Excess nutrients, particularly nitrogen and phosphorus, wash into the water as pollution and promote plant growth.
 - Algae grow rapidly, some producing toxins, and then die.
 - The decomposition of the algae (by bacteria and other micro-organisms) uses up the oxygen in the water and the water becomes stagnant.
 - This shortage of dissolved oxygen leads to the death of aquatic organisms.
- (c) The addition of excess nutrients to waterways from farm run-off, detergents, sewage or industrial effluent. The effect is worse if there is little flow of water, e.g. during drought.

5.4.3 Various, e.g.

Methods used to test for heavy metals	Chemistry
AAS – used to detect traces of heavy metals. Samples need to be sent to a lab.	AAS – Absorbance of the atomised water sample is measured at specific wavelengths. Each wavelength is selected to measure one element in the mixture. Then absorbance is related to concentration using a calibration curve.
Precipitation tests can be used in the field when an immediate indication is required, but is not as sensitive.	Precipitation tests utilise the varying solubility of ionic compounds, e.g. add potassium iodide solution to form a yellow precipitate of PbI_2 , indicating lead contamination. $2\text{KI}(\text{aq}) + \text{Pb}^{2+} \rightarrow 2\text{K}^+(\text{aq}) + \text{PbI}_2(\text{s})$

5.4.4 Various e.g.

Methods used to test for eutrophication	Chemistry
Measuring the nitrogen and phosphorus content of the water by colorimetric tests.	The nitrates or phosphates are converted to coloured compounds using standard reagents. Then the depth of the colour is measured and converted to concentration units with a calibration curve.
Measure turbidity. Turbidity increases as algae grow.	Turbidity is measured by the light that can penetrate the solution. Attach a faint black cross to the base of a long cylinder. Look down the tube. Slowly pour water into the tube until the cross disappears.
Measure DO and BOD. DO will decrease and BOD will increase as the algae die.	DO and BOD are measured by data loggers and an oxygen probe. The probe sets up an electrochemical cell with the oxygen and a voltage is generated that is proportional to the oxygen content.

5.4.5 Various, e.g.

A would probably contain a higher concentration of ions, especially heavy metal ions, nitrates and phosphates. B would have a higher DO and lower BOD and lower turbidity due to less organic material and hence less micro-organisms. It is likely that the pH of A would be more acidic due to effluent and acid rain discharged from the industrial area.

It would be likely that the fertilisers and animal wastes from the farms would lead to increased concentration of nutrients, possibly causing algal bloom before the river divided. Also erosion of topsoil may have increased turbidity.

The tributary A would not be likely to have the nutrient balance restored as more wastes from the town and possibly toxic wastes and organic wastes such as sewage would be contaminating A by the time it reached the sea. B could have its nutrient balance restored as it flowed through the forest as trees on the banks would absorb nutrients.

Tests to verify differences could include: tests for common ions especially nitrates and phosphates, AAS for metals, DO, BOD, turbidity, pH and micro-organisms.

- 5.5.1 (a) A natural area where rainwater and run-off are collected to provide a water supply.
- (b) Various. The following description applies to the Sydney catchment. Sydney has four main catchments west and south-west of the city. The largest is the area around Lake Burragorang. This is the lake formed by Warragamba Dam and is fed by the Cox, Wollondilly and Kowmung Rivers.

5.5.2 Permitted activities include picnicking, bushwalking and recreational activities.

Not permitted include: swimming or boating on the dams, farming, logging or urban development, industry or the use of chemicals such as insecticides.

5.5.3 Various, e.g. sediments from erosion, animal urine and faeces, decaying organisms, leaching of chemicals from surrounds or corrosion from structures in the area. Careless or illegal chemical use may also pose a risk.

5.5.4

Test for contaminants	Contaminants detected by this test
AAS	Metal ions especially heavy metals.
Flame test	Metal ions such as Ca^{2+} , Cu^{2+} , Ba^{2+} .
Precipitation reaction tests	Ions such as Cl^- (indicating salinity), SO_4^{2-} , Pb^{2+} .
Add acid and test for carbon dioxide produced	CO_3^{2-} ions.
Gravimetric analysis	Insoluble solids such as silt, clays, sludge suspended in the water.
Electrical conductivity	Total dissolved solids.
Turbidity	Insoluble solids such as silt, clays, sludge suspended in the water. An indication of microbial contamination such as algal growth, faecal contamination.
Acidity	Dumping of acid or alkali wastes, acid rain.
DO	Low DO indicates increased activity of aerobic microbes which use up the oxygen. Possible increase in organic wastes.
BOD	Measure of organic matter in water. High BOD can be due to industries such as food processing, paper production.
Colorimetric tests for nitrogen and phosphorus content and N:P ratio	Indicates sewage, fertiliser or detergents in water.

5.5.5 Coliform bacteria, e.g. *E. coli* indicate faecal contamination. Algal bloom indicates sewage, fertiliser or detergents. Protozoans such as giardia and cryptosporidium indicate contamination, e.g. dead animals.

5.5.6 (a)

Chemical additive	Reason for adding chemical
Iron(III) chloride or aluminium hydroxide and a cationic polymer	Coagulates fine suspended particles so that they will sediment or can be more easily filtered. Fe^{3+} also precipitates excessive phosphate.
Sulfuric acid	Breaks down organic wastes and aids coagulation.
Limewater or other alkali	Neutralises acid and restores neutral pH.
Fluoride	Hardens tooth enamel and helps prevent tooth decay.
Chlorine	Forms hypochlorite (ClO^-) which bleaches coloured matter in the water and disinfects the water by killing micro-organisms.

(b) Sieving, filtration

5.6.1 The following steps should be included:

- Solid objects (e.g. organisms, twigs) are removed by a screening device.
- Chemicals, e.g. aluminium hydroxide are added to coagulate fine particles and aid their removal. This is called flocculation.
- Sand filters are used to remove coagulated solids. A 2 m deep bed of sand is used. The solids are collected when the sand filters are cleaned and are used as compost.
- Water testing is carried out for ions, colour, pH, hardness, turbidity, conductivity, micro-organisms. Chemicals are then added as needed, e.g. sulfuric acid may be needed to break down organic matter, then limewater is added to neutralise the acid.
- Chlorine (to disinfect) and fluoride (for teeth) are added in regulated amounts.

5.6.2 As long as catchment areas are controlled so that contamination with sewage, agricultural wastes and industrial effluent does not occur, then the treatment applied to water supplies should be sufficient to ensure pure, healthy water.

Monitoring of catchment and treatment processes is necessary. If microbial levels are too great extra chlorine can be added, if organic matter is excessive, aeration of the water and longer storage can be done to allow decomposition to occur. This means that constant monitoring and adjustment is required for the process to be effective.

Our water is generally of a high standard, however the methods are not completely effective as on one occasion Sydney's water contained high levels of the organisms giardia and cryptosporidium which caused illness. This could be prevented, and our purification of water supplies improved, by installing membrane filters.

- 5.7.1** Australia is a very dry continent, suffering regular droughts and hence an unreliable water supply. To conserve water in the future, as population increases, it will be necessary to recycle water, desalinate sea water or even to treat sewage and bring it back to potable water (suitable for drinking). One possible technique is membrane filtration.
- 5.7.2**
- (a) Membrane filters are made from polymers such as cellulose acetate, PVC and polypropylene. They are partially permeable and have extremely tiny pores, hence water can pass through, but large organic molecules and micro-organisms including viruses cannot. If the polymer is in a mat form, it is useful as a pre-treatment and can remove a large load of solids. If the polymer is made into a thin film, it can act like a sieve, removing particles larger than the pore size. The size of the pores is controlled.
 - (b) The polymer sheets are formed into a cylinder or cartridge by winding or folding the sheets around a central core. The water is pumped in at one end and flows over the polymer sheets at right angles. The pressure forces the water through the polymer to the core and hence out the other end. Colloidal particles, micro-organisms and even solutes are removed. The direction of flow over the polymer surface reduces clogging of the pores, but the filters still need regular cleaning by backflushing.
 - (c) Filters can be classified according to the size of their pores and hence the size of molecules they will remove.

Microfiltration membranes can remove micro-organisms including virus particles and colloidal particles down to about 200 nm in diameter.

Ultrafiltration membranes (UF) remove particles from 100 nm to 2 nm in size. Large organic molecules are therefore removed. Some UF are coated so that they can also remove some ions, e.g. metal ions.

Nanofiltration membranes (NF) have pore sizes less than 1 nm and hence will remove even smaller molecules. They can remove molecules with molecular masses down to 300. They can be coated to remove metal ions and hence reduce hardness as well as removing toxic heavy metals.
- 5.7.3** Disadvantages -- high cost to purchase and install and need for regular cleaning (applies to all filters).

Advantages -- operation is not expensive; heavy metals could be removed and recycled; ensure tiny organisms such as the escape of giardia and cryptosporidium are kept out of our water supply; could be used to purify catchment water and also water from households and industry to be recycled. This ensures the water supply in droughts.
- 5.7.4** Various, e.g. Society's demand for a regular, fresh, safe water supply has put pressure on the authorities to improve the treatment of water as well as increasing the volume of water available for use. Increases in population and an uncertain rainfall have highlighted this need. This has resulted in money being made available for scientific research to develop new technologies such as membrane filtration and other techniques needed for recycling and desalination.

As technology improves, and products are mass produced, new technologies often become more affordable and thus their use spreads to more areas and applications. It is often the case that a need in society has resulted in new and improved technology.