

HSC Chemistry Notes - Chemical Monitoring & Management

9.4 - 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

Industry: **Environmental Chemistry**

Role: collect, *analyse* and *assess* environmental data from the air, water and soil. Their role is to evaluate data gathered in order to maintain the ecology and provide a **sustainable living environment for the current and future inhabitants**.

Branch: **Analytical Chemistry**

Chemical Principle: Environmental chemists must master their knowledge in *analytical thinking* and interpreting data. Also, chemists are required to perform **titrations** and chemical indication tests to **determine unknown chemicals in the area and unknown concentrations** in order to maintain the sustainable ecological balance. Environmental chemists are also required to process data using **Atomic Absorption Spectroscopy (AAS)** in order to determine the concentrations of a particular metals in a given sample.

Environmental chemists also find their work by analysing and determining the *polarity of molecules* so that they may be dissolved or disabled in other solutions - this can often be done so using **gas-liquid chromatography (GLC)**.

Environment chemists find employment in many government bodies including the CSIRO and the Environmental Protection Agency (EPA) who strive for the ecological and environmental sustainment of the natural resources.

2. identify the need for collaboration between chemists as they collect and analyse data

There is an extremely broad range of chemistry throughout the chemical world and each chemist continues their own specialisation and specific work that is focussed there. It is vital that all chemists collaborate and share their gathered data, even more so in similar fields of chemistry, **so that new discoveries can be founded and important chemical knowledge unlocked**.

If data and analytical knowledge is made aware to other chemists then they may collaborate and work on the same project together in order to catalyse progress and assist new developments.

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

The combustion of octane (a component of car fuel) has differing products depending on the conditions and oxygen supply. The different conditions under which octane combusts, alters the type of combustion that it undergoes.

Complete Combustion: is the complete reaction of octane with oxygen to form only carbon dioxide and water molecules (along with the desired energy from the combustion reaction). The reaction follows:



However, **Gas-liquid Chromatography (GLC) analysis** of exhaust fuels from internal combustion engines suggests that complete combustion rarely ever occurs and there is **always an incomplete combustion leaving traces of carbon monoxide (CO)** in the exhaust vapours. GLC analysis and data directs us to believe that **low concentrations of carbon monoxide occur when the engine is operating fastest with optimal oxygen intake**.

Incomplete Combustion: occurs when an internal combustion is not operating at full oxygen intake and as such there is the production of **carbon monoxide**:



The production of **soot** in the same internal combustion engine has a different reaction again:



Both carbon monoxide and soot are unpleasant and effectively dangerous products of the combustion of octane. Because of this, **the combustion reaction must be monitored and therefore controlled using technologies and chemical measures**. In order to keep emissions of the toxic carbon monoxide and unburnt hydrocarbons (including octane) chemists developed **catalytic converters**. Catalytic converters operate by:

- using sensors to **detect and control the ratio of oxygen intake and fuel input before combustion** to ensure an **optimum complete combustion** and efficient extraction of energy from the octane.
- **minimise** the production of **carbon monoxide**.
- speed up reactions that **convert pollutant gases to materials which are present in the air naturally**.

1. **gather, process and present information from secondary sources about the work of practising scientists identifying:**

- **the variety of chemical occupations**
- **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.
- **a specific chemical occupation for a more detailed study**

Refer to orange dot point 1.1

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

1. **identify and describe the industrial uses of ammonia**

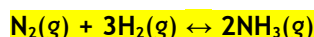
Product derived from ammonia	Use of product
Urea/Ammonium sulfate	<i>Fertilisers</i> for plant nutrients
Nitric Acid (NH_3)	<i>Explosives</i> such as TNT and strong laboratory acids
Acrylonitrile	<i>Acrylic plastics</i>

2. **identify that ammonia can be synthesised from its component gases, nitrogen and hydrogen**

Ammonia can be synthesised (produced) from the constituent gases which formulate its equation. The process for reacting **nitrogen** and **hydrogen** in their natural forms [N_2 and H_2] to synthesise ammonia [NH_3] is known as the **Haber process**.

3. **describe that synthesis of ammonia occurs as a reversible reaction that will reach equilibrium**

The reaction between nitrogen and hydrogen is a reversible reaction that **reaches equilibrium** to form ammonia. The highest yield of ammonia occurs only under certain conditions:



At **standard conditions** of temperature and pressure this **equilibrium lies well to the left**, and very little ammonia is present in the equilibrium mixture.

4. **identify the reaction of hydrogen with nitrogen as exothermic**

The reaction of nitrogen with hydrogen in the Haber process to synthesise ammonia is identified as an **exothermic** reaction with standard enthalpy: $\Delta H = -92 \text{ kJ mol}^{-1}$

Just as any exothermic reaction, there is an initial activation energy input required to initiate the reaction until it begins reacting and a negative value for ΔH is given - heat is given off.

5. **explain why the rate of reaction is increased by higher temperatures**

The particle theory and kinetic theory of gases predicts that the **rate of reaction will be increased when there is more collisions between the gaseous particles**. At higher temperatures, more energy is given to the nitrogen and hydrogen molecules and will increase in kinetic energy causing collisions between them → thus synthesising ammonia.

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

According to Le Chatelier's principle, that **when the overall temperature of the system is increased, the reaction will counterbalance the temperature change by moving to the left and therefore decreasing the yield of ammonia**. This is because the synthesis of ammonia is an exothermic reaction and will act endothermically when the equilibrium reaction is reversed.

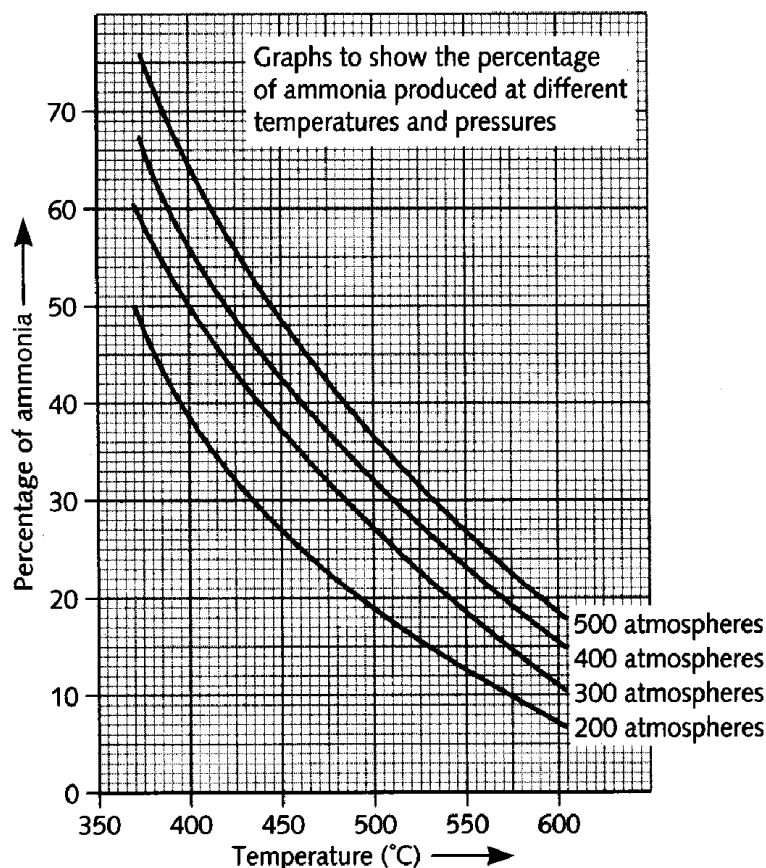
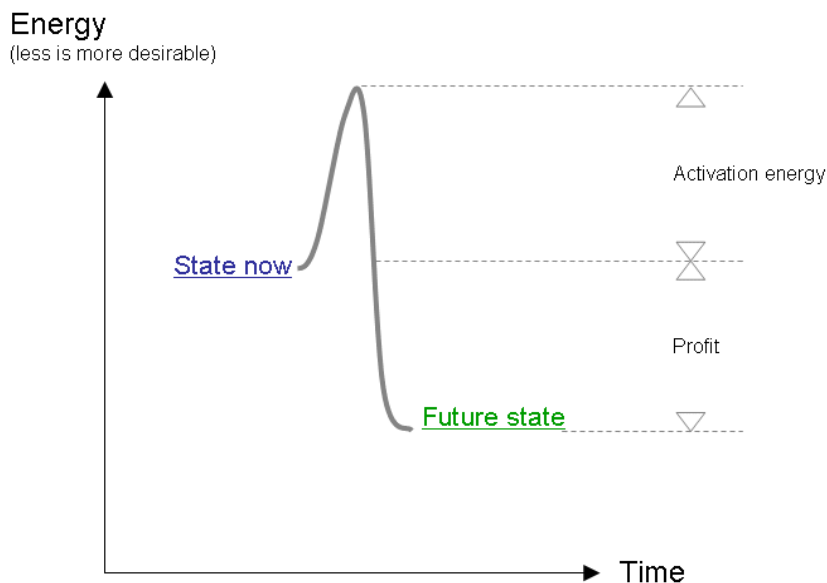
7. **explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium**

The Haber process is a means to achieve an end result of ammonia in the **fastest and most economic** way, resulting in a **high yield** level of ammonia. Factors such as temperature, pressure and catalysts must be controlled and constantly monitored in order to manage the delicate equilibrium equation → to arrive at the optimum yield.

The reaction between N_2 and H_2 has a high activation energy, which is caused by the very strong covalent triple bond between the two nitrogen atoms. This **activation energy is uneconomical** and inefficient for the Haber process, however, the activation energy can be **lowered through the use of a catalyst** which also assists in the rate of reaction.

To further **increase the yield** of NH_3 industrial chemists are able to **decrease the temperature** where the reaction is occurring; however, in doing so this **also rapidly slows down the rate of reaction in accordance with the particle theory** and does not allow fast collisions between nitrogen and hydrogen molecules. With a temperature that is too low the reaction rate is too slow and in actuality the yield of ammonia is not high at all. **A suitable balance must therefore be maintained between highest yield and efficiency.**

Furthermore, the **yield of ammonia can be increased by increasing the pressure** of the



system but this will also lower the reaction rate because the particles cannot move around as freely when the pressure is maintained lower. Higher pressures also make it difficult to maintain equipment at industry standard levels.

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

The addition and use of a catalyst in the Haber process speeds up the reaction rate by lowering the activation energy and therefore overall temperature of the reaction. The lowered temperature will also produce a higher yield.

The two catalysts used are **iron oxide** and **copper**.

9. **analyse** the impact of increased pressure on the system involved in the Haber process

The stoichiometric equation for the Haber process shows that a total of 4 moles of gas on the left is synthesised into 2 moles of ammonia on the right. By Le Chatelier's principle, the system will move toward the side that decreases the pressure (least moles of gas) when it is initially increased - therefore **increased pressure = higher yield of ammonia**.

Furthermore, increased pressure places stress on the pipes and chambers for containing the products used in the Haber process. This makes the pressurised pipes more hazardous and difficult to monitor; they must be maintained frequently.

10. **explain** why monitoring of the reaction vessel used in the Haber process is crucial and **discuss** the monitoring required

Monitoring of the reaction vessel and entire Haber process is crucial to ensure the safety of workers and scientists and also to provide the most efficient production of the optimum yield of ammonia. Monitoring requires technologies to be implemented:

- **Pressure:** This ensures that the pressure does not fall too low and the yield of ammonia falls into incommensurable ranges. Pressure data is therefore *monitored by sensors* which are centrally controlled.
- **Temperature:** It is critical that temperature is maintained within safe limits and to provide a temperature that is not so hot that the yield of ammonia is compromised. Heat is *monitored centrally by sensors* and recording data.
- **Raw products (nitrogen and hydrogen):** These feedstocks are monitored and controlled by computer assisted technologies to ensure that the input of raw material is in the correct molar ratio $N_2:H_2 = 1:3$. These furnaces must also be *kept free from sulfur compounds or carbon monoxide* and is therefore duly fitted with a CO sensor to transmit data to the central system.
- **Activity of Catalyst:** it is important to monitor and keep track of the *activity of the catalyst* which typically has a lifespan of 5-10 years, which must be maintained at a large surface area to be effective and efficient in the Haber process.

Because of the aforementioned, compromises must be made in either temperature, pressure or catalyst in order to achieve an acceptable yield of ammonia which does not cost more than a set budget and is also produced at a fast rate.

1. **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**

Early in the 20th century (during WWI and earlier) there was need for an industrially synthesised **fertiliser** to feed the world's growing population. Also the growing militancy in Germany needed a product for **explosives**. Haber's discovery was able to meet these demands. The method also contributed to Germany's effort in WWI as it insulated Germany from the cutting off of the import saltpetre (the current natural fertiliser) from South America and allowed explosives to be made from nitric acid. Therefore Haber's discovery had a significant impact on Germany in the early 20th century.

Due to Haber's situation and pressure to assist the threatened world, his process for synthesising ammonia was essential to the survival of Germany-Europe during the early 20th century.

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

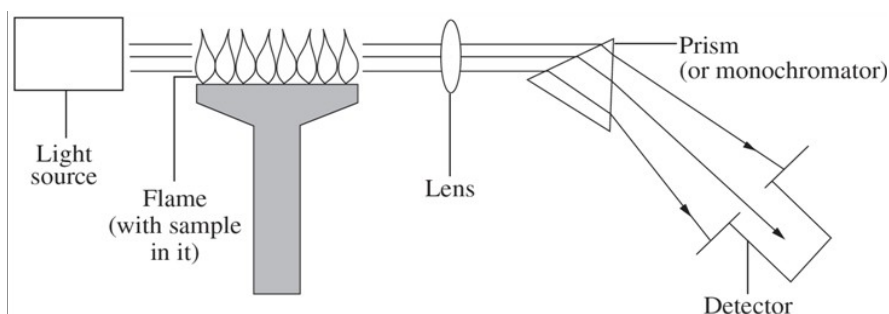
1. **deduce** the ions present in a sample from the results of tests

- **Flame Test:** Many ions will exhibit a characteristic colour when they are volatilised in a blue-flame from a Bunsen burner flame. It is a test that can be used to distinguish some cations by the colour their salts impart to a flame. Two methods can be used to utilise the flame test:
 1. Dissolve the chloride salts in water and spray the resulting solution into the blue Bunsen flame using an atomiser. The flame will take on a characteristic colour.
 2. Dipping an unreactive platinum wire into hydrochloric acid (to first clean it) and then heating it to remove contaminant salts - dip the platinum wire into the acid once more and then into the salt that is to be tested. When the wire is placed over a Bunsen flame, the chloride salt ions will emit a colour throughout the plasma (flame).
- **Precipitation Test:** is used when a fresh sample of the ions that must be tested is mixed with one of three acids: HCl, H₂SO₄ or NaOH. When each of these acids is mixed with a chosen salt, the ions will exhibit a characteristic colour throughout the solution. The precipitation test simply requires the addition of an acid and a salt so that the salt will dissolve and disperse throughout. An insoluble precipitate is formed and the cation (or anion) can be determined using further testing.

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


When metal ions are placed in a flame, specific electromagnetic radiation wavelengths are absorbed by the metal ion. The wavelengths missing from the light passed through can tell us which element ion the metal is and the strength of the electromagnetic radiation can tell us the concentration of the metal ion. The light source is needed to allow the spectra to be absorbed. The flame vaporises the substance which allows the light to pass through to be analysed.

Atomic Absorption Spectroscopy uses this principle to detect which ions are present in an unknown sample of soil (most commonly tested) or other natural materials. The input of energy can cause electrons to jump from one valence shell to the next. When the electron returns to its valence shell, the energy will be emitted as a unique light of the spectrum: this can determine the type of heavy metal. AAS is most commonly used to detect concentrations of metals and their ions - reasons in above dot points. Trace elements are essential for many living animals and discovering characteristics and properties of such trace elements will assist chemists and biologists for artificial synthesis of the trace elements.



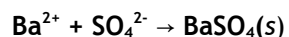
The use of AAS has had a positive impact on scientific understanding of the effects of trace elements. It has allowed for trace elements to be detected that would otherwise go undetected and therefore investigate the impact of trace elements.

1. perform first-hand investigations to carry out a range of tests, including flame tests, to identify the following ions:

Precipitate Test	Flame Test
<p><u>phosphate (PO₄³⁻)</u></p> <p>Yellow precipitate forms when silver ions (Ag⁺) are added to the phosphate ions.</p> <p>$\text{Ag}^+ + \text{PO}_4^{3-} \rightarrow \text{Ag}_3\text{PO}_4(\text{s})$</p> 	<p><u>barium (Ba²⁺)</u></p> <p>Apple green flame</p>

sulfate (SO_4^{2-})

White precipitate forms when a barium nitrate solution is added.

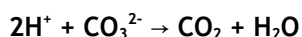


calcium (Ca^{2+})

Brick red flame

carbonate (CO_3^{2-})

When **HCl** is added, it will produce gas, which will turn **limewater** milky.

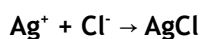


copper (Cu^{2+})

Green flame

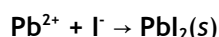
chloride (Cl^-)

White precipitate forms when **silver nitrate** is added → which then turns **purple** under *light*.



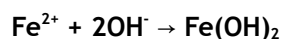
lead (Pb^{2+})

Bright yellow precipitate forms when mixed with iodine (I^-) ions.



iron (Fe^{2+})

Brown precipitate forms when mixed with sodium hydroxide (NaOH).



2. 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

Lead ions (Pb^{2+}) must be monitored because of the damage they cause to the environment and danger to civilians - as a result of lead ions' **toxicity**. Lead is polluted into the environment from **leaded petrol emissions** (despite their lessened use), **manufacturing plants and paints**. Dangerous levels of the toxic substance do not need to be alarmingly high, because even in the smallest of concentrations, lead is dangerous.

For instance, lead is able to *enter the waterways and estuaries* - this would therefore lead to the **poisoning of fresh water and damage aquatic life**, including fish. Once the fish become ill, humans cannot consume aquatic life that has been poisoned by lead ions; otherwise the lead will **poison humans when consumed**.

More specifically, recent **news stories have identified a range of children's toys** (such as the Thomas the Tank Engine merchandise) which are **coated in a lead base paint**. The lead paint easily chips and is extremely poisonous when consumed by young children. Thus all substances containing lead must be *monitored by techniques and technologies that prevent Pb^{2+} ions from entering the natural and built environment, such that they cause damage to life*.

3. identify data, plan, select equipment and perform firsthand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved

Refer to Lawn Fertiliser Practical. **AAS + Gravimetric Analysis**

4. analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure

- **Reliable:** the experiment can be conducted numerous times and achieve the same results with little error.
- **Accurate:** Results are close or you achieve the accepted values; however the data may not be reproducible and therefore may be caused by errors.
- **Valid:** The results are reliable and also accurate - they can be compared to secondary accepted data, which is close to these values.

Specific issues included safety, which had to be controlled when using ammonia and nitric acid → **safety goggles** must always be worn and gloves as an option.

5. gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control



The above shows the absorption spectra of **mercury**.

AAS processes have allowed for trace elements to be detected and analysed. This has **helped** pollution control as testing can be done to find these trace elements, which would have otherwise gone unnoticed. Atomic Absorption Spectroscopy has also **aided chemists and biologists to detect levels of metallic concentrations in the environment** and therefore can be controlled.

This dot point simply requires to be able to analyse which **parts of the colour spectra**. This shows that mercury **will emit certain colours of the electromagnetic radiation when the valence electrons relax back to their ground energy state** → emission spectroscopy. In AAS, the **electromagnetic frequencies that are emitted will be absorbed and will be missing from an emission spectrum**.

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 consists of a number of essential gases and are layered in a structured way. The main gases of the atmosphere and their constituent values are:

- **Nitrogen** (~78%)
- **Oxygen** (~21%)
- **Argon** (~0.9%)
- **Carbon Dioxide** (~0.03%)
- **Other gases** (~0.07%)

The main two layers in which we consider are the **troposphere** (extending **15km** above the Earth's surface and contains 90% of all gases) and the **stratosphere**, with the troposphere being the layer of atmosphere where weather occurs. Between the two layers is the 'tropopause' in which ozone exists. *Note:* The higher altitude → lower oxygen concentrations.

2. identify the main pollutants found in the lower atmosphere and their sources

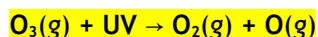
The main pollutants found in the lower atmosphere are considered pollutants because they respectively are **poisonous**, cause **acid rain/smog** and contribute to the **greenhouse effect**.

Pollutant	Source
Carbon Dioxide	Car emissions, oil burning
Sulfur Oxides	Burning of fossil fuels
Oxides of Nitrogen	Internal combustion
Methane	Decomposing organic matter

3. describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower

atmosphere pollutant

Ozone, O₃, is an *allotrope* of the oxygen element that exists naturally in the atmosphere at both high and low altitudes; however it serves both as a UV radiation shield and poisonous pollutant. Ozone breaks down into O₂ and O when exposed to UV light:

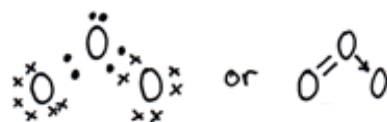


In **lower atmosphere**, such as ground level and the troposphere **ozone exists as a pollutant** and is dangerous to humans. Despite this, ozone *in normal clean air only exists as 0.02ppm* and is of no danger to humans. Ozone, **when inhaled by humans** has detrimental effects which irritate the throat and cause **respiration problems which lead to headaches and premature fatigue** (as the double bond in ozone easily breaks down) → for this reason, ozone is considered a pollutant in the lower atmosphere.

However, in **higher atmospheric levels**, the concentration of **ozone exists between 2-8ppm** where ozone acts as a **radiation filter from the sun's ultraviolet rays**. Thus, ozone with higher concentrations in the stratosphere acts as a protection for all Earth life; shielding from harmful rays.

4. describe the formation of a coordinate covalent bond

A **coordinate covalent bond forms when one atom provides both electrons for the shared pair**. Coordinate covalent bonding occurs in a number of combination of elements, including **ozone**, which exists as a bent molecule with **1 covalent double-bond (=)** and **1 covalent single bond (-)**. The centre oxygen atom will provide the electrons in the coordinate bond in O₃.

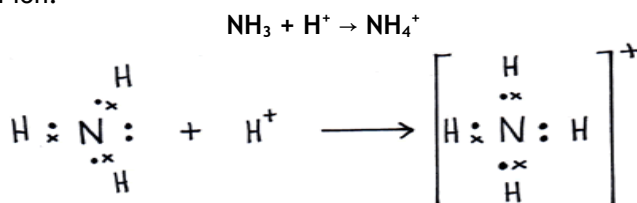


- An '→' is designated to represent a coordinate covalent bond between two atoms.

5. demonstrate the formation of coordinate covalent bonds using Lewis electron dot structures

This requires the practising and application of drawing any required substances using Lewis electron dot structures. *Refer to above ozone coordinate covalent bonding.*

Ammonium (NH₄⁺) is also another coordinate covalent bonding molecule which occurs by combining ammonia with an hydrogen ion.



- The square brackets and sign signify the overall charge of the molecule

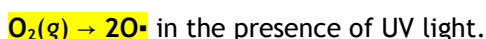
6. compare the properties of the oxygen allotropes O₂ and O₃ and account for them on the basis of molecular structure and bonding

Property	O ₂ - Oxygen gas	O ₃ - Ozone	Reason
Structure	Contains one double bond. O=O	Contains one double bond and one coordinate covalent bond. O-O=O	For this reason, ozone and oxygen gas take on different shapes: ozone is bent.
Melting Point / Boiling Point	-219/-183	-193/-111	Ozone has stronger <i>intermolecular forces</i> which result in the higher mp's and bp's
Solubility in H ₂ O	Sparingly soluble	Considerably more soluble than O ₂ gas.	Due to ozone's dipolar nature (two centres of polarity), it will dissolve more of and easier than

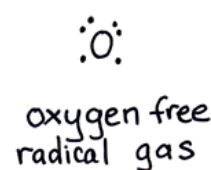
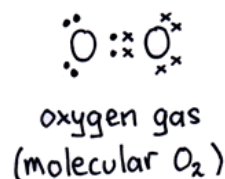
			oxygen gas.
Stability	Very stable	Unstable. Decomposes into O ₂ and O	Ozone's coordinate covalent bond requires considerably low energies to break.
Chemical reactivity	Highly reactive - <i>oxidising agent</i>	Very highly reactive - more so than O ₂	Ozone's coordinate covalent bond requires considerably low energies to break.

7. compare the properties of the gaseous forms of oxygen and the oxygen free radical

Oxygen exists as O₂ in its most common gaseous form throughout the atmosphere in different layers. Oxygen gas is formed when two single 'ground level' oxygen atoms combine and share their valence electrons. **If these two oxygen atoms**, held by a double covalent bond, **are split** due to a lightning strike in low pressures or *UV light* in high pressure systems an **oxygen free radical** is formed.



An **oxygen free radical** is different than a regular oxygen atom as it **contains two paired electrons, and two unpaired electrons**, making it extremely reactive → even more so than ozone.



8. identify the origins of chlorofluorocarbons (CFCs) and halons in the atmosphere

Chlorofluorocarbons (types of haloalkanes) were developed to replace ammonia as a refrigerant in the 1930s. At the time, their properties were found to be 'safer' than the ammonia. The properties of these CFCs, such as **low boiling points** and their **inertness** led to their **wide distribution** and use in refrigeration systems and aerosol propellants.

These CFCs were widely used and then distributed in the air because of the knowledge they were inert and would not cause damage to the Earth → however, **CFCs react above the troposphere** (in the stratosphere) where **UV light breaks the C-Cl bonds** and **reactive chlorine free radicals begin to damage the atmospheric ozone layer**.

Halons are chlorofluorocarbons containing bromine - which were widely used in fire extinguishers. Bromine atoms more dangerous toward the depletion of the ozone layer because they are faster to conduct a **chain reaction**. Fortunately, halons were not as used as widely as CFCs and as such there are now only very low concentrations in the atmosphere.

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

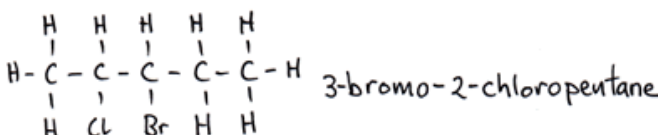
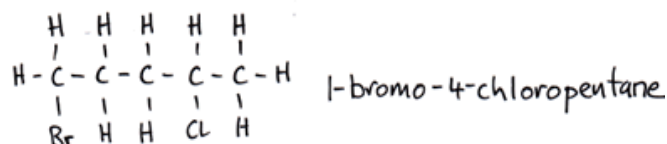
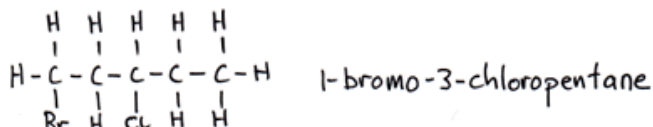
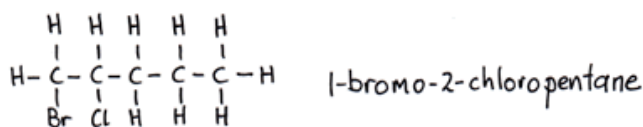
Haloalkanes often exist in isomeric forms. The location of the halogen functional group within each of these haloalkane molecules leads to their different properties and isomers.

- All haloalkanes are **organic compounds** because they are based on carbon. **Halogens = Group 7.**

The naming system exists as following:

Isomers of C₅H₁₀BrCl include the following:

1. **Identify the parent alkane** which contains the longest unbroken chain of carbon atoms
2. observe the halogen functional groups and ensure their **position** → whether they are 1, 2, 3. and **count how many** of each halogen there are.
3. Taking the first part of the atom, **dropping 'ine'** and **adding 'o'**. e.g. chlorine = **chloro**
4. Name the position and each halogen, **alphabetically**, followed by the parent alkane.



10. discuss the problems associated with the use of CFCs and assess the effectiveness of steps taken to alleviate these problems

Chlorinated hydrocarbons and other halogenated hydrocarbons are responsible for the thinning of the ozone layer resulting in increased UV levels which lead to evidence of **increased sunburn, cancer and overall heating of the planet** → **decrease in marine life** where these stratospheric ozone 'holes' appear.

Several measures and agreements have been made, however unsuccessful, since 1987. The most recent agreement formed, the **Montreal Protocol, in 1992** sets out the following agreements:

- **Cease use of halons by 1994**
- **Cease production and use of CFCs by 1996**
- **HFCs were to replace traditional CFCs, however must also cease during the early 21st century**

Hydrochlorofluorocarbons (HCFCs) were the first alternatives to chlorofluorocarbons to be introduced. They were successfully implemented → **containing a C-H which is extremely susceptible to attack** in the lower atmosphere. Thus, most HCFCs would break down before reaching the stratosphere and their **impact on the ozone layer was significantly lower**.

- another alternative to CFCs are **hydrofluorocarbons** which contain **no chlorine atoms** in their composition → HFCs break down extremely fast in the atmosphere and have **no impact on the ozone layer**

The reason that **CFCs** must be monitored is because they **break down by UV light to form chlorine oxide radicals (ClO•)** which attack the ozone layer. Such stratospheric ozone depletion is monitored by ground-based instruments, weather balloons and satellite instruments. *UV spectrophotometers measure the intensity of light* entering the atmosphere which is used to calculate the **thickness of stratospheric atmosphere** in DU (Dobson Units).

- **Since the introduction of the Montreal Protocol significant decreases in levels of CFCs** have been detected in the atmosphere and thickness of stratospheric atmosphere is returning, gradually, as **chlorine oxide free radicals are deactivated by NO₂ molecules**.
- Decreases in levels of CFCs can be attributed to the use of HFCs in refrigeration systems.

By observing data and gauging the opinions and judgements of authoritative scientists, the effectiveness of the steps taken to decrease the effect of CFCs on the ozone layer can be deemed significantly effective. An obvious trend is obvious due to the targets and protocols set by the Montreal Protocol.

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

The concentration of ozone in the upper atmosphere has been decreasing since the industrial revolution. However in recent times, presumably due to the **banning of CFCs**, the concentration of ozone has **increased**, however the hole still exists and there is a long way to go before it being completely repaired.

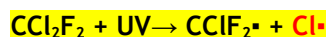
Ozone concentration is monitored from **ground based instruments**. These ground based instruments **measure the intensity of light received from the sun at a wavelength that ozone absorbs**. *A comparison of these intensities gives a measure of the total ozone in the atmosphere per unit area of Earth's surface at that location.*

The **total ozone mapping spectrophotometers (TOMS)** work in a similar way to the ground instruments but because the satellites are in orbit they **can obtain information about the ozone concentration at various altitudes** rather than as an average at a given geographic position.

Huge helium-filled **weather balloons** have also been used to carry instruments into the atmosphere to measure concentrations of various substances including ozone as a function of altitude and geographic position.

1. present information from secondary sources to write the equations to show the reactions involving CFCs and ozone to demonstrate the removal of ozone from the atmosphere

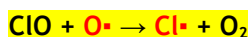
Firstly, CFCs are polluted into the atmosphere as haloalkanes which must contain a chlorine molecule and most often a fluorine atom. **UV breaks down the Chlorofluorocarbons creating a Cl radical (Cl•).**



The **Cl radical** is extremely reactive (wishing to complete its outer shell) and will attack/ **decompose the ozone O₃**. → This produces oxygen gas (O₂) and chlorine oxide (ClO).



Furthermore, this **ClO will react with oxygen free radicals in the atmosphere** which could have been used to recreate ozone - eliminating chances to reform decomposed ozone. This forms another chlorine free radical and oxygen gas.



From this process, it can be seen that just one chlorine free radical in any CFCs is extremely dangerous and will cause a **chain reaction** (where the reactive species, Cl, continues on its reaction because it is regenerated) that continues to decompose the ozone layer. **The chlorine free radical (Cl·) is never consumed** → thus will not be deactivated reacted with NO₂.

2. gather, process and present information from secondary sources including simulations, molecular model kits or pictorial representations to model isomers of haloalkanes

Refer to orange dot point 4.9

Using **model kits**, safety precautions had to be taken due to the small (and sometimes damaged) springs could easily be consumed or hit another student in the eye. Care was taken when handling the model kits to ensure that springs were not lost and conducted in groups.

Once modelling a haloalkane, we named them through the IUPAC system → then modelling them through the use of **computer aided software** which made obvious each haloalkane's specific characteristics, including atoms and bonds.

3. 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

Refer to orange dot point 4.10

Alternatives:

- **Hydrochlorofluorocarbons** (eg. CHClF₂) - contain at least hydrogen molecule and because of this a C-H bond is established which will be attacked and broken down before reaching the stratospheric atmosphere.
- **Hydrofluorocarbons** (eg. CF₃CH₂F) - contain at least one C-H bond and also contain no chlorine atoms → thus no chlorine oxide atoms or chlorine free radicals can form. These have no effect on the atmosphere.

The introduction of the HCFCs and HFCs have been extremely effective - and now HCFCs are being phased out across the world as HCFs become more efficient as a refrigerant. A grace period is given to 3rd world countries that need to adapt to this change.

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

By determining the concentration of dissolved and un-dissociated ions in samples of water, chemists are able to evaluate the quality of water. **As the concentration of ions increases, the quality (and purity) of the water decreases.** Gravimetric analysis, AAS (quantitative) and qualitative tests are used to determine the concentration and/or presence of ions in a sample of water.

- total dissolved solids

In comparison with salt water, levels of total dissolved solids in fresh water samples is much lower. Most TDS are **ionic compounds** which may be tested for using AAS or *evaporation* techniques. The levels of these dissolved solids fluctuates over time in all water supplies due to the flux and intake of external

water from oceans and rain. **The more TDS the more harmful the water is to drink.**

– hardness

Water may be classed as hard or soft water. **Hard water is defined as containing dissolved and increased levels of magnesium, calcium or hydrogen carbonate ions** → which forms an *insoluble scum* that will decrease the quality and 'consumability' of the water. Hard water, containing the insoluble scum, can be qualitatively tested using **common household soap, which will not lather** in the slightly acidic hard water and so can be tested in small test tubes and vigorously shaken, observing there to be no lathering of soap.

– turbidity

Turbidity is a measure of **suspended solids** in a water sample which will affect its transparency or cloudiness. Extremely turbid water appears dark and cloudy due to a high concentration of undissolved solids in the water.

Turbidity of water can be measured in a number of ways:

- **Filtering TSS:** By filtering a sample of water through extremely fine filter paper and collecting, then weighing the total amount of undissolved particles, we can have a quantitative and qualitative comparison of turbidity of a water sample.
- **Appearance:** Filling a measuring cylinder and placing a cross at the bottom is an effective qualitative measure to determine the turbidity and therefore quality of a water sample.

– acidity

The acidity of water affects its quality and ability to support life and thus whether it is suitable for drinking. Clean drinking water will generally have a **pH between 6.5 and 8.5** → tap water is generally slightly acidic due to pollutants.

Water which is outside this pH range is considered **polluted** and will generally not support delicate sea life. Water acidity can be tested using a *pH probe* or general pool indicators.

– dissolved oxygen and biochemical oxygen demand

Oxygen has a very low solubility level in water (9ppm), however, the small concentrations of oxygen that do dissolve in the water are vital for supporting marine and biological life. **Higher oxygen concentrations in water indicate a better quality** for both supporting life and drinking. Lower dissolution levels can be caused by anaerobic bacteria in the water or pollutants which prevent oxygen from dissolving.

- Oxygen concentrations can be increased by adding plant life and phytoplankton into the water-system so that they produce oxygen via photosynthesis.

Biochemical Oxygen Demand (BOD) is the required oxygen amount to support marine and plant life. The BOD of a water reservoir will depend on the amount of living creatures, plants and carbon-based or decomposing matter. **The lower the BOD, the higher quality water.** Gives an indication of the stagnant level of the water.

Oxygen concentrations can be detected using electrolysis or Winkler titrations. Qualitatively this can be determined by evaluating the amount of living matter in the sample of water (BOD test).

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

Factor	Effect on ion concentration
Heavy rain/flooding	Due to the addition of so much water, the concentration of ions will slightly decrease as it is effectively diluted. The frequency of heavy rain will also affect the concentration of ions in natural bodies of water.
Water temperature	Minerals dissolve faster at higher water temperatures.
Agriculture	Farmers who fertilise their crops pose a danger for affecting the quality of water and increasing ion concentrations of ammonia, nitrate and phosphate. Rain water carrying fertiliser or animal faeces into the water.
	Different rocks which exist at the bottom of a river bed have different

Solubility of rocks

solubility levels, and as a result, different ions will be dissolved in the water. For example, Limestone is easily **leached**

3. describe and assess the effectiveness of methods used to purify and sanitise mass water supplies

Untreated mass water that is taken directly from a natural source is known as raw water and will usually contain many disease causing micro-organisms and bacteria, very turbid and also be very unfit for drinking or household use. The water must be purified and sanitised using the following methods:

1. **Screening** - is a process in which water is forced through a **sieve-like device** that will *catch large undissolved, solid objects such as rocks, branches and dead animals*.
2. **pH change** - the **addition of NaOH** and sometimes other chemicals to raise the pH level of the raw water so that it is above 6.5 and therefore suitable for drinking.
3. **Mixing/Flocculation Tank** - water is processed into a large tank where **metal ions undergo oxidation and form insoluble oxides**. During this process, **Fe³⁺ ions are added to the water to form Fe(OH)₂** and other particle coagulate. **Lime softening** is used to balance the levels of calcium and magnesium ions - which affect the 'hardness' of the water.
4. **Sand filtration** - chemically imbalanced water now passes through fine and coarse sand where **coagulated solids** are collected and **insoluble ions are removed**. Clean water passes through.
5. **Chemical Treatment (Disinfection)** - chemicals such as **chlorine** (to *kill bacteria* and micro-organisms) and **fluorine** (to prevent tooth decay) are added to the clear water so that it meets regulation drinking water standards.

No one method is sufficient on its own to sanitise and purify the water to drinking standards. The combination of all techniques has a cumulative and methodical effect → each step is vital and important to the complete removal of solids and chemical purification of the water.

Maintain a cheap and efficient process for treating water for human consumption. Desalination plants for removing salts are, at the present time, too expensive.

4. describe the design and composition of microscopic membrane filters and explain how they purify contaminated water

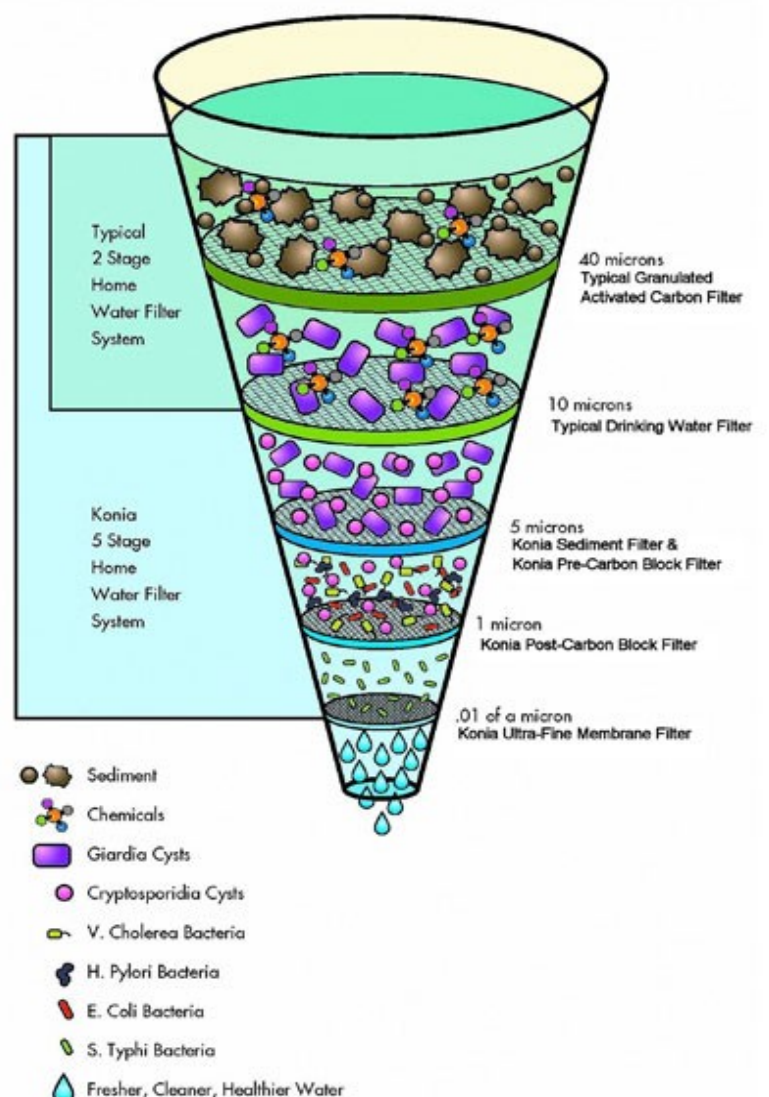
A range of microscopic membrane filters can be used to filter and purify contaminated water from the home. Microscopic membranes are composed of **extremely small and thin tubes of membrane** that allow only the molecules to pass through → *removing all solids and some large bacteria*.

These filters are made from thin tubes of polypropylene.

Contaminated water is forced through the minute membrane pores and clean, purified water is ejected out the other end. Large salts and ions can be removed using reverse osmosis with a diameter of 0.1 nanometre → this is extremely expensive.

Types of filtration that are able to clean contaminated water via microscopic membrane filters; include:

- **Micro-filtration**



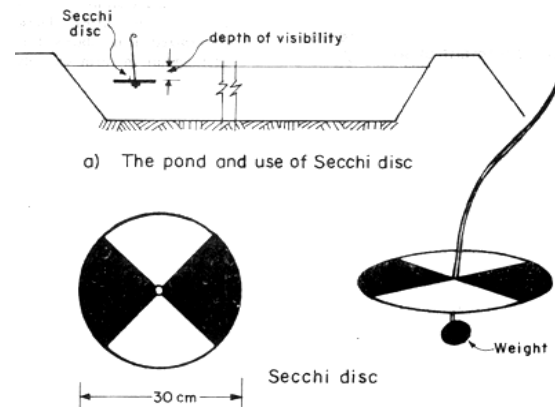
- Ultra-filtration
- Nano-filtration

Eutrophication: the abundant growth of algae and water plants due to the presence of high levels of nitrogenous and phosphate nutrients. When these *algal blooms* die and decomposed in the water → it leads to the **depletion of oxygen** concentration and an **increase in toxicity**. This can decrease the primary productivity of the water ecosystem and unsuitable for human/animal/plant use

1. perform first-hand investigations to use qualitative and quantitative tests to analyse and compare the quality of water samples

The quality of a water sample can be qualitatively and quantitatively determined by evaluating the factors considered in *orange dot point 5.1*. First-hand investigations conducted included:

- To test for the presence of **common ions** - first tried evaporation techniques to see if the ions would form and be left after the water had evaporated, however, no ions were left. Using gravimetric analysis we were able to gather some unidentified ions. To tell what these common ions were → we compared **flame test** colours and **precipitate** colours when certain chemicals were added (accordingly).
- **Evaporation** techniques were employed to achieve an approximate level of the **total dissolved solids** in our sample of polluted water. However, beforehand this water was allowed to run a current of 6V testing the electrical conductivity of the water.
- By simply observing whether **soap would lather** in our water sample, we could qualitatively determine the **hardness** of the water and tell whether there were high concentrations of calcium or magnesium ions.
- To test the **turbidity** of the water, a **secchi disc** was utilised. This is a circular disc divided into four quadrants with alternate ones painted black and silver. The disc is lowered into the water until the quadrants just become invisible; the **length of the string** gives a **relative measure of the turbidity of the water**.



2. gather, process and present information on the range and chemistry of the tests used to:

- identify heavy metal pollution of water

Concentrations of heavy metals in water samples can be detected qualitatively and quantitatively through **Atomic Absorption Spectroscopy (AAS)**. Heavy metals in polluted water can include mercury and lead which are extremely toxic to humans → cause damage to the immune system.

Gravimetric analysis can be used if the pollutant heavy metals are able to be separated using simple physical separation techniques.

- monitor possible eutrophication of waterways

Eutrophication involves the decrease in dissolved oxygen in the water. This is caused by the decay of plants in the water as well as phosphates in the water from agriculture and fertilisers. These phosphates promote algal bloom where organic matter grows. There is simply not enough oxygen dissolved in the water to support the plants and the plants decay.

Eutrophication is monitored by performing **dissolved oxygen or BOD tests**. Qualitative tests include **looking at the water**, if it is green and full of algae then eutrophication has occurred. Also if eutrophication has occurred then *phosphate ions will most likely be present* and so **tests for phosphate ions** can be done.

3. gather, process and present information on the features of the local town water supply in terms of:

- catchment area

The catchment area refers to all parts of the main river system that *catch and collect water* that is taken to the local dam for water supply. The catchment area includes all **small estuaries and creeks** in the surrounding vicinity, **mountain ranges** and general areas which have expected rainfall and then flow into the main water supply dam. The local catchment area is extremely arbitrary and extends a number of

kilometres covering a large diameter.

– possible sources of contamination in this catchment

Because the local river system extends far and wide, in the country regions, the following contaminations are possible and most likely to occur:

- **dissolving rocks** → In the Macleay river and catchment area there are increased levels of Arsenic and heavy metals; such as lead. These dissolved ions of metals have occurred naturally. **These exist in different oxidation states.**
- **farming** → pollution from water run-off that includes fertilisers and animal waste. This includes chemicals and pesticides to spray crops and vegetation. This easily seeps into the river system.
- **decay plants** in and around the river
- pollution from **industrial processes** → coal refinery

– chemical tests available to determine levels and types of contaminants

Refer to orange dot point 5.1

– physical and chemical processes used to purify water

Refer to orange dot point 5.3

– chemical additives in the water and the reasons for the presence of these additives

- **Fluoride** - Added to water to **strengthen teeth of humans.**
- **Chlorine** - **Kills bacteria** and viruses. The chlorine **sanitises** the water.
- **Biochemical organisms** - Added to 'remedialize' water contaminations.