1. Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions

1) Outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses
   - Plant chemist at a chemical manufacturing company that makes ethylene from ethane then polymerises it to polyethylene
   - ROLE – monitoring quality of ethylene and propylene products from the plant to ensure that they meet the requirements for the next stage of manufacture in particular determining the nature and amount of any impurities present. Also monitors waste water – pH, suspended solids, sulfates, hydrocarbons, grease, etc
   - BRANCH OF CHEMISTRY - Analytical chemistry – the part of chemistry concerned with determining what substances (and how much of each) are present in materials
     - Many of his analyses use gas chromatography
     - Mixture vaporised into a stream of helium that flows over a stationary phase which can be a solid, or a liquid coated on the surface of a solid. The stationary phase can be a finely divided solid packed in a long thin tube or column, called gas-solid chromatography, it can be a liquid coated on the walls of a long thin glass (silica) capillary tube – called gas-liquid chromatography (GLC).
   - CHEMICAL PRINCIPLES
     - Adsorption (for gas-solid chromatography) and solubility (for GLC)
     - Gas-solid chromatography – If stationary phase is a solid, then the components of the mixture adsorb on to it (stick on to the surface) to differing extents, pass through the column at different rates and so are separated. A device at the end of the column detects each substance as it passes out of the column and measures it quantitatively
     - If stationary phase is a liquid, then the components of the mixture dissolve in it to differing extents. The more soluble a substance is in the stationary liquid, then the slower that substance moves through the tube (column). Polarity of molecules is often a key factor in GLC separations: if the stationary phase is a polar liquid, then the more polar a component of the mixture to be analysed, the greater is its solubility and so the more slowly it moves through the column. Hence a separation is effected and the detector measures the amount of each component as it emerges from the column
     - Polarity of molecules is often a key factor in GLC separations: if the stationary phase is a polar liquid, then the more polar a component of the mixture to be analysed, the greater its solubility and sot he more slowly it moves through the column.

2) Identify the need for collaboration between chemists as they collect and analyse data

   Chemists, like scientists generally, work in teams. Some will have particular expertise and roles in the task at hand. Some may have expertise in special technology, others in understanding previous work, others in analysis of new data and so forth.

   This means that collaboration is a vital aspect of the collection and analysis of data.

3) Describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring

   EXAMPLE 1 – Combustion Reactions
   - Combustion reactions can produce solely carbon dioxide or a mixture of carbon dioxide, carbon monoxide and soot (carbon) depending upon the relative amount of oxygen provided

   EXAMPLE 2 – Ethene + Oxygen
   - In a plentiful supply of oxygen at a high temp. ethene reacts to form carbon dioxide (normal combustion):
     - $C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(g)}$
   - However at lower temps and with lesser amount of oxygen and with suitable catalysts, quite different products are formed
   - With a silver catalyst and a temperature of 250°C ethylene oxide is formed
     - $C_2H_4 + \frac{1}{2} O_2 \rightarrow C_2H_4O$ (ethylene oxide)
   - With a palladium catalyst and a temperature of 150°C, acetaldehyde, another important industrial chemical, is formed:
     - $C_2H_4 + \frac{1}{2} O_2 \rightarrow CH_3COH$ (acetaldehyde)
   - Even with these catalysts and the lower temperatures some ethene reacts by the first reaction. Hence, it is important to monitor reactions conditions to ensure that the yield of the desired product is maximised.

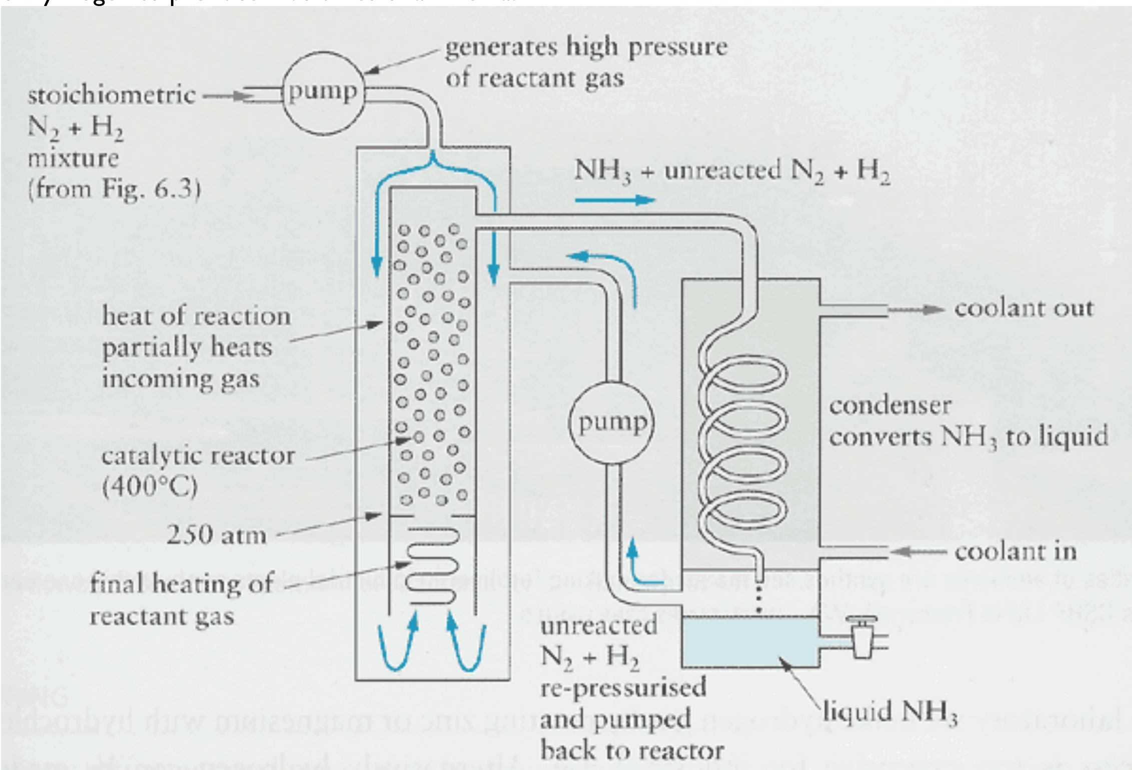
4) Gather, process and present information from secondary sources about the work of practising scientists identifying:
   - the variety of chemical occupations
   - a specific chemical occupation for more detailed study

- Environmental chemists - monitoring water and air samples for pollutants
- Metallurgical chemists - give advice on the extraction of metals from ores and ways in which they could be combined with other materials such as polymers or ceramics. Employed in mining, metal manufacturing and engineering fields
- Industrial chemists - Research into development of petrochemicals, detergents, plastics, to semiconductors. Reaction speeds, efficiency, etc.
- Biochemists - Chemical structure and functions of molecules in living things. Research into developing new medical, industrial and agricultural products
- Polymer chemists - properties of large polymeric molecules. Develop new adhesives, packaging materials, synthetic fibres and coatings for the automotive, biomedical and aerospace industries.

2. Chemical processes in industry require monitoring and management to maximise production

1) Identify and describe the industrial uses of ammonia
Ammonia can be used to produce:
   - fertilisers
   - fibres and plastics (rayon, acrylics, nylon)
   - nitric acid, which in turn is used to make fertiliser (ammonium nitrate), dyes, and plastics
   - household cleaners
   - detergents

2) Identify that ammonia can be synthesised from its component gases, nitrogen and hydrogen
Under pressure and heat, nitrogen and hydrogen react in the ratio of 3 volumes of nitrogen to 1 volume of hydrogen to produce 2 volumes of ammonia.



3) Describe that synthesis of ammonia occurs as a reversible reaction that will reach equilibrium
The synthesis of ammonia occurs as a reversible reaction. This means that ammonia is formed from nitrogen and hydrogen (the forward reaction) and once some ammonia is produced, some nitrogen and hydrogen are formed from the ammonia (the reverse reaction). When nitrogen and hydrogen are initially added to a reaction vessel, the reaction is slow. Equilibrium is reached when the rate of the forward reaction is the same as the rate of the reverse reaction.

To ensure that sufficient ammonia is produced, conditions need to be established that shift the equilibrium position to the right.

4) Identify the reaction of hydrogen with nitrogen as exothermic

The forward reaction, to produce ammonia, releases 46 kJ of energy for each mol of ammonia formed.

5) Explain why the rate of reaction is increased by higher temperatures

As the temperature rises, the particles move more quickly and have higher kinetic energy. This increases the frequency of collisions between particles that can react and also increases the amount of energy available for the reaction. Most of the increased rate of reaction comes from more of the colliding particles exceeding the activation energy needed for the reaction to occur. The increased frequency of collisions is less important in increasing the rate of reaction. The rate of both the forward and reverse reactions is increased.

6) Explain why the yield of product in the Haber process is reduced at higher temperatures using Le Chatelier's principle

$$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$$

- increase in temperature
- equilibrium will shift to oppose the change, i.e. Lower the temperature
- the reaction that reduces temperature is the reverse reaction
- therefore equilibrium will shift to the left

Thus, an increase in temperature will result in a reduction in the yield of ammonia.

7) Explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium

A high temperature in the production system will result in a higher *rate* of reaction, however as production of ammonia by the Haber process is an exothermic reaction and increased temperature will result in a lower *yield* of ammonia. Thus a compromise between increased reaction rate and lower yield must be achieved. Typical conditions for the industrial process are:

- a temperature of about 400°C and
- a total pressure of about 250 atmospheres (Smith)

8) Explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst(s) used in the Haber process

With the use of catalyst, the activation energy for the reaction is lowered. A finely ground iron catalyst with large surface area, magnetite (Fe3O4), with reduced iron on the surface, is used in the Haber process. The gaseous nitrogen and hydrogen molecules are adsorbed on to the solid catalyst surface and rearrange forming the ammonia molecules. By lowering the activation energy, a catalyst enables a more rapid reaction at lower temperatures.

9) Analyse the impact of increased pressure on the system involved in the Haber process

$$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$$

- increase in pressure
- equilibrium will shift to oppose the change, i.e. decrease the pressure
- the reaction that reduces the moles of gases is the forward reaction
- therefore equilibrium shifts to the right

Thus, an increase in pressure on the production system will cause the equilibrium to shift to the right and produce more ammonia.

10) Explain why monitoring of the reaction vessel used in the Haber process is crucial and discuss the monitoring required

Since many different conditions must be maintained for the efficient and safe operation of the Haber process, monitoring is essential. First temperature and total pressure must be monitored to keep them in the range for optimum conversion of reactants to products: in addition excessive temperature can damage the catalyst. Then it is essential to monitor the composition of the incoming gas stream. The ratio of H_2 to N_2 must be kept at 1:3 to avoid the build up of one reactant. Oxygen must be absent from the reaction vessel to avoid the risk of explosions, and that concentrations of carbon monoxide and sulfur-containing species are sufficiently low to prevent poisoning of the catalyst.

11) Gather and process information from secondary sources to describe the conditions under which Haber developed the industrial synthesis of ammonia and evaluate its significance at that time in world history

The German scientist Fritz Haber developed the method of producing ammonia from hydrogen and nitrogen. By 1909 he had been able to synthesise about 100g of ammonia using his procedure. Carl Bosch a chemical engineer then scaled the production up to industrial levels. In 1913, the process was producing 30 tonnes of ammonia a day.

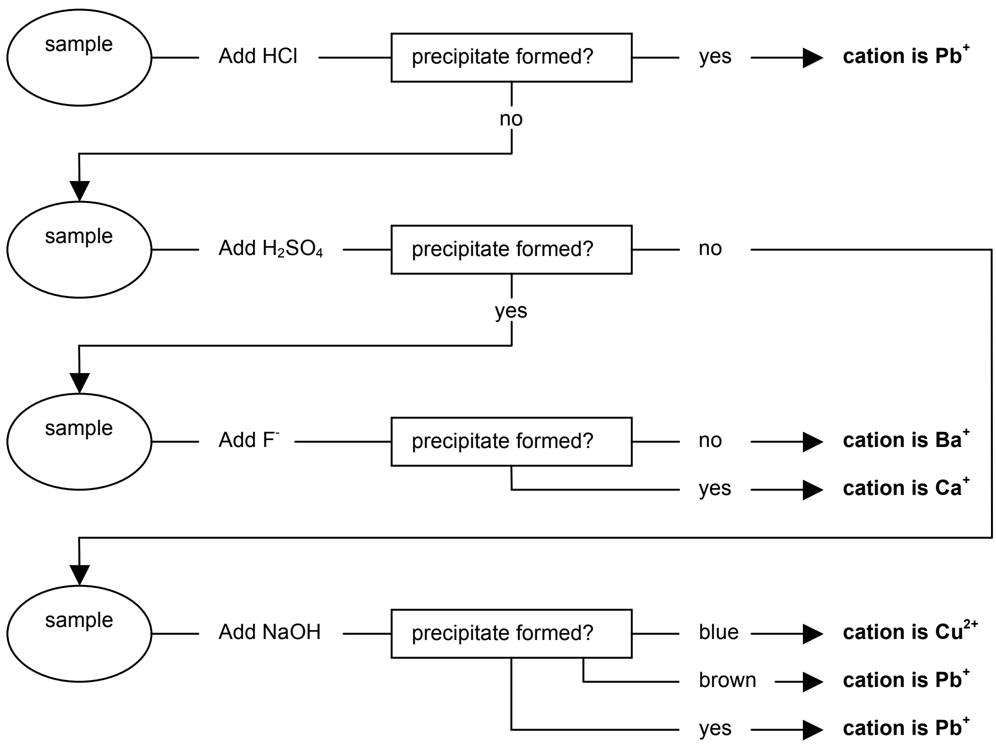
In the years leading up to World War I Haber realised that the manufacture of nitric acid from the oxidation of ammonia would be vital for the production of chemical weapons and explosives. The Allies superior navy blocked German supplies of nitrates from Chile, so Haber's ammonia process allowed Germany to supply the explosives for its war effort. Haber served in the German army during the war and helped to direct the use of poison gas warfare against the Allied troops in the trenches. This use of toxic gas almost won the war for Germany.

The success and relative ease of the Haber process in producing ammonia for weapons production prolonged the war, causing many more deaths than would have occurred otherwise.

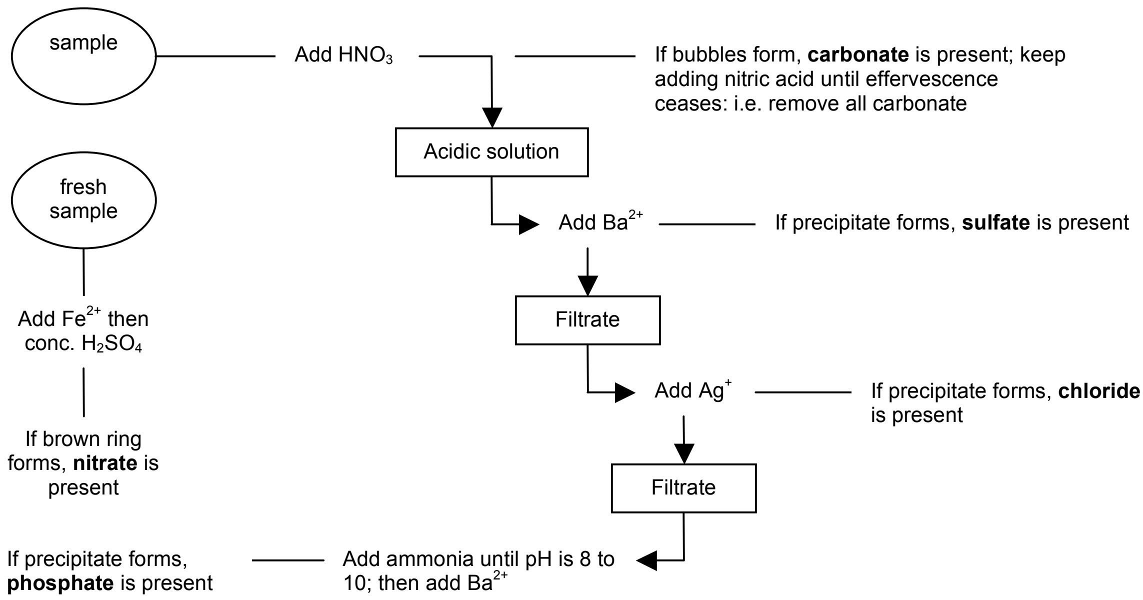
3. Manufactured products, including food, drugs and household chemicals, are analysed to determine or ensure their chemical composition

1) Deduce the ions present in a sample from the results of tests

<u>Flowchart for Identifying Cations</u>



Flowchart for Identifying Anions



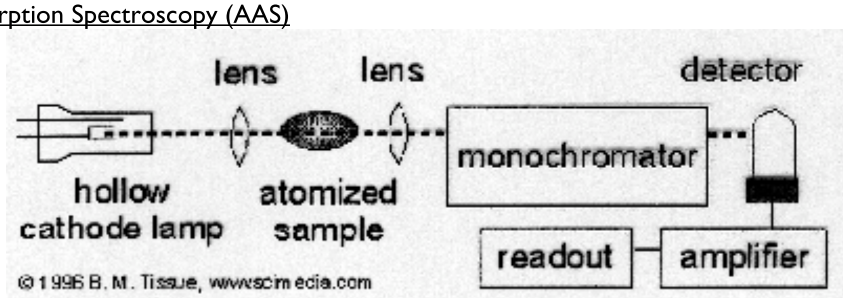
2) Describe the use of atomic absorption spectroscopy (AAS) in detecting concentrations of metal ions in solutions and assess its impact on scientific understanding of the effects of trace elements

Atomic Emission Spectroscopy

If atoms are heated to a high temperature (>1500°C), some of the electrons are excited out of their normal energy levels. After a short time these electrons fall back from these high energy levels to their normal levels. As this occurs, excess energy is liberated as light. The energy emitted as an electron falls back to its *ground state* is the same as the energy absorbed when it was raised to its *excited state*.

If the emitted light is broken into its various wavelength components by passing it through a prism, visible omissions have occurred at just a few discrete wavelengths. The pattern of lines is called an *emission spectrum*. Each element has its own unique emission spectrum. By measuring its emission spectrum, we can identify an unknown element. This is called *atomic emission spectroscopy*, and is useful for qualitatively identifying elements.

Atomic Absorption Spectroscopy (AAS)



Atomic absorption spectroscopy (AAS) is an important technique in measuring the concentrations of metal ions in very minute quantities. In atomic spectroscopy a liquid sample containing the metal ion to be tested is aspirated through a plastic tube into a flame hot enough to vaporise the molecules into atoms. A cathode lamp of the specific metal passes through the vaporised sample. A detector measures the amount passing through the flame and gives out the absorbance (amount absorbed) reading.

The basis of AAS is the result of the electron structure of the atom. Under quantum theory, electrons move to higher or lower energy levels by absorbing or releasing electromagnetic radiation of a particular frequency. Since each element has a different set of electron energy levels, each has its own set of absorption lines. The greater the concentration of the metal ion, the more radiation is absorbed and the less reaches the detector. According to the Beel-Lambert Law, the amount of light absorbed is proportional to the amount of a substance present. A calibration graph using solutions of known concentrations allows the concentration of the unknown to be determined.

The development of the AAS has allowed chemists to measure accurately and rapidly concentrations of metal ions in water systems and in animals and plants. Such has lead to our understanding of trace elements, those elements which are required by living things in very minute quantities. Prior to this understanding, there were instances where animals had health problems in seemingly good pastureland due to deficiencies in cobalt and human illnesses, due to lack of trace elements in their diet, could not be diagnosed. Now, with atomic absorption spectroscopy, these problems are easily and effectively rectified.

3) Perform first-hand investigations to carry out a range of tests, including flame tests, to identify the following ions: phosphate, sulfate, carbonate, chloride, barium, calcium, lead, copper, iron

See Prac Book (3.1)

4) Gather, process and present information to describe and explain evidence for the need to monitor levels of one of the above ions in substances used in society

Some foodstuffs are monitored for the presence of lead to ensure we are not consuming a poison that can accumulate in our bodies. The concentration of lead in our blood increases when we inhale air from busy roads. The concentration of lead in blood need to be monitored, especially for populations of children and the elderly living near busy roads and workers in lead smelters.

5) Identify data, plan, select equipment and perform firsthand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved
6) Analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure

See Prac Book (3.2)

7) Gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control

In the University of Sydney's High School Chemistry Workshop, an AAS machine was demonstrated to us and used to test the concentration of Fe^{2+} ions in various samples of water. The results were as follows:

Source of Water	Absorbance Reading	Concentration (ppm)
Tap	0.003	0.0
Creek	0.0012	0.2
A rusted rainwater tank	0.252	4.0

As can be seen, the ability of the AAS technique to measure in parts per million (ppm) allows chemists to measure metal ions of a very low concentration. However, the AAS must be daily calibrated with the ion to be measured for the machine to measure accurately. By monitoring the ions that are known pollutants, atomic absorption spectroscopy is a very effective and inexpensive method to control pollution.

4. Human activity has caused changes in the composition and the structure of the atmosphere. Chemists monitor these changes so that further damage can be limited

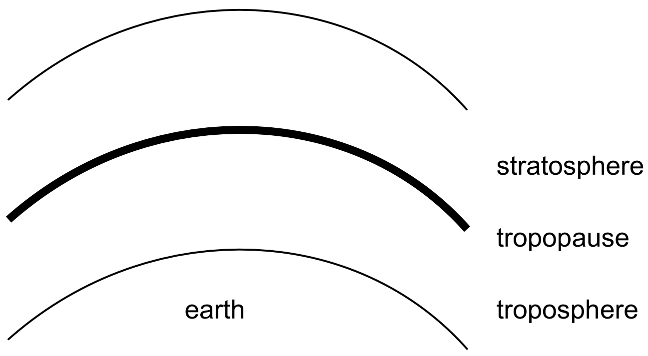
1) Describe the composition and layered structure of the atmosphere

The atmosphere is comprised of two main layers; the troposphere and the stratosphere. It is within these two layers that ozone exists. The troposphere extends from the earth's surface to 15km above sea level. Over 90% of the earth's gases are in the troposphere. As altitude increases, temperature drops in the troposphere.

At the top of the troposphere there is a region where the temperature remains relatively stable. This is called the tropopause and it is a region where there is a reduce mixing of gases.

Above the tropopause is the stratosphere. In the stratosphere, temperatures rise with increasing altitude.

The atmosphere is predominantly composed of nitrogen (78% by volume), oxygen (21% by volume) and argon (0.93% by volume), with other gases in very small concentrations.



2) Identify the main pollutants found in the lower atmosphere and their sources

Main Pollutants	**Main Sources**
Carbon monoxide	Motor cars, cigarettes, bushfires, incomplete combustion
Nitrogen oxides	Combustion (vehicles and power stations)
VOCs and hydrocarbons	Solvents and unburnt fuels
Sulfur dioxide	Metal extraction processes, burning of fossil fuels
Lead	Leaded fuels, metal extraction, leaded paints, old house renovations
Particulates	Incomplete combustion, dust storms, agricultural and industrial practices

3) Describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower atmosphere pollutant

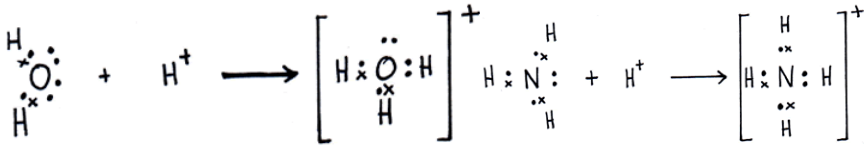
In the upper atmosphere, ozone acts as a shield against UV radiation preventing it from reaching the Earth's surface. UV radiation is capable of breaking covalent bonds in organic molecules and thus, is dangerous to most life forms on earth. In the stratosphere, ozone is 'good', since it prevents dangerous UV radiation from reaching the Earth's surface

However, in the lower atmosphere, ozone is 'bad'. Ozone is a very reactive molecule capable of oxidising many substances. At a concentration of 0.12 ppm, asthmatics may begin having breathing difficulties, and at a concentration of 0.2 ppm, plant damage becomes obvious.

4) Describe the formation of a co-ordinate covalent bond

A co-ordinate covalent bond is a covalent bond where the shared pair of electrons comes from only one of the two atoms bonded. Although this type of bond forms differently from other covalent bonds, its behaviour is indistinguishable from a normal covalent bond.

5) Demonstrate the formation of co-ordinate covalent bonds using Lewis electron dot structures

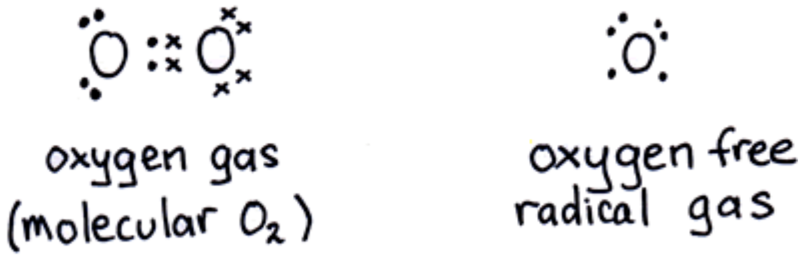


Formation of a coordinate covalent bond in a hydronium and ammonium ion

6) Compare the properties of oxygen allotropes O_2 and O_3 and account for them on the basis of molecular structure and bonding

Property	**Oxygen**	**Ozone**
	• Colourless gas, condensing to a pale blue liquid • Odourless • Essential for most living matter	• Colourless gas condensing to a distinctly blue liquid • Strong distinctive odour • Poisonous
Boiling point	-183°C	-111°C
Density	Same as air	1.5 times that of air
Solubility	Sparingly soluble (9ppm)	Considerably more soluble than O_2
Stability	Very stable	Easily decomposed to O_2
Reactivity	• Reacts with most other elements to form oxides • Moderately strong oxidising agent	• Much more reactive than O_2 • Very strong oxidising agent
Uses	• Widely used medically to overcome breathing problems • Steelmaking • Oxyacetylene torches • Liquid O_2 used in space shuttles as oxidiser for fuel	• As a steriliser in restaurants • Purification of water • A bleaching agent in paper and textile manufacturing

7) Compare the properties of the gaseous forms of oxygen and oxygen free radical



The oxygen atom in its ground state (electrons in the lowest possible energy levels) has 3 pairs of electrons in its valence shell.

When UV energy splits an oxygen molecule, two oxygen atom radicals are formed, i.e. they each have two electron pairs and two unpaired electrons. The energy absorbed in the splitting and the unpaired electrons make the free radical very reactive.
Lewis electron dot structure of gaseous forms of oxygen

In order of reactivity, the diatomic oxygen molecule is less reactive than the ozone molecule, which is less reactive than the oxygen free radical.

8) Identify the origins of CFCs and halons in the atmosphere

CFCs were developed to replace ammonia as a refrigerant in the 1930s. At the time their properties were found to be 'safer' than ammonia

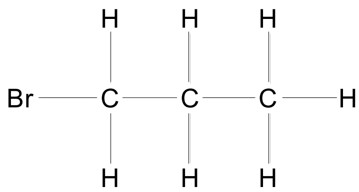
Their inert properties as well as their low boiling point also led to their widespread use as solvents, propellants and blowing agents in foams.

As CFC products were used, the gases were released into the atmosphere. CFCs were inert, thus no reaction took place in the troposphere, but once they made their way into the stratosphere, UV energy broke the C-Cl bonds, releasing chlorine free radicals.

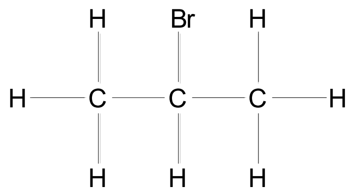
9) Identify and name examples of isomers (excluding geometrical and optical) of haloalkanes up to eight carbon atoms

Isomer – molecules with same chemical formula but different structural formula.

e.g. C_3H_7Br – bromopropane

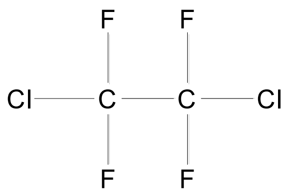


1-bromopropane

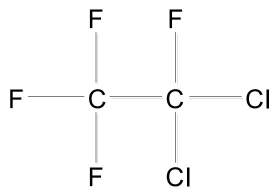


2-brompropane

e.g. $C_2F_4Cl_2$



1,2-dichloro-1,1,2,2-tetrafluroethane



2,2-dichloro-1,1,1,2-tetrafluroethane

10) Discuss problems associated with he use of CFCs and assess the effectiveness of steps taken to alleviate these problems

CFCs undergo photodissociation (reactions using the energy of light to break bonds); thereupon they release chlorine atom radicals. It is these radicals which destroy ozone molecules:

1) $CClF_{3(g)}$ + UV radiation → $CF_{3(g)} + Cl\bullet_{(g)}$

2) $Cl\bullet_{(g)} + O_{3(g)} \rightarrow ClO_{(g)} + O_{2(g)}$

3) $ClO_{(g)} + O_{(g)} \rightarrow O_{2(g)} + Cl\bullet_{(g)}$

Therefore, the direct effect of CFC use is the long-term depletion of the ozone layer; the chlorine radical is regenerated in the process and can thus deplete more ozone molecules. Since the ozone layer is important in the lower stratosphere as a UV absorption shield, its depletion will result in more UV rays reaching the earth; further, UV radiation can damage the skin and eyes of animals and promote cancerous tumours.

In 1987, the Montreal Protocol was signed to alleviate the problems cause by CFC use. The member countries of the protocol promised to immediately replace all CFCs with HCFCs (hydrochlorofluorocarbons), which are less reactive and destructive than CFCs. It was planned that HCFCs will then be phased and out replaced by other hydrocarbons by the year 2000. The protocol also offered assistance to developing countries to help them minimise their use of CFCs.

The protocol has been effective in that CFCs have been removed from all developed countries, but in developing countries CFCs are still in use. However the protocol has been very effective in that CFC use has been dramatically minimised and 2003 was the first year that the rate of ozone depletion has levelled off.

11) Analyse the information available that indicates changes in atmospheric ozone concentrations, describe the changes observed and explain how this information was obtained

In the late 1980s, the TOMS (Total Ozone Mapping Spectrometer) aboard the Nimbus-7 satellite recorded significant thinning of the ozone layer over Antarctica, evidence led to the acceptance of the theory that CFCs and the chlorine radicals they produce led to the decline of the ozone layer. Since then, very large decreases (known as 'holes') have been observed by TOMS.

There is an increase in ozone thinning during spring in Antarctica after a long winter, because ice crystal surfaces help generate molecular chlorine by the reaction of HCl and ClONO2. The Cl2 photodissociates with the extra UV radiation in spring to produce more chlorine free radicals that increases ozone depletion. By summer the Cl2 levels have depleted and ozone concentrations return to normal levels.

The information about ozone concentrations are collected by TOMS on satellites, spectrometers on scientific balloons and ground-based spectrometers.

12) Present information from secondary sources to write equations to show the reactions involving CFCs and ozone to demonstrate the removal of ozone from the atmosphere

CFC reaches stratosphere. UV light breaks C-Cl bond, forming a chlorine free radical
CCl_3F + u.v. light → Cl• + CCl_2F

Chlorine free radical abstracts an oxygen atom from the ozone molecule forming ClO
Cl• + O_3 → ClO + O_2

The ClO reacts with oxygen atoms forming a molecule of oxygen and a chlorine free radical
ClO + O → Cl• + O_2

The net reaction is O_3 + O → $2O_2$

The overall effect is destruction of ozone, becoming oxygen gas instead. Additionally, the chlorine free radical ends up remaining unused, ready to deal more damage.

13) Gather, process and present information from secondary sources including simulations, molecular kits or pictorial representations to model isomers of haloalkanes

14) Present information from secondary sources to identify alternative chemicals used to replace CFCs and evaluate the effectiveness of their use as a replacement for CFCs

5. Human activity also impacts on waterways. Chemical monitoring and management assists in providing safe water for human use and to protect the habitats of other organisms

1) Identify that water quality can be determined by considering: concentrations of common ions; total dissolved solids; hardness; turbidity; acidity; dissolved oxygen and biochemical oxygen demand

Water quality can be determined by considering: concentrations of common ions; total dissolved solids; hardness; turbidity; acidity; dissolved oxygen and biochemical oxygen demand

2) Identify factors that affect the concentrations of a range of ions in solution in natural bodies of water such as rivers and oceans

Factors affecting ion concentration include:

- **The pathway from rain to water body**

  Rainwater contains very few ions (CO_3^{2-}, Na^+, Cl^-, SO_4^{2-}). When rain runs off bushland into streams it picks up small amounts of nitrates and phosphates from nutrients on the surface and some Ca^{2+} and Mg^{2+} from decomposing minerals.

  If the water runs through underground aquifiers it will contain increased amounts of Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, CO_3^{2-} because of dissolved tocks

  If the water percolates through deep underground aquifiers such as artesian basins, it will contain much higher levels of the above ions and Fe^{3+}, Mn^{2+}, Cu^{2+}, Zn^{2+}

- **pH of the rain**

  Water from acid rain is better able to leach cations such as Ca^{2+}, Mg^{2+} and Fe^{3+} from the soil it passes through

- **The nature of and amount of human activity in the catchment area**

  Land Clearing – water runs more rapidly across smooth surfaces. It facilitates the dissolution of Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^{-}, CO_3^{2-}

  Agricultural Pursuits – leads to fertiliser runoff (NO_3^{-}, PO_4^{3-})

- **Effluent discharged into water bodies**

  Raw and/or untreated sewage increases the concentration of many ions including nitrates and phosphates. Even well-treated sewage may increase TDS of the water by more than 200 ppm

  Stormwater runoff and industrial effluent can similarly increase the concentration of a variety of ions

- **Leaching from rubbish dumps**

  When water runs through poorly designed dumps, it dissolved many harmful substances including Cd^{2+}, Hg^{+}, Pb^{2+}, Zn^{2+}, NO_3^{-}, PO_4^{3-}

3) Describe and assess the effectiveness of methods used to purify and sanitise mass water supplies

There are several methods used to purify mass water supplies. Most are variants on the following process:

Flocculation and sedimentation → filtration → sanitisation → pH adjustment

Water is collected in dams and pumped to a treatment site where the larger solids such as pieces of plastic are removed by screens.

Fine particles suspended in water have electric charges on their surface that keep the particles from joining together. This stops particles from becoming large enough to settle as sediment. Separation of fine particulate matter suspended in water involves the addition of coagulants, such as iron(III) chloride, FeCl3, to the water. The added FeCl3 neutralises these surface charges so the particles come together. Iron (III) hydroxide is formed by reaction of FeCl3 with water and precipitates out as a floc (flocculant). The floc collects the neutralised particles into large masses that are more easily filtered.

In some instances, after flocculation the particle size of suspended solids is too fine for filtration through sand beds and so membrane filters are used. They are more effective than sand filters as they can have a very small pore size. However membrane filtration is more costly than sand bed filtration.

Sanitising mass water supplies involves disinfecting with chlorine gas, Cl2, liquid sodium hypochlorite solution, $NaOCl_{(aq)}$, or solid calcium hypochlorite, $Ca(OCl)_2$. Sedimentation and filtration removes some harmful organisms, such as bacteria, viruses, Cryptosporidium and Giardia, but disinfection is needed to ensure concentrations are acceptably low.

Regular microbiological testing of water samples through the distribution system, in particular before and after sanitisation processes, is required to maintain the purity of drinking water.

4) Describe the design and composition of microscopic membrane filters and explain how they purify contaminated water

Microscopic membrane filters have microscopic pores and the use of appropriate sized filters can avoid the need to chemically treat the water. The filters can be classified as micro-filtration, ultrafiltration, nano-filtration or reverse osmosis membranes depending on the size of the pore.

The membrane is made from synthetic polymers dissolved in a mixture of solvents. Water-soluble powders of a particular size are added. The mixture is spread out over a plate and left for the solvent to dry. The polymer membrane formed, containing particles of water-soluble powder, is then placed in water. Remaining solvent and the powder particles dissolve, leaving a very thin polymer sheet with definite sized microscopic pores where the water-soluble particles were located.

Semi-permeable membranes used in reverse osmosis are either made of cellulose acetate or a layer of polyamide attached to another polymer. Under pressure these polymers allow the passage of water molecules but not that of most atoms, ions or other molecules.

Water is made to flow across the membrane not through it. This reduces the blockage factor. Micro-filtration removes protozoans, bacteria, colloids, some colouration and some viruses. The size of the pore determines which sized particle or organism may pass through the membrane. The finer the pore size the smaller the particles trapped and the more expensive the membrane.

5) Perform first-hand investigations to use qualitative and quantitative tests to analyse and compare the quality of water samples

See Prac Book (3.3)

6) gather, process and present information on the range and chemistry of the tests used to: identify heavy metal pollution of water; monitor possible eutrophication of waterways

See Water Research Assignment

7) Gather, process and present information on the features of the local town water supply in terms of: catchment area; possible sources of contamination in this catchment; chemical tests available to determine levels and types of contaminants; physical and chemical processes used to purify water; chemical additives in the water and the reasons for the presence of these additives

See Water Research Assignment